A Comparative Study of Modern Chemical Based Agriculture and Organic Farming in terms of Sustainability

Thesis submitted to the Jawaharlal Nehru University in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy

Volume I: Text

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Certificate

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Certified that the thesis *A Comparative Study of Modern Chemical Based Agriculture and Organic Farms in terms of Sustainability*, submitted by Mr. Nandan Nawn, is in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy from the University. The work presented here is original and has not been submitted, in part or in full, for any other degree in this or any other University.

We recommend that this thesis be placed before the examiners for evaluation.

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Prof. Arun Kumar
(Chairperson)

Prince Kanha (August 22, 2011--September 28, 2011),
you will always be remembered.

BABA HAS ALWAYS WANTED
ONE OF HIS THREE WARDS
TO WRITE A DOCTORAL THESIS, AND
MAA HAS ALWAYS RAISED THE BAR FOR THEM
NO SOONER THAN ONE WAS REACHED

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In the Red: Accounting for Indebtedness

Writing this thesis has been a turbulent, long yet memorable journey for many reasons. It has taught me many things: to be patient, to believe in myself and instilling the confidence take the road less travelled. At the very beginning, I wish to thank all those who had kept faith on me, that includes little Ekka who always wondered what kind of 'study' his baobao had been engaged with taking so many days and Rukmini, who always wondered why I had been handling a dataset spread over 1,84,237 rows and 40 columns rather than a few farmer's narratives!

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(Nandan Nawn) JNU, New Delhi

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Abbreviations used

AICRP	All India Coordinated Research Project
BMR	Basal Metabolic Rate
CACP	Commission for Agricultural Costs and Prices
Cal	Kilo-calorie
CCS	Cost of Cultivation Studies a.k.a. Comprehensive Scheme for Studying Cost of Cultivation/production of Principal Crops, Department of Economics & Statistics, Ministry of Agriculture, Govt. of India
CSO	Central Statistical Organisation
DES	Department of Economics & Statistics
EA	Energy Analysis
EBA	Energy Balance Analysis
EROI	Energy Return On Input
FAO	Food and Agriculture Organisation
FMS	Farm Management Studies a.k.a. Studies in the Economics of Farm Management, Directorate of Economics & Statistics, Ministry of Agriculture, Govt. of India
FYM	Farm-yard Manure
GJ	Giga-joule
ha	Hectare
hp	Horse-power
hr	Hour
HYV	High yielding variety
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
IFIAS	International Federation of Institutes of Advanced Study
kcal	Kilo-calorie
kg	Kilogram
MJ	Mega-joule
NSSO/NSS	National Sample Survey Organisation
PSC	Plot-season-crop
TDN	Total Digestable Nutrients
TTFFRRPS-C	Tehsil-farm-parcel-plot-season-crop
WHO	World Health Organisation

> When belief in established institutions and practices declines, the search for comprehensive philosophies of life and rival policies compete in the name of one or another *Weltanschauung*. (Eric Roll, 1938, *A History of Economic Thought*, Fifth impression, Faber and Faber, London, p. 23)

This thesis defines the sustainability of agriculture in terms of whether the farm household is able to yield an energy surplus, when its members and the animals in its possession are obtaining an adequate Calorie intake. Appropriate Calorie norms have been assumed, their fulfilment being a necessary but not a sufficient condition for the generation of surplus. Further, the route this thesis has taken, does not look into the magnitude of the actual surplus or its distribution. The latter is based on the property relations, which can be extremely exploitative in nature. Even while producing an adequate energy surplus for the members and the animals in the sense defined in this thesis, a household can end up with a negative surplus because property relations are such that it gets expropriated. Thus, the results of this thesis show only the upper bound of the number of households producing a surplus, without the consideration of the factor incomes.

The method employed in such an evaluation is the energy balance analysis, which takes into account not just the economic but the ecological dimension as well. In fact, it is independent of the prices of inputs and outputs altogether. Energy is taken as the standard. This approach is motivated by the agrarian distress that has received much attention in the recent times: be it the farmer's suicides of epidemic magnitude in many parts of the country, or the rising food prices. Arguably, at the minimum, it indicates that the agricultural production system has been in a state of great stress, in terms of its capacity to sustain an adequate surplus. The direct, obvious and visible human society-nature interactions and exchanges in agriculture necessitated foraying into the intersection of the two disciplines, ecology and economics, or ecological economics.

Surplus, conceptually speaking, has undergone significant changes in the past two and half centuries of economic thought. The standard in terms of which both inputs and output are measured moved even in early years of economics from corn to embodied labour. Certainly, a logical extension is the embodied energy measured with the units of Calorie (kcal) or Mega-joule (MJ). Apart from its being a convenient standard, there also exist a number of arguments, supporting such a development, of which a few may be listed here.

First, price or wage or income, and in the process, the problems related to imputation can be avoided altogether. After all, in agriculture, for most of the inputs and outputs, the markets either do not exist or are heavily distorted. Second, the use of 'energy income' or food calorie for the human labourers certainly has served as a norm for identifying the productive capacity of their labour power, as manifested in the construction of poverty lines. The third reason is the impending crisis facing the present mode of energy use which is exhausting the non-renewable low entropy ones at a much faster rate than they could be produced. Clearly, there is a need to combine appropriately the non-renewable and renewable sources of embodied energy in the inputs, excluding the living labour, for the sustainability of the surplus. There are many other compelling reasons, to be discussed as we progress. In sum, we may restate the objective: to explore the possibilities of augmenting the surplus from agriculture, through an energy balance analysis.

For the purposes of comparison, the analysis was carried out across two time-periods in the State of West Bengal: the year 2004–05 represents the 'modern' chemical based agriculture, while it is 1956–57 for the traditional type of organic farming. Admittedly, the latter is one of the many varieties of the organic methods of crop production, and as a result, conclusions of the thesis, will be limited to this particular type only.

This chapter is devoted to the development of concept of surplus towards establishing the connection between the surplus and its sustainability using the method of energy balance analysis. Chapter 2 will discuss the method itself, along with the specific assumptions made in this work. Various energy values or coefficients are also included. Some of the conceptual issues linking surplus and the energy balance analysis, towards defining four alternative scales of sustainability employed in this thesis will be presented in Chapter 3 along with a brief description of the 2004–05 dataset. Chapter 4 will explore the sustainability of agriculture in West Bengal in 2004–05 through some of the results. The following chapter will be engaged with the patterns of input usage in 2004–05 and their impact on surplus along with the constituents of output. A comparison between the traditional and the 'modern' methods will be offered in chapter 6. Finally, chapter 7 will summarise the thesis with a conclusion.

1.1. Development of the Concept of Surplus

Physiocrats mark the beginning of the 'curious sociological phenomenon' called 'school of thought' in the history of economics (Meek 1962: 27; Roll 1938: 130); at times, this set of French economists are also regarded as pioneers in classical political economic thought.[1] Like Adam Smith, for François Quesnay the fundamental economic problem was to inquire into the nature and causes of the 'wealth of nations': 'Of what did wealth consist? How was it produced and increased? And, in particular, what action should be taken to maximise its rate of increase?' (Meek 1951: 26; also, Bharadwaj 1978: 14).[2] These are precisely the questions for the present thesis as well.

[1] To be more precise, it was the celebrated interview between a 63 year François Quesnay and 42 year Marquis de Mirabeau to discuss latter's *Friend of Mankind*, towards the end of July 1757, at the Palace of Versailles: 'at this interview the potential disciple was won over, and from that date to his death played the role of Engels to his master's Marx' (Meek 1962: 15).

For Schumpeter (1976: 223), the fidelity of the Physiocrats to absorb and accept their master's teachings had 'but two analogues in the whole history of economics: the fidelity of the orthodox Marxists to the message of Marx and the fidelity of the orthodox Keynesians to the message of Keynes'.

Meek (1962: 370) joined many others in arguing that 'Physiocrats took the decisive step leading from politics to political economy'. However, for Roll (1938: 22) political economy could appeared as 'a science' only when the foundations of industrial capitalism were well established. In particular, it came to maturity during the forty years between *Wealth of Nations* and *Principles*. Its roots were threefold—first, the philosophical, from 'its canonical origin to philosophic radicalism'; second, progress of the English economic thought since later Mercantilists; and third, Physiocrats (1938: 88).

On the other hand, consider Leontyev (1968: 21), notwithstanding the polemics:

> Political economy studies the most important aspect of society's existence and advance—its economic life. Disclosing the laws governing social production, it provides the key to an understanding of the whole complex process of social development. [...] Political economy deals with the burning problems of the class struggle. It studies the vital interests of the main classes of capitalist society. What is more, it poses and answers the question of the very existence of the society. For that reason, political economy cannot be neutral in the class struggle. On the contrary, it is a class, a party science. All talk of a neutral or above-party political economy is no more than a guise for economists who, defending the interests of the moribund classes, prefer not to reveal their true face.

Also see, Marx (1954a: preface), Dobb (1973: 142fn), and Bharadwaj (1978: 10)

[2] The following had engaged the 'most speculative minds':

> (a) what does this surplus consist of and what determines is size, (b) where does it originate, (c) among whom is it distributed, (d) how, i.e. by what principles, is it distributed, (e) what determines its growth over time, (f) what happens to the relative shares of surplus accruing to the different classes of appropriators as the size of the surplus increases? (Bharadwaj 1978: 14)

Notions of 'wealth' had undergone a tremendous change from stock to flow with the Physiocrats (Pasinetti 1977: 2–3).[3] The former refers to the abundance of the stock of goods at the disposal of an individual or of a community while the flow dimension refers to the income of a country in terms of its production of goods and services. For a significantly long time, at least before the industrial revolution in Britain, wealth meant endowment of available economic resources, represented most dramatically by the Mercantilists' position. For Physiocrats, production and distribution quite prominently featured in the concept of wealth as a flow.[4] A given stock was to be continually consumed through its employment in the process of employed and replaced by this process itself: additionally, in the process, the 'given' was to be enlarged. Such an idea of circularity of flow remained with the classical economists, to be revived later by Pierro Sraffa in the mid-twentieth century. Mayumi (2001a) had shown that, formally, embodied energy input-output framework is identical to the Sraffian framework expressed in the current and dated labour terms (Burkett 2003: 139).[5] Mayumi (2001a) in fact had compared the theoretical basis of embodied energy analysis using Sraffian approach and flow-fund model of 'bio-economist' Georgescu-roegen (1971: 219–234) and found conditions under which the Sraffa's and Georgescu's analyses converged.

The first necessary step for the classicists was to divide the annual produce received directly, into two parts. One was towards the replacement or compensation against those items physically used up during the production process within a referred period, while the second was the net social gain or the

[3] Anne-Robert-Jacques Turgot, one of the most politically influential Physiocrats, had explained *produit net*, one of the key contributions of this school of thought as the following:

> The produce of the land divides into two parts. The one comprehends the subsistence and the profits of the husbandsman, which are the rewards of his labour, and the conditions on which he agrees to cultivate the field of the proprietor; the other which remains is that independent and disposable part, which the earth produces as a free gift to the proprietor over and above what he had disbursed (quoted in Stokes 1992: 24).

[4] Flow of commodities from one class to another, in the form of exchanges, was essential at the end of each production period so that the produced wealth be distributed among the various members of the society, in order to continue the production process in the next period: the famous *Tableau Economique* represented these flows (Pasinetti 1977: 5; Stokes 1992: 25).

[5] Resonance of such similarities could also be found in their criticism:

> After all, such energy analysis is essentially an energy theory of value, and why should one take seriously any movement which simply replaces Marx and the discredited labor theory of value with Carnot and thermodynamics? Energy is but one of many scarce inputs, and the beauty of the market price system is that it provides incentives for the combined wise use of all scarce inputs, not just energy. (Berndt 1982: 3)

'disposable' surplus, to be either consumed 'unproductively' by the community or for increasing its productive powers. The latter, by definition, was not connected with maintaining the productive powers of the community intact, and was denoted by diverse terms like '*produit net*', 'net real income', 'disposable income' or even 'surplus' (Meek 1951: 27, 1962: 346). It could have been defined also as 'surplus energy' or the 'energy available to man in excess of that expended to make more energy available' (Cottrell 1955/2009).[6]

Indeed, the central question for classical political economy remained the *modi operandi* for increasing the size of the second part.[7] The first part, on the other hand, was assumed as given in the theoretical formulations as well as in the calculations. Thus, satisfaction of this condition for *sustaining* the productive powers of the community or the community itself was taken as the necessary one for augmenting the surplus. This thesis employs such a notion of sustainability as one of its core concepts.

'Value' appeared first in the classical economic thought with respect to the quantification of this surplus and comparison of the magnitudes of surplus over different time and space (Bharadwaj 1978: 20). The present thesis computes the

6 At any given moment of time a person, a group, or any other socially functioning unit has available a limited supply of energy. This can be utilized immediately in its present form. It can also be used in an operation designed to increase the future supply of available energy. The simplest example would be grain, which may be eaten or planted. It is obvious that if the planter does not even get his seed back from the harvest, he has less energy at his disposal than he previously had: he has incurred a deficit. On the other hand, if he harvests enough grain to replace the seed, to supply the amount of energy expended making the tools or machines he used in planting, cultivating, and harvesting his crop, plus his labour and something more, he has gained energy beyond that which was previously his to command: he has surplus energy.

[...]

Surplus energy becomes a key factor in any social system but there are only a few ways to get it. All of them are limited. To get those surpluses man has to discover the sources and build converters that will change his potential into forms of energy that man can use. So he is dependent both upon his ability to find and possess the raw materials furnished by nature, and to design and create converters that will make the energy in them available to man in the forms and at times and places he wants them. The energy expended in doing this must be subtracted from the energy resulting in it. Only the result is net surplus. (Cottrell 1955/2009)

7 Sir William Petty had been referred as the founder of political economy by many (Roll 1938: 102). Occupations of 'cabin-boy, hawker, seaman, clothier, physician, professor of anatomy, professor of music, surveyor, and wealthy land-owner' could have influenced him to declare that 'Labour is the Father and active principle of Wealth, as Lands are the mother' (William Petty, 1662, *A Treatise of Taxes & Contributions* ..., N. Brooke, at the Angel in Cornhill, London, p. 68, as cited in Roll 1938: 106). It may have also led him to posit that food required by the labourer determined value and price: 'The day's food of an adult Man, at a Medium, and not the days of labour, is the common measure of value' (cited in Roll 1938: 107).

surplus in various parts of the State of West Bengal, located in Eastern India for selected food crops across two different time-periods, almost 50 years apart.

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Such an analysis of the necessary conditions for surplus was carried out in a framework which is closer to those theories of value where the 'search' for the origin of surplus is conducted within the sphere of production and not in exchange as in 'supply-and-demand-based approach to explanations of value and distribution' (Bharadwaj 1978: 10).[8] The strength of such 'classical' approach rests in its 'openness', of 'the possibility of allowing for a wide range of historical, socio-political factors to enter into the determination of "quantities", that is, output, consumption, methods of production' (Bharadwaj 1989: 10).

1.1.1. Form, Constituents and Size of Social Surplus

The 'first and foremost unifying link' that Bharadwaj (1978: 14) had noted among the classical political economists was their 'recognition of the distinction between processes of production and those of circulation from the point of view of the generation of surplus'. Marx had put this in the most precise yet comprehensive manner that while surplus originates in production, it is realised in circulation (Bharadwaj 1978: 15).

Surplus was necessary for the new capital to be accumulated, and for the early contributors of 'scientific' political economic thought, like Quesnay, it was seen as the only possible source, as in *Wealth of Nations* (Meek 1951: 27). It could be traced in the recommendation for the application of capitalist methods in agriculture and manufacture alike by the later Physiocrats like Du Pont, Baudeau

[8] Pasinetti (1977: 24–26) had pointed to the dominance of formal economic thinking by marginal economic analysis since 1970, who 'had left aside the phenomenon of production' and the 'the problem it deals with is the optimal allocation, through exchange, of a certain initial endowment and distribution of resources'. Admittedly, this 'model of pure exchange' was modified subsequently to include the process of production in the form of marginal productivity theory, but in such a way 'as to meet the requirements of a preexisting theory concerning the optimal 'allocation' of certain stocks of resources. [...] [I]t has inevitably contributed to keeping the phenomenon of production in a secondary and subordinate position'.

England (1986: 231–2) had mentioned three important features of the neoclassical production theory: of an 'analytical dichotomy' between factors of production and final outputs, of conceiving production as a 'purely technical and unidirectional transformation of productive factors into commodity outputs' and of attaching no importance to the 'historical process' through which factors of production have come about.

and Turgot, 'responsible for removing feudal trappings from Quesnay's system' (Meek 1951: 27); so was the call for capitalist methods in cultivation in their 'master's' first economic article, *Fermiers*. Indeed, the key variable or the basic factor determining the expansion or contraction in the dimensions of the circle, or the general level of economic activity was the celebrated '*produit net*', i.e. disposable surplus over the necessary cost, whose yield depended on the capacity of agriculture (Meek 1962: 19) (here, the usual caveat applies to the term 'capitalist', following Dobb: 1950).[9] Accordingly the classification of social groups was done on the basis of the ability to yield the 'net product': those in agriculture were deemed as 'productive',[10] occupations like manufacture or commerce were categorised as 'sterile', and the third 'class of proprietors' was thought to have belonged to a 'no-man's land' between these two classes possessing some of the characteristics of the other two.

Physiocracy literally means 'rule of nature' (Cleveland 1999: 126). In Physiocratic understanding, nature was relied upon for deriving the 'economic value'. *Produit net* from agriculture was seen as a component of an 'original and real substance', made available by nature.[11] Other economic activities were just reworking on it. Here '[a]griculture was inherently capable of yielding a physical surplus, which in

9 One should, perhaps, at once make it clear that the word "capitalistic" which has become fashionable among some economists, [...] has little in common with Capitalism as a category of historical interpretation. "Capitalistic" has been used by economists in a purely technical sense to refer to the use of so-called "roundabout" or time-using methods of production, and has been largely associated with a particular view of the nature of capital. It has no reference to the way in which the instruments of production are *owned*, and refers mainly to their economic origin and the extent of their use. (Dobb 1950: 3)

10 Productive 'because the physical quantity of goods it obtains by working on the land can directly seen to be greater than the physical quantity of the same good which had to be used up' (Pasinetti 1977: 5). Meek (1962: 380–383) however, argued that there was

> [...] nothing peculiarly Physiocratic about the idea that agriculture was inherently capable of yielding a disposable surplus over necessary cost in physical terms. [...] But the Physiocrats were of course concerned to emphasize not only the productive of agriculture in physical terms, but also its productivity in value terms. [...] Agriculture, in their view, was certainly productive in both senses—i.e. it was inherently capable of yielding a physical surplus which in a market economy was inherently capable of being transformed into a value surplus. [...] When the Physiocrats claimed that manufacture was sterile, what they meant was simply that it was inherently incapable of yielding any disposable surplus over necessary cost in terms of value.

11 Physiocrats argued in general terms that labour was the cause but not the source of wealth. Labour's function was to transport wealth from one 'larder' to the other. Clearly, in this understanding labour was passive, 'a machine for changing inputs rather than outputs'. Stokes (1992: 25) pointed that change in productivity in this understanding also depicted similar passivity: no matter what the technological processes or how efficient they were, the source of the product will always be nature, irrespective of the ability of humans to control it. Marx was to give credit to Physiocrats for providing expression to a form of materialism, and to criticize them for failing to see the role of labour in creating value (Burkett 2003: 146).

a market economy was capable of being transformed into a value surplus' (Stokes 1992: 26).

This philosophy was contextualised within the then France, overwhelmingly agricultural yet different from England with s relative lack of 'enclosures'. A very large number of small peasant proprietors were present with small land and primitive methods living a 'wretched existence' and subjected to rather heavy seigneurial dues, and were often forced to hire out labour in one rural industry or the other.[12] Along with this, there were a small number of cultivators with large land holdings, living off cultivation in reasonable comfort (Meek 1962: 23). The specific and chief hindrance towards augmenting the net product—the Physiocrats had realised—was the 'prevalence of small-scale, capital-starved, subsistence farming' (Meek 1962: 24). It was to be substituted by 'large-scale farming by up-to-date methods' aided by 'wealth' or capital to be brought by a new class of '*fermiers*', 'the men of substance' (Meek 1962: 24, 26).[13] However, '[i]t was not so much men who were required in the country, Quesnay insisted—it was rather wealth' (Meek 1951: 28).[14]

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[12] The seigneurial dues and tithes were joined by the multiple taxes imposed by the crown, under severe financial strain following a series of disastrous wars and extravagance of courts, which 'as Physiocrats correctly observed, more often than not had the ultimate effect of increasing the deficit instead of reducing it'. At the same time, privileged classes were exempted from many of the taxes (Meek 1962: 25).

[13] Large-scale was referred as the 'proper' cultivation with greater expenditure for the purchase of livestock and greater number of labourers. Small-scale was classified as 'poor' that involved a great amount of labour, but ended up mostly in vain in absence of the necessary expenditure (Meek 1962: 82). Indeed, one of the crucial assumptions in the Physiocrat's model was 'a large kingdom, whose territory, fully cultivated by the best possible methods, yields every year a reproduction to the value of five millards; [...]' (François Quesnay, 'Analysis' as translated in Meek (1962: 151).

> *It is the wealth of the cultivators which causes the wealth employed in cultivation to be generated*: The product of labour of cultivation may be worth nothing or almost nothing to the state when the cultivator cannot meet the costs necessary for proper cultivation. [...] Thus the employment of men in cultivation may be useless in a kingdom which lacks the wealth necessary to prepare the land so that it will yield abundant harvests. But the revenue of landed property is always assured in a kingdom which is well furnished with wealthy husbandmen. (Meek 1962: 74; emphasis as in original)

[14]

> Land, I repeat, constitutes wealth only because of the fact that its products are necessary to satisfy man's needs, and because it is these needs themselves which lay the basis of wealth. Thus the more men there are in a kingdom with a very extensive and fertile territory the greater its wealth will be. It is cultivation, stimulated by men's needs, which is the most fertile source of wealth and the most important mainstay population. It supplies the materials which are required to satisfy our needs, and procures revenue for the sovereign and the proprietors. Population increases much more through revenue and expenditure than it does through the propagation of the nation itself. [Francois Quesnay, 1757, 'Corn', translated in Meek (1962: 84)]

The prescribed policies were: imposition of *impôt unique* or single tax on land rent, removal of Mercantilist restrictions on internal and external trade of agricultural produce, and discontinuation of 'exclusive privileges' like subsidies to certain manufacturing establishments, so as to curb the diversion of investment away from agriculture and 'perversion of taste', resulting in a lower demand for agricultural products. These proposals towards increasing the magnitude of the net product by stimulating both output (through replacement of *la petite culture* by *la grande culture*) and price of corn were argued to be the 'essential precondition of the rehabilitation of French agriculture' (Meek 1962: 27). Three successive editions of the famous *Tableau Economique* (1758–59), clubbed with *Philosophie Rurale* (Rural Philosophy, 1763) by Mirabeau and Quesnay, 'designed as a sort of basic text-book' of Physiocratic theory and policy, had been marked as the outlining doctrine necessary for the foundation of the 'school' (Meek 1962: 30). Physiocratic system clearly and fully reflected the sharp conflicts that were in the making between the 'decadent feudal order and the emerging capitalist one' (Bharadwaj 1978: 17). The declaration of May 25, 1763 showed the early acceptance of Physiocratic prescriptions in State policies, and the ascent to power by Turgot represented its triumph, which was achieved despite the fact that everyone opposed the Physiocratic doctrine on one ground or the other.[15] The year 1776 marked the end of Physiocratic reforms with the fall of Turgot. It also saw the publication of *Wealth of Nations* (Meek 1962: 34).[16] Despite holding Physiocrats and Smith and his followers within the same genus of 'Classicism', Meek (1951: 29) was quick to point out the important differences in the assumptions that each school had held over the form taken by the social surplus.

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15 The tax-farmers and other 'men of finance' could take exception to the direct attacks made against them; the 'school of Gournay' to the relatively subordinate emphasis given to free trade; the Enclyclopedists to the doctrine of 'legal despotism'; the manufacturers and merchants to the description of their callings as 'sterile' and the agitation for the ending of their 'exclusive privileges'; the guilds to the cries for their abolition; the landowners to the advocacy of the single tax and land rent; and the common people to the doctrine of 'proper price' which would make (and in fact appeared to be making) their bread dearer. (Meek 1962: 33)

16 Physiocrats had been attributed by Meek (1962: 370) for bringing forward

> [...] for the first time in the history of economic thought, [...] the fact that the 'areas of decision' open to policy-makers in the economic sphere have certain limits, and that a theoretical model of the economy is necessary in order to define these limits. We are unfree, the Physiocrats in effect proclaimed, so long as we do not understand the necessities by which we are bound in our society; and we can understand these necessities, in a society as complex as ours, only if we use the methods of simplification, selection, and generalization in our analysis of it. It was in their recognition of this vital fact that the Physiocrats took the decisive step leading from politics to political economy.

Indeed, the basic Physiocratic doctrine of surplus from the land being the sole source of wealth of a nation did have British predecessors (for example, Richard Cantillon, the forerunner of the 'circular' conception of economy, or William Petty), but its systematisation in Britain did not take the form it took in France (Meek 1951: 31).[17] Rather, it had been a matter of debate within the British Political Economy in the early years of nineteenth century (Meek 1951: 26). The reasons could be located in the constituents of social surplus and their definitions.

1.1.1.1. *Rent, Profit and Interest*

In Cantillon's *Essay*, three types of 'rents' could be located, which were the principal sources for circulation. Each rent was roughly equal to one-third of the farm's produce: (1) 'True Rent' paid to the proprietor, (2) compensation for the farmer's costs and subsistence expenses, and (3) a net income 'which ought to remain with him to make his undertaking profitable' (Meek 1962: 268). In *Corn*, Quesnay took this approach of putting the farmers' profit in the net product, but nowhere else (Meek 1962: 268). In fact, an 'apparent contradiction' had remained in Physiocrats on the treatment of profit (Meek 1962: 297–8).[18]

Originating from the understanding that surplus could only take the form of land rent, the earth was regarded as the unique source of wealth, and agriculture as the only productive activity. Meek (1951: 29) had argued that there was no 'net profit' as a category of income for the early Physiocrats, but 'interest' on farmer's capital certainly existed, to denote the compensation for wear and tear, or acts of god, etc. While 'exclusive privileges' could have permitted the manufacturers to receive an income in the nature of 'net profits', the latter was regarded either as a superior kind of wage or resulting from the sale of commodities by the entrepreneur to the landowner at a price greater than the 'real value' (Meek 1951). Net product was the source of the latter, and therefore, even if the profit on capital existed, it was not an independent category of income, as its origin was still rent.

[17] Influence of Richard Cantillon's *Essai sur la Nature du Commerce en Général* (*Essay on the Nature of Trade in General*, 1755), was noted by several authors beginning with Marx (1954a, c), as pointed by Meek (1962: 267).
[18] See, 'The Physiocratic Concept of Profit' in Meek (1962: 297–312).

Admittedly, in the understanding of the economic writers prior to the eighteenth century, there were profits, 'the margin between price of sale and price of purchase' which 'might suffice to cover the merchant's expenses, and if he were not too luckless secure him a bare livelihood as well' (Dobb 1973: 199–200). Still, it was difficult to imagine any substantial profit being 'naturally' made by the investment in production. Such profits were unthinkable within conditions of unfettered competition: and thus, 'it is not surprising in this period that profit should have been regarded as fruit of successful speculation, in the sense of taking advantage of price differences. [...] Competition and surplus-value could not endure long in company' (Dobb 1950: 199–200). The notion of profit, as surplus value, without any conscious regulations to produce it, was still distant.

Despite similarities with the Physiocrats as noted earlier, the Smithian school accorded independent status to 'profit on stock' along with 'rent on land', as two parts of social surplus, defined as the difference between the annual produce and cost of production.

> [...] The whole annual produce of the land and labour of every country, or, what comes to the same thing, the whole price of that annual produce, naturally divides itself, it has already been observed, into three parts; the rent of land, the wages of labour, and the profits of stock; and constitutes a revenue to three different orders of people; to those who live by rent, to those who live by wages, and to those who live by profit. These are the three great, original, and constituent, orders of every civilized society, from whose revenue that of every other order is ultimately derived. (Smith, 1776)[19]

Smith had argued that competition would tend to reduce the profit to an 'ordinary or average' rate on the employed capital, and had considered profit at this 'natural' rate as being akin to wages and rent. Such profit was different from wages of management, and appeared in the form of a surplus after taking care of all other payments, out of which 'new capital could be accumulated' (Meek 1962: 297). Profit thus appeared as a distinct category of surplus, apart from rent, while interest was only a 'derivative revenue from it' (Bharadwaj 1978: 17).

1.1.1.2. *Value in Production and Value in Exchange: the beginnings*

In mercantilist Britain, commercial gains from foreign trade were substantial, owing to the application of a system of colonial trade to ensure some element of monopoly to the parent country. Primarily through this 'exploitation of a dependent colonial system' State-regulated exploitation through 'economic policy

[19] Book I, Chapter XI: Of the Rent of Land, section 'Conclusion of the Chapter'.

of an age of primitive accumulation' had become so important that some Mercantilist writers had treated gains from foreign trade 'as the only form of surplus, and hence as the only source both of accumulation and of State revenue' akin to rent as the exclusive *produit net* of Physiocrats (Dobb 1950: 209). Thus, in the last century of the Mercantilist period in Britain, 'the economic analysis of production was almost always subordinated to the analysis of exchange' (Meek 1951: 31). In contrast, gains from external trade in France were of little economic significance and thus, 'it was possible for the foundations of the Classical analysis, with its emphasis on production [...]' (Meek 1950: 31–32) to emerge in that country.

Eventually classical analysis had crossed the English Channel, again due to a couple of historical reasons, but not in the Physiocratic form. First, more intense competition in foreign trade had forced British merchants to devote more attention towards reduction of production costs in manufacture, aided by the developments in the industrial techniques. Second, as a distinct and normal category of income, net profit on capital had emerged slowly, which was found to be almost at the same rate per cent on 'capital employed not only in commerce but also in manufacture and agriculture' (Meek 1951: 32).[20] As a result, '[e]conomists gradually began to regard profit as *originating* in the process of production and as merely being *realised* in the act of sale [and] naturally began to seek for the origin of the social surplus in the sphere of production rather than in the sphere of exchange' (Meek 1951: 32; emphasis as in original).

For Smith, labour was differentiated as productive and unproductive—the former assisting in creation of surplus while the latter simply shared it—just like Physiocratic differentiation of classes into productive and sterile, but with the important difference that manufacturing was held as productive like any other similar surplus contributing sector.[21] The productivity of labour as well as the

[20] Turgot had anticipated the equalisation of interest rate (or profit rate) between different activities. See, Brewer (1987)

[21] Oft quoted beginning of *An Inquiry into the Nature and Causes of the Wealth of Nations*:

> The annual labour of every nation is the fund which originally supplies it with all the necessaries and conveniencies of life which it annually consumes, and which consist always either in the immediate produce of that labour, or in what is purchased with that produce from other nations.
> According, therefore, as this produce, or what is purchased with it, bears a greater or smaller proportion to the number of those who are to consume it, the nation will be better or worse supplied with all the necessaries and conveniencies for which it has occasion.

proportion between productive and unproductive labour were argued to be dependent upon the accumulation of capital. The latter's importance also resulted from the possibilities of extension of division of labour. Within such a prospective surplus by productive labour in manufacturing, lay the roots of the existence of industrial profit, which was thus regarded as 'being an income in the nature of a surplus' (Meek 1951: 33). Thus in the Smithian world, social surplus assumed the dual form of rent and profits, unlike the solitary form of rent for the Physiocrats. Profit thus became independent of rent and its continuation did not require regulatory assistance by the state: it was possible even under the competitive conditions.

1.2. Classical Theories of Value

The Smithian assertion of profit as a normal category of income and one of the constituents of social surplus had put the prevailing constructions over value of a commodity, the 'physical cost' theory, into a difficulty. According to it, no surplus came out of production, as the 'value' of what went in and that of produce were identical. Thus, to account for profit within this theory, it was necessary to presume commodities being sold above their 'value'. At the same time, with the emergence of competition, following the development of capitalism, 'economists became increasingly impressed by the fact that the actual prices received for a commodity tended to oscillate around a sort of mean or average price [...]' (Meek 1951: 34). Thus, '[i]t began to be felt that value ought to be conceived, not as something which a commodity usually sold *above*, but as something which under competition it tended to sell *at*' (Meek 1951: 34: emphasis as in original). Clearly, it was not possible for the physical cost theory to consider profit as one of the constituents of value-surplus originating in the production, whose realisation takes place only during the sale of the commodity at the market. Further, for Smith, surplus had become heterogeneous in content unlike for the Physiocrats, for which purpose a price theory of value became a necessity.[22] However, Smith

> But this proportion must in every nation be regulated by two different circumstances: first, by the skill, dexterity, and judgment with which its labour is generally applied; and, secondly, by the proportion between the number of those who are employed in useful labour, and that of those who are not so employed. Whatever be the soil, climate, or extent of territory of any particular nation, the abundance or scantiness of its annual supply must, in that particular situation, depend upon those two circumstances.

[22] Physiocrats did not require a value theory, in order to conceive rent as the sole constituent of surplus. In the earlier agricultural production, unlike in manufacturing, the ingredients of

was interested more in the 'standard of measurement' for estimation of the values of commodities and of changes in them rather than the cause or rule (i.e. principle) of value or the determination of prices per se (Dobb 1973: 47; Bharadwaj 1978: 21). This 'theory of price' was called 'Adding-up Theory' following Sraffa's description—'a summation (merely) of three primary components of price [...] alternately [...] described as a simple Cost of Production Theory: in which guise it has been handed down through the nineteenth century and become known in text-books of the subject' (Dobb 1973: 46).

However, the resonance of the Physiocratic notion of a pre-eminent agricultural surplus remained in *Wealth of Nations*, as Meek (1951) pointed out: 'It is the surplus produce of the country only, or what is over and above the maintenance of the cultivators, that constitutes the subsistence of the town, which can therefore increase only with the increase of the surplus produce' (Book III).[23] In other words, such surplus from country became a necessity for the rest of the society to survive and make progress.[24] This fundamental physiological fact pioneered by the Physiocrats shall always remain true, albeit with its own historical specificities. The notion of surplus, in this thesis, rests on this 'objective fact'.

To return to Smith, it is also interesting to find the differences within his treatment of productive powers of labour in agriculture and manufacture:

> [...] No equal capital puts into motion a greater quantity of productive labour than that of the farmer. Not only his labouring servants, but his labouring

both input and output were qualitatively very similar, 'so that the creation of the surplus can be plausibly described in *real* terms without the intervention of a value theory' (Meek 1951: 35; emphasis as in original).

[23] Such 'ambiguities' by Smith could also be located in his treatment of rents, profit and wages—they were stated to the original source of value, as well as components of price (Bharadwaj 1989: 14). She (1978: 18, 1989: 14) is of the view that Smith, the 'harmony' economist, had simultaneously followed a number of arguments which can explain his paternity in economics and his 'security' as one of the originators and founder-scholars of the surplus based theories. Dobb (1973: 55) on the other hand, had reminded that Smith's writing took place

> [...] in a century when some of the most notable progress in capitalist investment and new productive methods was made in agriculture rather than in industry. His doctrine can be properly understood only as reflection of a period of transition, whose problems essentially consisted in clearing the ground for industrial investment and expansion [...].

[24]

> § 3. In some degree therefore, let the terms of the question be varied, keeping however its principle in view; and with the Chinese state the proposition thus: that part of society only can be considered as productive, whose labour and skill are devoted to the cultivation of the soil, in order to the production of food. (Wakefield, 1804: 2–3; emphasis as in original, words changed from Old English).

> cattle, are productive labourers. *In agriculture, too, Nature labours along with man*; and though her labour costs no expense, its produce has its *value*, as well as that of the most expensive workmen. The most important operations of agriculture seem intended, [...] as to direct the fertility of Nature towards the production of the plants most profitable to man. [...] Planting and tillage frequently regulate more than they animate the active fertility of Nature; and after all their labour, a great part of the work always remains to be done by her. The labourers and labouring cattle, therefore, employed in agriculture, not only occasion, like the workmen in manufactures, the reproduction of a value equal to their own consumption, or to the capital which employs them, together with its owner's profits, but of a much greater value. (1776, Book II; emphasis added)

Nature's contributions in production, and the obvious visibility of the difference between working time and production time in agriculture, were to influence Marx later.

1.2.1. The Primacy of Factor Incomes: 'overture' to the theories of value

Smith represented a transition from a primarily agricultural society to a developed capitalist economy (Meek 1951: 36).[25] While profit could become independent of rent, the status it enjoyed was similar to that of rent, if not a little less, considering Smith's opinion on the relative productiveness of labour across agriculture and manufacturing. However, historical factors were to play their role, yet again, on the question of the origin of capitalist profit and its relation to the land rent.

While massive increases in productivity and profit in British manufacturing and losses suffered by British commerce due to the Napoleonic wars had played catalytic roles, it was the political struggle between the recipients of rents and profits that had culminated in the passing of the historic Great (or First) Reform Act of 1832 (Representation of the People Act 1832). As per the preamble, this was *An Act to amend the representation of the people in England and Wales*, that began with the following sentence: 'Whereas it is expedient to take effectual Measures for correcting diverse abuses that have long prevailed in the choice of members to serve in the commons' house of parliament'.

> [Its passing] marked the consummation of the victory of the capitalist order in Britain. The question of the origin of profit and the nature of the interdependence between rent and profit began to be regarded as *politically* significant. If the agricultural surplus was in fact the basic income out of which all the other incomes were ultimately paid, this might be presumptive

[25] Such transition was between a predominantly agricultural society, where land rent is likely to be 'primary and original' category of income, leaving profit as a secondary and derivative category, and developed capitalist economy where profit is more likely to be primary category and land-rent as secondary income (Meek 1951: 36).

> evidence in favour of special discriminatory measures protecting agriculture and the recipients of rent [and not to others]. (Meek 1951: 37; emphasis as in original)

The debate on productive and unproductive labour continued in Britain through 'pamphleteering' (Dobb 1973: 65–66; Bharadwaj 1978: 12), followed by passing and repealing of regulations.[26] 'It was not a question of the classes against the masses, or, of the rich against the poor, but of the land-owning class against the commercial and manufacturing class' which was to influence Ricardo's discussion on value, distribution and accumulation (Bharadwaj 1978: 19).

John Gray in *The Essential Principles of the Wealth of Nations* (1797), had argued for 'ingenuity and labour of inhabitants exercised upon the fertility of the soil' to be the sole origin for social surplus. Thus, only the agricultural labour was found to be productive. Further, it was argued that the profit outside agriculture originated not in production but in exchange.

> [...] The proprietors of land as mere receivers of land rents are not an essential class in society, any more than engravers, statuaries, &c. It is by the constitutional appropriation of the rents of land to the defence of the state, that the receivers of those rents become an essential class in society. By separating the rents of lands from the constitutional purpose of the defence of the state, the receivers of those rents instead of being an essential class, render themselves one of the most unessential and most burdensome classes in society. (Gray 1797: 51; spellings from old English changed)

A response came from Wakefield (1804) in his *Essay upon Political Economy* which started with questioning the division of the society done by French economists into productive and unproductive.[27] While evaluating the doctrines of 'Persians', 'Chinese', Locke, Quesnay, French economists including Turgot, Malthus, Arch-deacon Paley, Xenophon, Aristotle, D'Avenant, Colbert, Steuart, Smith, Necker, Casaux, Hamilton, Wallace, and Canard (1804: fn, 6), he had framed the first question of inquiry: 'Whether labour employed in manufactures be productive?' (Wakefield 1804: 6–7). With appropriate definitions for labour,[28]

[26] Corn Laws to protect cereal producers in Britain against less expensive import by erecting legal barriers through Importation Act, 1815 and its subsequent repeal through Importation Act, 1846 provided further impetus.

[27] How could it be that,

> simple possession of a property in land, intitles a man to be considered as a productive member of society; [...] [as] by this division, every species of labour employed upon land, as well as every production of the soil, is considered as productive and valuable, though it must be apparent, that articles of the least possible use, not unfrequently engage the labour and occupy the land of the cultivator. (Wakefield 1804: 1–2)

[28] Every employment of the time and exercise of the skill or faculties of man.

manufacture,[29] productive[30] and surplus value,[31] the object of interest was set to be the respective processes of 'a previous annihilation' in agriculture and manufacturing. For the cultivator they included the following: 'first, of his own intermediate support, between seed time and harvest; secondly, of the wear of his stock advances (live and dead stock, as cattle for work, implements, sheds, &c); and thirdly, of the seed sown'. For the manufacturer they were 'first, of his own intermediate support between the beginning and completion of the manufacture; secondly, of the wear of his stock advances (tools, machines, buildings, &c.); and thirdly, of the raw material used' (1804: 9–10). Wakefeld's conclusion on the sources of surplus was straightforward (1804: 14–15, 28):

> [...] surplus of the manufacturer, whether real or nominal, resolves itself into profits of stock and interest of capital; while that of the cultivator resolves itself into profits of stock and rent of land [...] and [...] it can be shown that the causes of the interest of capital are also the causes of the rent of land, [and] it will go near to prove, that the labour of the manufacturer yields a surplus value.
>
> [...]
>
> [T]o conclude, that rent and interest are equally caused by the labour and ingenuity of man, producing a surplus value, whether employed on land or capital, in agriculture or manufactures.

Wakefield's analysis of the problem through the route of cost and surplus, as per the classical tradition, resulted in a 'theory of value' (Meek 1951: 39). He argued against the possible Physiocratic objections to the productiveness of labour employed in manufacture being only of nominal increase or being only a transfer of produce from one class to other with the assertion that an identical objection could be made in the case of cultivators as well.

> [If labour of the cultivator yields] a value, greater than the value or the cost of what he annihilated in order to procure his harvest [...] labour of the manufacturer [...] yields a material, or act, or quality, which will exchange for more, or which is worth more in the estimation of the consumer, [...] and it is contended, that the estimation of the consumer is an evidence to the value of the labour of the manufacturer. (Wakefield 1804: 12–13)

Among the other pamphlets, *Britain Independent of Commerce* (1807) by William Spence had created quite a furore (Meek 1951: 41). Its long subtitle,[32]

[29] Every exercise of human labour upon a natural production, or raw material, either in heightening its original, or annexing to it some foreign properties, or in converting it into some other form.

[30] Yield or creation of a material thing, or of some property or quality not before in such thing, or so latent, that but for an exertion of labour it would neither have been apparent, nor of use.

[31] Only such a yield or creation, as shall be in value more than the cost of the labour expended in procuring such yield or creation.

[32] *Proofs, deduced from an investigation into the true causes of the wealth of nations, that our riches, prosperity, and power, are derived from resources inherent in ourselves, and would not be affected, even though our commerce were annihilated.*

made obvious the arguments and conclusions. Even if the master-manufacturer may have received a surplus from selling the produce at more than the 'real value' in physical cost terms, and may have accumulated a portion as profits, it was nothing but a transfer and had made no addition to the 'national wealth', echoing Physiocrats once again. In 1808, James Mill had published *Commerce Defended,* with a rather self-evident and provocative sub-title.[33] The chapter 'Consumption', Meek (1951: 41) argued, elucidated the 'main ideas associated with the mature Classical outlook—that production is primary and consumption secondary, that the economic progress of society depends upon the accumulation of capital, and that the only possible source of funds for accumulation is the social surplus'. The attack was based on a class-based analysis, and brought together politics and economics closer than it was before, and that too rather clearly.[34] Two species of 'consumption' were identified: 'one is an absolute destruction of property, and is consumption properly so called; the other is consumption for the sake of reproduction, and might perhaps with more propriety be called *employment* [...]' (Mill 1808: 69; emphasis as in original).

Ricardo's *On the Principles of Political Economy and Taxation* appeared in 1817. 'Chapter 1: On Value', section 1 began with the following heading: '1.1. The value of a commodity, or the quantity of any other commodity for which it will exchange, depends on the relative quantity of labour which is necessary for its production, and not on the greater or less compensation which is paid for that labour' (emphasis as in original). This essentially, broke 'the ties' which still existed between the physical cost and labour cost concepts. A 'theory of value' was born, which was 'free from any bias towards the old physical cost concept, and which was capable of distinguishing between cost and surplus in manufacture as well as in agriculture' (Meek 1951: 47). Its necessity arose from the fact that, even

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33 *An answer to the arguments by which Mr. Spence, Mr. Cobbett, and others, have attempted to prove that commerce is not a source of national wealth.*

34 It is clear then that expenditure, not parsimony, is the province of the class of land proprietors; and that it is upon the due performance of this duty by the class in question, that the production of national wealth depends. And not only does the production of national wealth depend upon the expenditure of the class of land-proprietors, but for the due increase of this wealth, and for the constantly progressive maintenance of the prosperity of the community, it is absolutely requisite that this class should go on progressively increasing its expenditure. It will follow, as a consequence, that in countries constituted as this and those composing the rest of Europe are, the increase of *luxury* is absolutely essential to their necessities. (Mill 1808: 66)

if production of surplus in agriculture could have been visualised in physical terms, it was not true for manufacture, as for latter inputs and output consisted usually of heterogeneous and different commodities. While it was well established that labour could produce surplus in manufacture, as in agriculture, it could only be visualised in terms of 'value', and 'which required quite a considerable development in the use of abstraction in economic analysis' (Meek 1951: 46). Further, by then, capitalist methods had spread throughout the then Britain and substantial increases in productivity had occurred throughout the economy:

> [...] as accumulation came to be made more and more out of profits and less and less out of rents, the idea naturally became current that profits were not just equally important as rents, but somehow superior to them [...] elements akin to rent are found in profit and wages [...] there was nothing sacrosanct about rent and nothing unique about agriculture. (Meek 1951: 46)

1.2.2. Use-value and Exchange-value

> [...] Of everything which we possess there are two uses: both belong to the thing as such, but not in the same manner, for one is the proper, and the other the improper or secondary use of it. For example, a shoe is used for wear, and is used for exchange: both are uses of the shoe. He who gives a shoe in exchange for money or food to him who wants one, does indeed use the shoe as a shoe, but this is not its proper or primary purpose, for a shoe is not made to be an object of barter. (Aristotle, 350 BCE: 10)

With these words, the foundation was laid for the difference between use-value and exchange-value (Roll 1938: 34). Aristotle was claimed also to have a 'concept of value' elaborated in *Politics* and *Nicomachean Ethics*, but not a labour theory of value (Johnson 1939).[35] Later, with the inheritance of labour theory from Petty and Cantillon, Smith went on with his 'value in use' and 'value in exchange' to develop his own labour theory of value.

[35] Johnson (1939) argued that for both Plato and Aristotle, labour contained value but not something that gave value. Aristotle was argued to have also believed 'in labor as a commodity, by including "wage labor" along with "commerce", "usury", and "chrematistic"', with the latter not 'unjustly rendered as 'mercantile capitalism'. True wealth for the Greek thinker, was defined as 'a quantity of tools'. Since slaves were only 'live tools' no labor was necessary to make the tools productive. As they work themselves, wealth was argued to be provided 'by nature herself' and not by πόνος, pain or labour.

> Perhaps Aristotle, when he wrote the *Politics*, and Marx, when he wrote *Das Kapital*, would have acknowledged that demand is necessary for exchange; yet each would have maintained that there was something on the other side of the equation more fundamental for the creation of value: in the case of the Greek thinker, use; in the case of the German economist, labor (Johnson 1938: 448).

1.2.3. Labour Theory of Value

While the measurement of surplus containing heterogeneous commodities had prompted Smith to envisage a 'price theory', the search was for a stable and invariant standard, for assessment and comparison over time and across nations, prompted by the interest in the real accumulation process determining relative powers of countries (Bharadwaj 1978: 20–21).

> [...] As a measure of quantity, such as natural foot, fathom, or handful, which is continually varying in its own country, can never be an accurate measure of the quantity of other things, so a commodity which is itself continually varying in its own value can never be an accurate measure of the value of the other commodities. (Smith 1776, cited in Dobb 1973: 47–48)

Money prices were regarded too fickle, and labour was thought to be the 'real money', the only possible standard.

> [...] Equal quantities of labour, at all times and places, may be said to be of equal value to the labourer. In his ordinary state of health, strength, and spirits; in the ordinary degree of his skill and dexterity, he must always lay down the same portion of his ease, his liberty, and his happiness. [...] Labour alone, therefore, never varying in its own value, is alone the ultimate and real standard by which the value of all commodities can at all times and places be estimated and compared. It is their real price; money is their nominal price only.
>
> But though equal quantities of labour are always of equal value to the labourer, yet to the person who employs him they appear sometimes to be of greater, and sometimes of smaller value. He purchases them sometimes with a greater, and sometimes with a smaller quantity of goods, and to him the price of labour seems to vary like that of all other things. It appears to him dear in the one case, and cheap in the other. In reality, however, it is the goods which are cheap in the one case, and dear in the other. (Smith 1776)

This distinction between labour-embodied and labour-commanded were quite clear, (Dobb 1973: 48) and referred to the distinction between the 'amount of labour which the production of a commodity costs' and 'the price at which that labour will exchange in the market'. The latter was to be termed value or price of labour-power by Marx later. Smith's dilemma foreshadowed the split between the 'production cost theories of value' and the 'subjective preference theory of value' which exist to this day in economics' (Patterson 1998).

Bharadwaj (1989: 24) had underscored two specific contributions of Smith to the problem of value. One is his clear formulation of 'natural price', which was 'sufficient to pay the rent of the land, the wages of the labour, and the profits of the stock employed in raising, preparing and bringing it to market, according to their natural rates'. These were 'central prices' around which commodity prices continually gravitated or constantly tended towards. 'Such "natural values" then became a term of comparison, or norm, with which all "artificial prices" [...] could be contrasted and exposed' (Dobb 1973: 43). The second was the distinction maintained between 'natural price' and 'market price', with the latter higher or lower than the former. Natural price was more of a 'theoretical price' compatible with the viable reproduction of the 'natural state', for which all the three basic elements of 'effectual demand', methods of production and wage, were rooted in historical experience.

In the first two editions of *Principles* (1817 and 1819) the requirement of invariant standard was met by embodied labour, which Bharadwaj (1989: 43) had referred to as a 'simple' labour theory of value.[36] However, the third edition (1821) and the unfinished manuscript of 'Absolute Value and Exchangeable Value', contained Ricardo's efforts to modify the labour theory of value in the light of different proportions of means of production to labour in different commodities. One attempt was through the equation relating rate of profit, social product (net of rent) and wage: as long as the latter two were expressed in homogenous commodities (of corn, say) or homogenous magnitudes (of labour, say) the surplus-based theory was facing no difficulty. However, once changes in wage resulted in variations in relative prices, problem of simultaneity appeared. Ricardo could not transcend the difficulties and it was 'left to Marx to restate the problem of transforming labour values into prices of production [...]' (Bharadwaj 1989: 45).

For Marx, the important questions were explanation of the origin of the surplus itself, and how was it extracted and appropriated in the competitive capitalist

[36] In the opening sentences of section vi, Ricardo made obvious the desirable properties of invariable standard:

> When commodities varied in relative value, it would be desirable to have the means of ascertaining which of them fell and which rose in real value, and this could be effected only by comparing them one after another with some invariable standard measure of value, which should itself be subject to none of the fluctuations to which other commodities are exposed. Of such a measure it is impossible to be possessed, because there is no commodity which is not itself exposed to the same variations as the things, the value of which is to be ascertained; that is, there is none which is not subject to require more or less labour for its production. (Ricardo 1817)

Dobb (1973: 82) commented that 'he seems to have accepted the view that invariability in a standard was not only impossible to find in practice but was impossible in principle'. He had credited Sraffa for revealing the true nature of the problem that Ricardo had. '[H]is primary concern was with the effect of rise or fall of wages—with 'change' rather than with 'difference'. In the words of Sraffa in Ricardo (2005: xlviii–xlix),

> [...] the problem of value which interested Ricardo was how to find a measure of value which would be invariant to changes in the division of the product; for, if a rise or fall of wages by itself brought about a change in the magnitude of the social product, it would be hard to determine accurately the effect on profits.

economy.[37] Holding that competitive prices were the specific form exchange value had taken historically under competitive capitalism, or even under equivalent competitive exchange, surplus, Marx argued, was generated and appropriated in the process of production through the exploitation of wage labour, while it was realised only in the sphere of circulation. Reconciliation between surplus value and the 'law of value' in his own framework followed the crucial distinction between labour and labour-power.[38] While this issue will return later, the approach may be indicated here. In *Capital*, labour-power was defined as the 'energy transferred to a human organism by means of nourishing matter' and was 'the aggregate of those mental and physical capabilities existing in a human being which he exercises whenever he produces a use-value of any description'. As Dobb had put it,

> [T]he 'nourishing matter' needed to replace the energy used-up in work was the material input into human labour; and the possibility and dimensions of surplus-value depended upon the *value of the former being less than the value 'created' as output by the labour it sustained.* The difference between the two he spoke of as the difference between 'necessary labour-time' (the input) and the total labour-time actually expended in production. (Dobb 1973: 151; emphasis added)

Nature of inquiry in the present thesis rests on this difference between the value of the input and the value created, measured in energy terms.[39] This is in line with the 'classical' approach of inquiry into socio-economic problems of the day, which in our case concern the 'unsustainability' of the agricultural operations.

Classical theories held that a number of complex factors influence exchange value of a commodity in actual practice. While the prices of production were viewed as 'a highly simplified way of approaching the problem of competitive value through a scheme of abstraction', the 'predominant influence of cost of production in the determination of the value of commodities' remained as the 'fundamental factor' [Pierro Sraffa, 1926, 'The Laws of Returns under Competitive Conditions', *Economic Journal*, 36 (144): 535–50 quoted in Bharadwaj (1978: 66)]. Thus 'it did not include *within the explanation of value* any theory, explicitly or

37 Dobb (1973: 141) had evaluated Marx as the one who 'has been more variously estimated, as well as more misinterpreted, than almost any other economist of note'.

38 Marx's theory of surplus value also included the questions on increasing its rate—through lengthening of the working day (absolute surplus value) or reduction of 'necessary labour time' as a proportion of total labour time (relative surplus value) (Dobb 1973: 154).

39 For inputs, material input to human and animal labour as well as material consumption and depreciation in stock have been converted into their corresponding energy (or embodied energy) values. Calculation of the calorie value of the selected food crops and their by-products is used to estimate the value created.

implicitly, of what determines social consumption and social output, its level or composition, taking these as provisionally the *data* of the problem, within historically given conditions' (Bharadwaj 1978: 66; emphasis as in original).

Indeed, two features of classical approach weigh in favour of its adoption for addressing the research question at hand, besides the advantages of 'openness' that it offers towards incorporating a number of 'historical and social influences'. One, the separation of quantities from prices that allows examining one without the other, and two, its view of production as a circular process, in contrast to the given factor endowments approach of neoclassical theory. While the method of energy balance analysis shall be discussed in detail later, its basic feature remained as a cost of production theory of value, and it enjoys an obvious similarity with the embodied labour theory of value. One may reiterate the central analytical features of classical political economy before establishing the link between classical approach and the energy analysis in the following section.

> [...] The classical theorists had sought the determinants of value in the material conditions of production, later termed as 'costs of production' (Pierro Sraffa pointed out to me that the term 'cost of production' came into vogue only at a later stage when a distinction was made between exchange value (price) and cost. In earlier theories, value was used synonymously to represent 'costs' in production). While the notion of 'costs' itself gradually changed [...] and various components of costs were variously analysed, still one may say that it was the 'objective' material basis of production that determined the value of products. The labour theory of value was initially constructed on the implicit premise that all means of production were reducible to labour directly or indirectly. [...] [U]nder whatever specific form values were discussed—whether as labour values or prices of production—the basis of value was located firmly in the sphere of production and costs reckoned in terms of 'productive consumption' (material inputs plus wage goods) essential to support the productive process. This implied, as a method, a reliance on objective conditions. (Bharadwaj 1978: 30)

1.3. Classical Approach, Standard Commodity and Embodied Energy

In 1960, Pierro Sraffa had published 'a short work' of less than one hundred pages, which took him 'a rather disproportionate length of time' of more than 30 years to complete (Sraffa 1960: vi). This 'slender but classic' (Dobb 1973: 248) work had revived the classical approach, in contrast to the marginalists', in vogue since 1870s. The 'investigation' was 'concerned exclusively with such properties of an economic system as do not depend on changes in the scale of production or in the proportions of "factors"' (Sraffa 1960: v). While marginalists' approach required attention focussed on change, the system under study by Sraffa was where 'day after day, production continued unchanged in those respects' and where 'the marginal product of a factor (or alternatively the marginal cost of a product) would not merely be hard to find—it just would not be there to be found' (Sraffa 1960: v).

The property of capital as 'an independent quantitative entity' which could be 'substituted in defined amounts for other factors of production' in particular, and the entire notion of 'production function' in general was questioned (Dobb 1973: 252). In Sraffa's framework of 'dated labour', the cost and final price of a commodity was 'conceived as the summation of a vertical series of stages of production spread out backwards in time, each consisting of a labour-input *plus* commodity-inputs (machines, raw materials, components) that are products of some earlier stage; each with its labour-input having its attached date in the vertical series' (Dobb 1973: 253).

In algebraic terms, Sraffa's system can be depicted as a corollary of the Dmitriev's equation with substitution of labour terms by quantities of wage goods (Dobb 1973: 259). In particular, 'reduction to dated quantities of labour' equation of Sraffa was interpreted by Dobb (1973: 260) as the one where prices were derived from the description of 'production in terms of labour expenditures per unit of output, with a time period attached to these expenditures'.

England (1986), and many others, had pointed out that Sraffa's analysis of joint production is amenable to include waste emission and environmental protection. It is the similarity between the assumptions made by the neo-Ricardians on the one hand and those of the ecological economists, that had resulted in such a conclusion. Among others, they included viewing production as a circular process rather than a linear flow from 'inputs' to outputs, and its link to the creation of surplus. Indeed, for the latter, this framework 'encourages one to theorize about the *reproduction* of economic systems and the particular requirements which must be satisfied if reproduction is to occur' (England 1986: 233; emphasis as in original).[40]

It is not just with regard to the neo-Ricardians; research in the last thirty years has also established similarities in the analytical approach between the Marxian framework and ecological economics. Gowdy (1984) in one such early attempt.[41] Further, it had asserted that in Marxian terms the social relations of production could influence the efficiency of capital by speeding up the entropic process. In fact, Marx's critique of capitalist agriculture for leading to premature exhaustion of the land followed this argument.[42]

Neo-Ricardian approaches had received much attention following Sraffa's work. In it, exchange values of any particular commodity, in relationship with every other commodity in the economy were to be entirely determined by the sociotechnical conditions of production. Clearly subjective tastes and preferences of the consumer had no role, as was the case in Classical approaches. However, their primary contribution was in arguing that subject to certain conditions, test of 'invariable standard' could be fulfilled by any commodity: even energy was a serious candidate.

> [...] With this theoretical tour de force in hand, Neo-Ricardian's began to challenge the Marxian analysis, arguing that labor [...] is only one of many inputs into the production of commodities. [...] The fundamental challenge [...] is their contention that the value of any commodity can be expressed as

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40 For a critique over such an interpretation of Sraffa as an ecologist, see Patterson (1998).

41 Wealth consists of use values which may arise from nature:

> Labor is not the source of all wealth. Nature is just as much the source of use values (and it is surely of such that material wealth consists!) as labor, which itself is only the manifestation of a force of nature, human labor power. [...] And insofar as man from the beginning behaves toward nature, the primary source of all instruments and subjects of labor, as an owner, treats her as belonging to him, his labor becomes the source of use values, therefore also of wealth (Marx 1970).

On the other hand, exchange value arises from the process of production, specifically from direct or indirect human labor power. Thus, while labor becomes the source of all value in exchange, nature is the ultimate source of wealth (value in use).

42 Briefly put, in Marx's formulation, premature exhaustion of the soil occurs due to economic disincentives to maintaining long-lived capital investments. While rising cost of raw materials depresses the rate of profit through increase in resource exhaustion, in reality the 'marginal cost' of a non-renewable resource happens to be only the marginal cost of extraction and not production, thus creating a surplus for the producer (Gowdy 1984).

> its exchange ratio to any "standard" or "basic" commodity, not only in terms of its required labor content. (Judson 1989: 262)

Judson (1989: 261) argued that it is only since 1985 that 'concepts of energy and entropy have made significant inroads into economic thought'.[43] Arguably, this took so long despite efforts by Georgescu-roegen to replace the 'logo for old economics [of] [...] frictionless Newtonian pendulum which swings forever' with that of 'an *hourglass* whose sands run downward as the arrow of time advances, and an irreversible process that admits of no permanently renewable steady state for maintainable economic consumption' (Samuelson 1999: xiv; emphasis as in original).

Judson (1989: 262) had found 'ecoenergetics' to be closer to the classical approach to economics rather than the neo-classical one.[44] Further, Christensen had pointed that the central weakness of the neoclassical production theory lay in its neglect of material and energy resources within the primary factors.[45]

Parallel to the Sraffian revolution, developments in the modern ecology (to be discussed in the next section) had put forward the importance of energy 'content' of the commodity (expressed as the amount of energy that can be released from it in combustion or behaviour), and the energy cost of production of a commodity (expressed as the energy used up in the manufacture of the good). Added was a third perspective, that had argued for the energy input or content as an important

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[43] '[...] [T]endency of energy toward a universal equilibrium is called *dispersion of energy*, or according to Clausius's terminology, *Entropy*. This last term expresses the quantity of energy transformed that cannot undergo additional subsequent transformations. These two principles of Clausius derive from it: *The energy of the universe is constant. The entropy of" the universe tends towards a maximum*' (Podolinsky 1881/2004: 62; emphasis as in original).

[44] This term has the same qualifications as Dobb (1973: 248). There are well-recognized criticisms on the assumptions behind such theoretical formulation (Söderbaum 1999; Burkett 2003/04; Martinez-alier 1997: 32), which is beyond the scope of this work to address.

Judson (1989) identified three dimensions that are important in theories of value which resulted in the confusion between classical and neoclassical economic theories:

(1) *macro-* versus *micro-level* analysis—the central conflict in this respect is over the question as to 'whether the individual or the society is made the starting point of economics'. It is manifested for example, between marginal utility perspective and the embodied labour perspective on value

(2) *objective* versus *subjective* analysis—debate over this question is classic and continued ad infinitum, between, anthropocentric, ecocentric and even anthromorphic perspectives, and

(3) *dynamic* versus *static* analysis—this can be best illustrated with the contrasting notions of efficiency: in one it is the ratio of output to input without any consideration to time while in the other it is the output per unit of time, without taking into account the inputs (Mayumi 2001b).

[45] 1987, 'Classical roots for a modern materials-energy analysis', *Ecological Modelling* 38, pp. 76–77, as cited in Judson (1989: 262).

factor in determining value, while maintaining that it is only one of many possible inputs. It is important to note that all the three approaches had been termed under 'energy theory of value', and just like the phrase, 'classicalist approaches to value' there lay crucial differences among them, which often resulted in unnecessary and avoidable confusion.

Most famous proponent of the first 'school of thought' was ecologist H T Odum, who had worked tirelessly in establishing energy values of various aspects of the biosphere, including biotic and abiotic resources and ecosystem services. Odum's 'maximum power principle' argued that eventually systems which transform energy at the most optimal rate would out-compete other systems and therefore will survive. His 'energy theory of value' was based on the idea of EMERGY, a measure of the value of a commodity in terms of the amount of energy required to produce it (Patterson 1998).[46] Most of the criticism over energy analysis from the economists had originated from the construction of this particular version of 'energy theory of value' (Slesser 1978: 3). Arguments from critics like Georgescu-roegen, Herman Daly and Kenneth Boulding ranged from the non-homogeneity of matter in contrast to the homogenous energy, to the ignorance of factors in the economic system 'other' than the energy constraints (Judson 1989; Patterson 1989). After all, '[m]atter matters, too' (Georgescu-roegen 1971).

For the purposes of this work, the second approach assumes more importance. Here, the energy 'content' of a commodity is analysed for arriving at the total cost of production in energy terms. In other words, such an embodied energy theory of value is essentially a cost of production theory, where all costs are carried back to the primary input, the only 'scarce' factor of production, the solar energy required to produce them, with labour, manufactured capital, and natural capital as 'intermediate' inputs (Slesser 1977: 259; Costanza 1980: 1224; Cleveland 1987; Farber et *al.* 2002: 382—383). However, there exist important differences over the purpose of this exercise.

One strand of thought, mainly from some of the ecological economists, argued that the energy use intensity and money use intensity could be compared, which was just a short step before treating energy values as the 'values in exchange'

[46] Chen et *al.* (2006) had performed an EMERGY analysis of Chinese agriculture, while Martin et al. (2006) did the same for three agricultural systems in US and Mexico.

(price). Indeed a few had claimed this approach to be a close parallel of neo-Ricardian labour-embodied theory of value with energy replacing labour as the primary costs of production (Farber et *al.* 2002, for example). For obvious reasons, there had been a number of arguments opposing such an assertion.

Primacy of energy as an input was criticised for the presumption about the reproducibility of the other factors in terms of pure energetics (Burkett 2003: 139). Further, eco-Sraffians argued that production and monetary exchange values depended on labour, resources and environmental services as well. Indeed, ecological economists like Martinez-alier had argued against ascribing value to energy or other 'primary input': there may not be any 'general theory of value'. Burkett (2003: fn 5) commented that following Sraffian framework but rejection of energy theory of value implied that 'composition of the standard commodity cannot plausibly be expressed in pure energy terms, given the material (physical, chemical and biological) differentiation of the production system'. Certainly, energy can serve as an ordinary standard of measure, but not as a 'standard commodity' which would be invariant to the distributional shifts between wages and profits.

The other strand, which consisted of mainly ecologists, thermodynamists, biologists, and energy analysts, had placed energy analysis as a tool for supplementing economic analysis in policymaking. The debate that took place among economists and energy analysts, on the appropriateness, applicability and usefulness of energy analysis in US public policy is illustrative in this regard.[47]

The third approach took the valuation exercise to the furthest, to the point of suggesting that energy intensities determined even the 'value' of biological components in an ecosystem and just not the economic components (for example, Hannon, Costanza and Herenden 1986).

[47] It was apparently motivated by the 'loss' of hegemonic position in the public policy decision-making that economists had enjoyed. Context was the Section 5, Non-Nuclear Energy Research and Development Act [1974] of US stated that 'potential for production of net energy by the proposed technology at the stage of commercial application shall be analysed and considered in evaluating proposals'. H Odum, an influential and notable Energy Analyst was instrumental in getting this law passed in US Congress (Slesser 1978: 6). See, Gulliland (1975) and Huettner (1976) for energy analysts' and mainstream economists' viewpoints respectively

At the same time, it is worth stating the position of the majority of energy analysts on the question of energy theory of value.

> [...] [W]e do *not* subscribe to any 'energy theory of value'. Our approach while resting on same scientific principles [...] aims to provide *description*, not *evaluation* [...]. Logically there is no way that descriptions of what *is* can be used to deduce what *ought* to be done. The decision about what to do involves a value judgment and, to be clear, this should be explicitly separated from the description of what is. (Chapman and Roberts, 1983; emphasis as in citation)[48]

Martinez-alier (1987: 147–8, 233) had argued that an energy theory of value might not mean return to the 'energetic dogma' that may force the economic planner to 'minimize the dissipation of energy to maximize the flow of energy utilized', but may also eliminate the differences in valuation between renewable, non-renewable and slowly renewable resources. At the same time, as prices, calories or production time, all satisfy the commensurability requirements; such a theory may enable us to compare the number of years taken to produce geologically equivalent calories of coal or oil as in the total world annual harvest.

Limitations of energy theory of value are many. First, it is related to the reverse translation from energy equivalent to matter in practice (the non-homogeneity problem referred earlier). Some of the factors or materials are non-substitutable, which however are of absolute necessity. On the other hand, different forms of energy are largely substitutable. Secondly, within the energy theory, in the realisation of value, exchange processes had not been incorporated. For example, 'can the value of nonessential luxury commodities be determined by their energy cost of production?' (Judson 1989: 269).[49] This problem is particularly manifested in economic states with surplus that requires distribution. Third, embodied energy theory had been found to be with a lack of focus. Fourth, energy theory is yet to find an acceptable way to handle capital. To be more precise, whether the straight-line method of depreciation is more applicable or a gradual depreciation of energy efficiency is more apt, remain to this day an issue that is yet to be resolved.[50] Fifth and finally, relationship between energy quality,

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[48] P F Chapman and F Roberts, 1983, *Metal Resources and Energy*, Butterworths, cited in Common (1995: 210).

[49] Elsewhere, Judson (1989: 274) elaborated the difference between 'basic' and 'non-basic' sectors as follows, which is different from Sraffa: while the non-basic sector is dependent upon the surplus of the basis sector, be it energy or money terms, system of valuation of non-basic goods are unlikely to reflect their cost of production. For example, 'value' of a recreational area through embodied energy.

[50] Also, see, Hannon et *al.* (1986: 398) that compared attempts by Sraffa and Samuelson on present value of the historic costs in economic systems with the time cost of capital

technological change and monetary value are far from being addressed satisfactorily. Indeed, energy quality is a major factor in energy use, and such effects are ignored in the homogeneity assumption of much empirical work (Judson 1989).

Norum (1983: 9) argued that, following 'energy as a measure of value' criterion might also result in unreasonable decisions. Consider, for example, the possibility of energy value for input of labour. It follows that worker's demand for goods and services are to be met with energy, given the general level of energy use in society. Now, with rise in use of fuel, value will rise in relation to energy It follows then that the 'optimal' choice between inputs of labour and fuels will result in substitution of labour by fuel, 'independent of resource depletion and rate of unemployment'!

In response to Duhring's arguments linking energy with value in a rather crude manner, Engels' response was noteworthy in this regard:

> [...] In so far as there is a meaning in this, it is: The value of a product of labour is determined by the labour-time necessary for its production; [......] It is simply wrong to say that the dimensions in which anyone invests his energies in anything (to keep to the bombastic style) is the immediate determining cause of value and of the magnitude of value. In the first place, it depends on what thing the energy is put into, and secondly, how the energy is put into it. If someone makes a thing which has no use-value for other people, his whole energy does not produce an atom of value; and if he is stiff-necked enough to produce by hand an object which a machine produces twenty times cheaper, nineteen-twentieths of the energy he put into it produces neither value in general nor any particular magnitude of value. (Engels 1947)

appropriate to its age and adding to the current cost with their own in the context of ecosystems.

1.4. Rise of the Energetics—ecological, social, and agricultural

Ecology had a history, even before it had a name, argued Worster (1994: x). It took one hundred more years to enter into the vernacular, 'but the *idea* of ecology is much older than the name'. In the eighteenth century, it had emerged as a more comprehensive way of looking at the earth's 'web of life' as an interacting whole.[51] German biologist and philosopher Ernst Haeckel, a disciple of Charles Darwin, 'the busiest name-maker of his time' in 1866 had suggested *Oecologie,* to

> [...] give a semblance of order to a scientific word that was splitting off into many different line of enquiry [...]. In the broadest sense it was to be the study of all the environmental conditions of existence, or, as his translator later put it, "the science of the relations of living organisms to the external world, their habitat, customs, energies, parasites, etc." (Worster 1994: 192)

The new word was to share the same root as the older word 'economy', with the original meaning of family household and its daily operations and maintenance. *Oecologie* too was thought to denote living organisms of the earth constituting a single economic unit, like a family or household. 'So if "ecology" at root means the study or science of the *oikos* and 'economy' means its management, then there would seem to be good reason to see ecology and economy as mutually dependent allies' (Hayward 1994: 91). Indeed, before the International Botanical Congress had given the modern spelling 'ecology' in 1893, biologists were using the phrase 'economy of nature' instead.[52] The common root between the disciplines was to result in the adoption of economic concepts in ecology, that was carried forward through parallel contributions from ecologists and economists towards the development of 'bio-economics'. The concept of Metabolism, the 'star', to analyse the human society—nature interactions, relationships and exchanges, with transdisciplinary recognition, acceptance and approval, is the result of such efforts.

By the early twentieth century, contours of the terrain of 'ecology' were quite clear: its *raison d'être* was the social relations of the natural world—'the science of the development of communities' (Worster 1994: 204). This withstood the test

[51] In contrast, at present it has achieved a cult status: it serves as the basis for international regulations on combating climate change, it has carved out a space within the spectrum of political ideologies as well as within the public policy, it has motivated 'new' social movements across the world—its 'mainstreaming' is complete, unlike gender, race/ethnicity, caste, children, or disability.

[52] Worster (1994) dwelled at length on the changing nature of this phrase throughout the book, as well as the word. See, pp. 192–204, for the interdisciplinary history of 'ecology'.

of time[53] and gained acceptance across disciplines.[54] In the ecologist's description, an individual became the fundamental unit of populations, communities, ecosystems and biomes. Essential to the understanding of the study was 'how they obtain their energy and nutrients', and a consideration of 'how these are allocated to maintenance, growth and reproduction'. This was an approach quite identical to that of economics (Chapman and Reiss 1995). 'Metabolic rate', 'energy budget', 'assimilative efficiency', 'production', 'growth efficiency', 'distribution' became its important terms, with meanings very similar to those in economics. There were definite historical reasons for this convergence of the two disciplines, apart from sharing the common root *oikos*, in the concepts and methods, cutting across the artificial disciplinary boundaries and chauvinisms, to extend a holistic, rigorous and appropriate treatment of the human society—nature relationship.

1.4.1. Idolising the Nature and the 'Ideal' Nature: idols and ideas in ecology

The end of nineteenth century and the beginning of the twentieth century had been exciting times for science: both for older ones like physics, and chemistry and even for the new field of ecology.[55] It was primarily the Anglo-Americans who had carried out developments in the various aspects of ecology. In Britain, it was the Scots, William and Robert Smith, Glasgow biologist Patrick Geddes (who studied with T H Huxley) and Oxford ecologist A G Tansley and in America it was Henry Chandler Cowles of the University of Chicago and Frederic Clements of the University of Nebraska (Worster 1994).

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53 A popular textbook begins as:

> Ecology is the study of organisms in relation to the surroundings in which they live. These surroundings are called the environment of the organism. This environment is made up to many different components, including other living organisms and their effects, and purely physical features such as the climate and soil type (Chapman and Reiss 1995).

54 See, for example, Bukharin's energetics, in 1.4.2.4 below.

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> The important fact is that the discovery of the Entropy Law brought the downfall of the mechanistic dogma of Classical physics which held that everything which happens in any phenomenal domain whatsoever consists of locomotion alone and, hence, there is no irrecoverable change in nature. It is precisely because this law proclaims the existence of such a change that before too long some students perceived the intimate connection with the phenomena peculiar to living structures. By now, no one would deny that the economy of biological processes is governed by the Entropy Law, not by laws of mechanics (Georgescu-roegen 1971: preface).

1.4.1.1. *Monoclimax Thesis*

In 1896, Cowles had applied Eugen Warming's 'model of succession' and climax formation to the vegetation growing in Lake Michigan, and incorporated the 'monoclimax' thesis.[56] In 1890, Clements was joined with Roscoe Pound, both as assistants to work under Charles Bessey, at Nebraska.[57] Clements' central contribution lay in identifying the ecological succession in the plant communities and the organismic character of the plant formation: 'Change upon change became the inescapable principle of Clements' science' (Worster 1994: 209–10). His notion of a 'vaguely climax stage', was based on his argument that, nature's course, is a steady flow towards stability that could be 'exactly' plotted by a scientist. Such notion of 'a relatively permanent equilibrium with the surrounding conditions capable of perpetuating themselves forever' was identical to that of Cowles (Worster 1994: 210).[58] This thesis had brought modern ecology in convergence with the organismic philosophy. In this view, competition, within the natural world, was essential for growth, for progress to achieve the full communal state. The idea was to remain until challenged by the 'age of new ecology', roughly quarter of a century later.

Clements' collaboration in 1939 with Victor Shelford had resulted in the development of 'bio-ecology', that had brought two sub-disciplines of ecology closer to each other. However, a much more important problem was waiting to be addressed by the ecologists: that of presence or influence of humans, which had remained hitherto neglected (Worster 1994: 217).

Meanwhile similarities became more visible between the succession in the plants in a habitat with that of the human society, namely, of pioneering and settlement. In 1893, Frederick Jackson, a historian from Wisconsin, identified the then

[56] 'All stages of their [dunes] life-history may be seen; the beginning, the climax, the destruction' (Cowles 1899: 195). Cowles, did not publish much beyond the 1899 article, and disappeared into oblivion; yet, many of his students became leaders in the field—a universal trait of a 'proverbial solitary and self-reliant pathfinder' (Worster 1994: 208).

[57] Pound had left for Harvard to study law and then become an authority of sociological jurisprudence. The other biologist turned sociologist was Herbert Spencer. For Spencer's ecological ideas, see, Worster (1994: 212–4).

[58] According to the classical ecological theory of Cowles and Clements, the succession stops when the 'sere' arrives at an equilibrium or steady state with the physical and biotic environment. Barring major disturbances, it will persist indefinitely. The end point of succession is called climax. Sere is a term coined by Clements to denote a system of developmental stages that starts with a primitive and inherently unbalanced plant assemblage and finishes with a complex of relatively permanent equilibrium (Worster 1994: 211). This is akin to the notion of 'steady-state' in economics, or physics.

westward moving pioneers as *the* process in forming the national character of the United States. Such ecology of pioneering became the dominant ethos of the day and was in line with the evolution of American society at the 'frontier'. This convergence of ecology and history resulted in an irony. At the frontier, where the biotic community was to 'climax' and a mature complex civilization was to emerge, '[...] the two processes of development were fated to meet, it seemed, in irreconcilable conflict. One would have to give way to the other; it was not possible to have both a climax state of vegetation and a highly developed human culture on the same territory' (Worster 1994: 219).

When the 'invading society seeking homes, wealth, and empire' with axe and rifle, finally entered 'the grassland', the last of the American West, the result was both a social and ecological disaster—the Dust Bowl of the 1930s. Henceforth, 'man' could not be left out of textbooks and models in ecology.

The pioneers and homesteaders had literally prepared the soil for this enormity.[59] Impact was equally gigantic:[60] forced migration,[61] poverty,[62] and soil erosion.[63] While there were definite agro-ecological reasons for the Dust Bowl, couple of socio-economic ones had also contributed.[64] 'Not drought but the machine drove most of these farmers from the land, but perhaps it was easier on their pride to blame the misfortune on nature' (Worster 1994: 225). The Sodbuster,

[59] Facts speak for themselves: 22 of regional extent in 1934, 40 in '35, 68 in '36 and 72 in '37—'dust was everywhere, blanketing crops and wiping out fence lines, filtering through the cracks around the door—no matter how many wet rags were stuffed in them' (Worster 1994: 221).

[60] In Thomas Country, Kansas, no wheat was harvested in 1933, '35, '36 and '40 with average yield in the intervening years as one-third of pre-drought years. By 1935, US were importing wheat. Average cotton ginnings reduced from 99,000 bales in late 1920s to 12,500 in 1934 and 26,500 in 1936 (Worster 1994: 222).

[61] In the second half of 1930s, 6,000 people entered California every month, and between 1935 and 1939, there were 300,000 'Dust Bowl refugees'.

[62] By 1935, within the southern plains, 80 percent of the families were living on relief.

[63] By 1838, the peak year of soil erosion by wind, 9 million acres were severely damaged, scattered over 51 million acres. For Great Plains, it was 500,000 square miles or half of total area.

[64] In included poor cultivation practices by the 'settler' tenants, in possession of very small land barely enough for subsistence. As a result, topsoil was washed away, and the new soil had to be worked upon hard. By early twentieth century, these lands had passed many settler hands before being consolidated in the hands of a few wealthy landowners. Economies of scale demanded consolidation of small farms, use of tractors and removal of the surplus population. Almost forty percent of the farmers throughout the Great Plains were tenants, and thus could be removed easily (Worster 1994).

representing the environmental ethic of conquest, arguably, gave birth to the 'Dust Bowl refugees'.[65]

Further, with patriotic appeals from the US President to supply wheat to the European allies to win the First World War, coupled with a promising market price, mass production could reach the plains. Great Plains Committee (1936) in its report had concluded, '[a]fter fifty years of being hailed for his heroic exploits, the sodbuster had become a menace to the nation' (quoted in Worster 1994: 230). It categorically blamed the imposition of a system of agriculture unsuitable for the region, and called the disaster wholly manmade.[66] However new dilemmas were to appear in the public policy soon.

1.4.1.2. *Anti-climax and Anthropogenic Climax*

For reasons of anti-technology implications of Clements' thesis as well as for purely scientific reasons, 'anti-climax' arguments began to appear in the 1930s. The 'carefully orchestrated, precise succession to the climax state' was to be challenged. For A G Tansley of Oxford, the distinctly discomforting issue was to visualize man as a disrupter of nature.

> [...] It is obvious that modern civilized man upsets the 'natural' ecosystems or 'biotic communities' on a very large scale. But it would be difficult, not to say impossible, to draw a natural line between the activities of the human tribes which presumably fitted into and formed parts of 'biotic communities' and the destructive human activities of the modern world. Is man part of 'nature' or not? Can his existence be harmonized with the concept of 'complex organism'? (Tansley 1935: 303)

This new climax was to be termed 'anthropogenic' representing a major clash of environmental values, which was waiting to happen in any case. Clements' system of inflexible, monolithic 'sere order'[67] was not always followed by nature. In addition, in the American consciousness, the idea of 'designating nature as a foe to be vanquished and a redeemer to be praised' and that of a wild, untrammelled

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65 Steel plough was his ammunition, with which dense root masses could be removed. Native sod, on the other hand, was the protector against strong wind and drought. Ill-advised practices of ploughing long straight furrows leaving large field completely bereft of any vegetation and planting a single cash crop replacing the diverse plant life had ignored the basic biological fact that soil erosion results from sickness of the vegetation and not from the sickness of the soil (Worster 1994: 226–30).

66 'Nature has established a balance in the Great Plains by what in human terms would be called the method of trial and error. The white man has disturbed this balance; he must restore it or devise a new one of his own'. (Worster 1994).

67 'Sere' was a term meant to imply a system of developmental stages which began with a 'primitive, inherently unbalanced plant assemblage' and finishes with a 'complex formation in relatively permanent equilibrium' with its environment, which was capable of perpetuating itself forever (Worster 1994: 210).

nature were just too strong, far more than in the European one (Worster 1994: 241). Tansley on the other hand, could make the distinction between Europe and America over the civilization's impact on natural succession.

> [...] Tansley did not want to accept any climax achieved by purely natural processes as an ideal for man to respect and follow. His concern was not to reestablish man as a part of nature, but to put down the threat to the legitimacy of human empire posed by the natural climax theory. If Tansley was right and there were no meaningful differences between the balance achieved by nature and that contrived by man—if the two systems were at least equals in quality and performance—then what reasonable objection could there be to man's rule over the biological community, or to the further extension of his empire? (Worster 1994: 241)

In other words, Tansley's argument was in favour of the removal of ecology as a 'scientific check on man's aggrandizing growth'—with the removal of Clements' thesis, there was to be no exterior model to serve as the benchmark for a scientific evaluation. In 1956, with the arrival of James Malin, of University of Kansas, the foremost scholar on the history of grassland, 'anti-climax' thesis had received a major boost. Malin had already written in 1953,[68] that '[t]he conventional or traditional concept of the state of nature must be abandoned—that mythical, idealized condition, in which natural forces, biological and physical, were supposed to exist in a state of virtual equilibrium, undisturbed by man' (quoted in Worster 1994: 242–3).

For him, it was the modern agriculture that had lent a stabilizing hand towards a 'reign of order, peace, and harmony', given the fact that dust storms had always been a 'natural phenomenon' in the Great Plains, with documented evidence since 1830, and most of them happened before the arrival of sodbuster. Interestingly, Malin had argued that the very process of wind erosion had been responsible for building a rich and fertile soil. Without the layering, removal of a feet or two of topsoil made no difference; indeed, it was a gift at the location of its deposit. Malin also refused to be hedged by ecological laws: 'To obey rather than conquer nature was a surrender [...] to the chain of determinism. [...] It is man, not nature, Malin believed, who creates norms and values' (Worster 1994: 246). Despite challenges from Malin, however, Climax thesis, had remained in vogue, without making it the final 'truth'.[69] Nevertheless, the idea of 'steady-state' equilibrium in

[68] 'Soil, Animal, and Plant Relations of the Grassland, Historically Reconsidered', *Scientific Monthly*, 76, pp. 207–220

[69] [S]uccession-climax model [...] is inextricably wrapped up in those muddled, subjective things called human values. Probably there is no final or compelling reply to the question of whether the climax ever existed or not, or at least no answer that

nature without 'disturbance' from man became passé at the end of this debate: the question was how to make economic progress that required natural resources through methods which are economically as well as ecologically sound.

1.4.2. Convergence of Economics with Ecology

The view that nature works through the economic principles of production, trade and consumption, was pioneered by Hermann Reinheimer.[70] In his view, organisms were considered as 'economic persons', and nature was argued to be having a refined division of labour to ensure 'ever-increasing efficiency [in] the production and storage of energies that go to sustain and to help advance life, to produce a maximum of organic and social utilities with a minimum organic cost' (quoted in Worster 1994: 251). It was promoting cooperation rather than competition, at odds with Darwinian biology, or with the laissez-faire capitalists. Nature was looked at through a different lens by this 'new ecology': of 'the forms, processes, and values of the modern economic order as shaped by technology' (Worster 1994: 293).

1.4.2.1. *'The Economy of Nature': 'new ecology' of productivity and efficiency*

Worster (1994) pointed out three important features of the modern economic system that the late-twentieth century 'new ecology' was to ape: cooperation among the economic agents, without which the system does not simply function; second, importance of productivity and efficiency as human goals; and third, development of the managerial ethos.

In 1927, a Cambridge University zoologist, Charles Elton, had published *Animal Ecology* (Chicago: University of Chicago Press), that brought together the existing knowledge in ecology to a new model of community, through an approach which had more to do with structure and functions rather than the dynamics. This was in line with the then emerging structural functionalism across social sciences, in place of the evolutionary or historical approaches.

Elton's 'bio-economics' was given a new and definite direction by Tansley (1935). The latter had argued for treating the 'whole' through a reductive analysis, where

science alone can give for all time. This issue of the climax is enduring conundrum. (Worster 1994: 249–50)

[70] 1913, *Evolution by Cooperation: A Study in Bio-Economic*, London: Kegan, Paul, Trench, and Trubner, as referred in Worster (1994: 291).

'the basic units of nature' could be isolated in such a manner that a researcher aware of all the properties of each component could accurately predict the result, like any 'mature science'.[71]

Tansley used the concept of ecosystem rather than community, which was argued to be 'misleading'.[72] In this approach, all relations among organisms in the ecosystem were described in terms of purely material exchange of energy and of such chemical substances such as water, phosphorus, nitrogen, and other nutrients that are the constituents of 'food'. This apparently reductive yet more inclusive concept brought together both living and non-living substances into a common ordering of material resources.

Such focus on the energy flow in the ecosystem, announced the coming of 'age of ecology' as an adjunct of physical science, with its parentage to modern thermodynamic physics, and not biology (Worster 1994: 302). Quantification of energy flow at every point of the progress of an ecosystem was certainly a giant step, especially in line with the agronomic and industrial view of nature as a storehouse of exploitable material resources. Natural scientist Elton was joined by social scientist Nicholas Georgescu-roegen a few decades later with a combination of evolutionary biology, conventional economics and thermodynamics to establish the 'new' discipline of bio-economics (Miernyk 1999: 69).

In 1926, Edgar Nelson Transeau, had attempted to calculate the amount of solar energy accumulated and used towards production of crops in one field at Illinois during one particular season. 'What is the natural energy cost of agriculture, he wondered, and how efficiently is it used in the production process?' (Worster 1994: 304). As per his calculation, the percentage of total energy 'fixed' in the gross output of corn was extremely low.

In 1940, Chancey Juday had calculated the 'physical and biological energy budget(s)' of a natural lake in Minnesota. His calculations involved energy spent

71 At the same time, such energetic reductionism had been questioned towards the development of bio-economics (Punti 1988: 79). As a possible way, it was suggested that to change some methods and concepts in energy analysis, and combine it with the study of the social relations, notably, human labour energetics. This thesis has done exactly the latter.

72 For Tansley, plants and animals in a locale may not be part of a genuine community due to absence of any psychic bond and thus a true social order (Worster 1994: 301).

and invested in the form of biomass at each level of the ecosystem. In particular, calculations were done for 'total quantity of stored and accumulated energy in the form of dry organic matter in the annual crop of plants and animals', and total energy value of the annual crop on the basis of the energy equivalents of various classes of organic matter. On the question of comparison of efficiency of nature's crop with that by man for utilizing energy, he concluded that the concerned lake

> [...] was not a very efficient manufacturer of biological products in so far as utilizing the annual supply of solar and sky radiation is concerned; on the other hand it belongs to the group of highly productive lakes. While the aquatic plant crop appears to be inefficient in its utilization of solar energy, it compares very favorably with some of the more important land crops in this respect. (Juday 1940: 448–9)

Common to both these pioneers, Elton and Tansley, were the use of distinctly agronomic concerns of productivity, yield, and efficiency towards a broader ecological model for measurement of natural as well as artificial ecosystems.[73] Such comparisons were distinctly economic. The methods they both followed were identical, only with different foci: how much of the available energy was being 'fixed' at every level, in consideration with the flows. This method will be modified later incorporating the non-living elements in the ecosystem through the concept of 'embodied energy': basic taxonomy however was to remain the same.

Within the ecology fold, Raymond Lindemann [74] offered further refinement to the method of energetics where all the interrelated biological events were reduced in energetic terms. It was termed as the 'most profitable method' within the new scientific paradigm where 'energy became economic' (Worster 1994: 306).

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73 Such efficiencies include photosynthetic, exploitation, assimilation, growth, reproductive, production, trophic, just to name a few. There exist clear algebraic relations between them as well. For example, trophic efficiency = exploitation efficiency x assimilation efficiency x production efficiency. For a diagrammatic representation and the formulas, see, Figure 12.9 and table 12.8 respectively in Chapman and Reiss (1995: 141, 147).

74 1942, 'The Trophic-Dynamic Aspect of Ecology', *Ecology*, 23(4), pp. 399—417.

1.4.2.2. *Metabolism: early beginnings by ecologists*

For a unified theory of ecology and economics, it was important to comprehend 'the relation of ecological processes and human practices without simply subsuming the one under the other' (Hayward 1994: 116). Certainly, the object of focus had to be the 'human metabolism with nature'. This included, among others, energetic and material exchanges between human beings and their natural environment, both at an individual and the social level.

Lindemann indeed was the first ecologist to have looked at this 'metabolism' of the whole, by dividing all the resident organisms[75] into a series of more or less discrete 'compartments' or 'trophic levels'.[76] In such an approach based on differentiation of the functional and dynamic components of ecosystems, energy and nutrients in use at one level were found to have never passed on in their entirety to the next higher level, as a portion was lost in the transfer as heat, in conformity with the principles of physics.[77] For a quantification of these losses, 'productivity' was calculated at each level in the food chain along with the 'efficiency' of energy transfers. For the former, the entire biomass at each of the trophic levels was taken into account along with calorific energy required to support the amount of organic matter, a method to be used in energy balance approach later. Accordingly, 'gross production',[78] 'net production',[79] 'gross primary productivity',[80] 'net primary productivity',[81] and 'ecological efficiency' of

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[75] They were producers, primary consumers, secondary consumers, and decomposers.

[76] The flow of energy in such a 'box and arrow' framework is generally from plants to herbivores to carnivores (as well as to decomposers all along the food chain). The pyramidal structure of the food chain gives rise to the concept of trophic levels. A trophic level represents a step in the dynamics of energy flow through an ecosystem. The first trophic level is made up of the producers, those within the ecosystem that harvests energy from an outside source like the Sun and stabilizes or 'fixes' it so that it remains in the system. The second level would comprise those who consume the producers, also known as the primary consumers. The next level would contain the secondary consumers (those who consume the primary consumers), and so on. Because of the limited amount of energy available to each level, these trophic pyramids rarely rise above a third or fourth level of structure. In terms of energy flow, trophic level concept has proven valid and useful. Since at each trophic level far more energy is used to power maintenance (metabolism or respiration) than growth (production), total amount of energy flowing through living systems decreases drastically from the lowest to the highest.

[77] It was Odum (1969: 262) who had extended the principles of 'ecological succession' and the method of social metabolism to the landscape level.

[78] All energy and matter stored or spent at one trophic level.

[79] Gross production 'net' of respiration.

[80] Total amount of dry matter made by a plant in photosynthesis, in terms of dry weight per unit per unit of time.

[81] 'Gross Primary Productivity' net of respiration (all definitions are from Chapman and Reiss 1995: 136). Both gross and net primary productivities take account of time and thus are more accurate than the usual productivity calculations employed by economists and agriculturists, where time is absent. For this observation, author is thankful to Prof. Utsa Patnaik.

organisms were defined.[82] The last was termed as 'Lindeman's law of trophic efficiency'. In quantitative terms, the efficiency of energy transfer from one trophic level to the next was stated to be about 10%, with the remaining used in metabolism and heat. Further, Lindeman had proposed that organisms high in the food chain were progressively more efficient. However, Chapman and Reiss (1995: 146) reported that recent data supported neither Lindeman's proposition of progressively increasing efficiencies within a food chain nor the 10% criterion for energy transfer. Behaviour and physiology of the organisms were found to be more important determinants in the variation in trophic efficiencies, rather than the relative positions of the organisms in the food web.[83]

Worster (1994: 310) had noted the general findings of the scientists using the same method: productivity and efficiency across ecosystems for the land-based ones were found to be higher than the aquatic ones, though with important exceptions. However, across all types of ecosystems, the primary efficiency of solar energy capture was near 1 per cent.[84] Technically, this 'efficiency of photosynthesis', first conceptualized and calculated by Transeau in 1926 in the corn field, equalled total energy fixed in photosynthesis/total energy falling on the field. The significance of this estimation of photosynthetic yield in agriculture was enormous, as it is today: perhaps more so now, given the depletion of energy sources of 'bottled sunshine', 'a store of solar energy from past lifeforms' (Boulding 1973: 122).

> [...] In short, ecology at last emerged as a full-blown science of natural economics, fulfilling a vague promise more than two centuries old. [...] Without economics, ecologists might have disappeared as an independent class of researchers; as it is, ecology claimed a clear, safe, and highly prominent place squarely between the two most influential disciplines of our times [Economics and Physics]. (Worster 1994: 311–2)

[82] How much of the energy available from the lower levels could be utilised by them and how much of that they could pass on, and how much they were to use for own metabolism.
[83] See, Chapman and Reiss (1995: 146).
[84] See, Table 12.1 & 12.3 in Chapman and Reiss (1995: 137, 140) for details.

1.4.2.3. *Early beginning of energy and economics–transdisciplinary agricultural energetics*

Martinez-alier (1987: 20) considered the following markers for the 'non-existent' discipline of ecological agricultural economics: the study of the cycles of materials during the 1840s and 1850s, beginning of agricultural energetics in around 1880, studies on the flow of energy in the 1970s and interest in the genetic variability in agro-ecosystems in the 1980s.

Corning (2002) argued that the roots of the 'long-standing but uneasy relationship between energetics and the discipline of economics', could be traced back to Jean Baptiste de Lamarck, Herbert Spencer, Ludwig Boltzmann and many others in the nineteenth century, who drew attention to the central role of energy capture and utilization in living systems. In the twentieth century, demographer cum physicist Alfred Lotka was the first to view the role of energy and evolution within the context of natural selection, apart from using an energetic perspective to illuminate the 'biophysical foundations of economics'. On the other hand, in the 1920s and 1930s, physical chemist and Nobel Laureate Frederick Soddy became the most vigorous proponent of an energy theory of economic value. Interestingly, most of the work done by non-economists in the past, like Rappaport, Odum, Pimentel, Leach, Chapman, and Cottrell, were in the sphere of agricultural energetics. Despite this long history of interaction between human ecological energetics and economics however, evaluation of the use of energy in the economy has only been a recent phenomenon (Martinez-alier 1987).

A more or less universal conclusion reached by these studies was that 'in principle, energy analysis and conventional economics seem to give contradictory judgments of the same process' (Martinez-alier 1987: 3). Energy analysis had found the traditional agriculture to be more efficient than modern agriculture, and also that the productivity of agriculture has not increased, but decreased over time. Notwithstanding the several limitations of energy analysis including its inability to undertake a cost-benefit analysis incorporating the present discounted value, something that may seem more profitable in monetary terms to a farmer, was not to be in terms of 'ecological agricultural energetics'.[85]

[85] One reason for higher monetary productivity (and lower energy efficiency) of the modern agriculture is subsidised energy inputs. Incorporation of negative externalities further reduces the productivity of modern agriculture.

> [...] It is a fact, for instance, that different agricultural products have use values which are not always related to their energy content, and even less to their energy cost, but rather to their protein or vitamin content, or simply to the pleasure to be gained by eating or drinking them. Nevertheless, such studies of the flow of energy in agriculture show that it is not appropriate to analyse economic growth in terms of an increased productivity of agriculture [...]. (Martinez-alier 1987: 3)

Frederick Soddy during the 1921 lectures delivered to students at London School of Economics and Birbeck College spoke about 'vital use' and 'laboral use' of energy in the context of the role of agriculture in the economy.[86] This crucial difference was in line with the classical framework, and pointed towards energy sources as a flow *and* stock.

Herman Daly and John Cobb joined Soddy in criticising economists for mistaking chrematistics as economics. The former meant 'the manipulation of property and wealth so as to maximize short-term monetary exchange value to the owner'[87] while the latter word with roots to *oikonomia*, was connected with good life (Hayward 1994: 91).

> [...] First, it [*oikomania*] takes the long-run rather than the short-run view. Second, it considers costs and benefits to the whole community, not just to the parties to the transaction. Third, it focuses on concrete use value and the limited accumulation thereof, rather than on abstract exchange value and its impetus toward unlimited accumulation. (Daly and Cobb 1990: 139)[88]

The contribution of Ukrainian populist and socialist physician Serhii Podolinsky's in ecological energetics was twofold (see, Podolinsky 1881/2004). The first was his emphasis that the viability of a society requires that 'the energy return to human energy expenditure covers the energy cost of human labour' (Martinez-alier 1987: 11). The second was his characterisation of 'productive work' by human and animal labour, and plants, for their capabilities in offering 'protection against the dissipation of energy into space', which could only be achieved

86 Former meant photosynthesis in plants and carbon oxidation in the nutrition of animals while the latter referred to the use of instruments by human beings, moved by the wind, waterfall, steam or internal combustion engine. While viral use of energy could not vary much from person to person, laboral use varied a lot from across individual, country, historical periods. This observation of Soddy is similar to that of Serhii Podolinsky, Eduard Sacher and Patrick Geddes (Martinez-alier 1987: 136).

87 Also defined as 'the branch of political economy relating to the manipulation of property and wealth so as to maximize short-term monetary exchange value to the owner' [Daly and Cobb (1989: 138) as cited in Gowdy and Mesner (1998: 152)]. Ecological economists allege that '[t]he subject matter of [the mainstream] neoclassical economics bas been reduced to chrematistics, as value has become synonymous with exchange value and the maximization principle equated with rationality' (Gowdy and Mesner 1998: 152).

88 Herman Daly and John B Cobb, 1990, *For the Common Good: Redirecting the Economy towards Community, the Environment, and a Sustainable Future*, London: Green Print, quoted in Hayward (1994: 92).

through agriculture (Martinez-alier 1987: 50; see, 2.3.1 below).[89] Engels had agreed on the application of this principle in most primitive branches of production like hunting, fishing, cattle-raising, agriculture (Engels 1986a). However, he remained unconvinced over the 'fixity' of energy and expressed reservation on the energy value of fertilizers and other auxiliary means like use of steam engine in threshing. Arguably, the latter were difficult to compute, given the then state of knowledge.

Podolinksky's other contribution was related to his analysis of capacity of the human organism to perform work. This had led to his incorrect assertion that that man was a more efficient transformer of energy than a steam engine with a much lower conversion rate. The consequent argument that humanity was a 'perfect machine' a la Sadi Carnot, had drawn Engels' rather heavy criticism (see, 2.3.1 below, for a detailed discussion).

Podolinsky had been credited by Martinez-alier (1987: 51) as the pioneer of the idea 'that one could determine the necessary minimum conditions of human survival on earth through an analysis of energy flows and energy coefficients'. This idea, arguably, is no different from the extension of Marxian concept of 'labour-power' as pointed out by Dobb (1973: 151) noted above, and followed in this thesis.

Among the 'physical indices of (un)sustainability',[90] the 'energy return on (energy) input' or EROI, that had been pioneered by the noted ecologist H T Odum, followed Podolinsky's idea of looking at the basic economics of human society on the basis of energy flow. Eduard Sacher also had followed Podolinsky in studying the flow of energy in agriculture.[91] His attempt to correlate stages of cultural progress with energy availability per caput, was even before Patrick

[89] The quantum of such fixing would of course be dependent on the degree of development of the means of production, Podolinsky had contended (Martinez-alier 1987: 47).

[90] Others are (1) Human Appropriation of Net Primary Production (HANPP), (2) Ecological Footprint, and (3) Material Input per Unit Service (and its variation Domestic Extraction/Production of Natural Resources).

[91] Physiologically speaking, he took the amount of physical work that a person could do in a day, as 1,000 Cal, for which at least 3,000 Cal was required in the form of food. However, the economic work performed was estimated to be only about 450 Cal/day/worker in the macro sense considering share of economically active population, period of economic work, etc. For him, the economic task before the labour force was 'winning' the maximum amount of energy from nature (Martinez-alier 1987: 65). To be discussed in more detail below.

Geddes,[92] Henry Adams and Wilhelm Ostwald (Martinez-alier 1987: 65–8).[93] His interest in finding out the ways, in which the surplus energy was appropriated by some of the groups in society to the exclusion of many others beyond the needs of subsistence, had a distinct Physiocratic, if not Marxist aura. Notwithstanding his 'energetic dogma' a la Georgescu-roegen in not considering any resource other than energy, Sacher had admitted the limitation of energy theory of exchange-value. Further the absence of 'mental work' in energy values and thus of skills, training, and other such possibilities of improvement in the productivity of human labour was pointed out by him, and remained an important limitation of the human labour energetics.

Josef Popper-Lynkeus (1838–1921), a member of the 'Austrian school' of ecological economics, had proposed a study of the economy in terms of the flow of materials and energy and perhaps was the first one to recommend moderation in the use of exhaustible resources.[94]. Leopold Pfaundler, the other member of the Austrian School, followed Popper-Lynkeus in designating the term 'energy crisis', to describe a situation with humans not being able to obtain 2,000 or 2,500 Cal per day, a requirement for their minimum sustenance, unlike its present usage bereft of any human dimension (Martinez-alier 1987: 10). On the basis of the then state of knowledge in physiology and nutrition, Pfaundler had made a claim in 1902, that the effort of a worker required 'on average, 118 grams of protein (sic), 56 grams of fat, and 500 grams of carbohydrate' to produce 3,055 Cal, with the calorie requirement varying according to race, intensity of work, sex and climate (Martinez-alier 1987: 108–9). German energy physiologist Ludimer Hermann

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[92] Geddes' contribution in energetics lay in his proposal to construct an input-output table like *Tableu Economique*, that included the losses at each stage of transformation in the form of dissipation and disintegration (Martinez-alier 1987: 94–5).

[93] Friedrich Wilhelm Ostwald, a German physical chemist is considered the founder of the 'school of energetics', and credited with being the originator of the term 'human energetics', a near-synonym and precursor to 'human thermodynamics'.

[94] In particular, Popper-Lynkeus recommended how the use exhaustible resources available to Germany just before the First World War could be gradually reduced so as to ensure the permanent viability of the economic system. His 1912 publication, *Die allgemeine Nährpflicht als Lösung der sozialen Frage* (*On the general duty of nutrition as a solution to the social question, statistically researched, with a demonstration of the lack of theoretical and practical validity of economic theory*) had been described as one fundamental text of ecological economics. Here, one finds the foundational thoughts of the later 'basic needs approach' in Development Economics. Requirements of human work were calculated so as to guarantee the whole population a subsistence minimum, clothing, housing and health services, to be provided by a 'conscription for food production', rather than the military one. The basic needs sector of the economy was to provide the subsistence minimum, free of charge to everybody, and the remaining sectors were to run on the principles of market economy, in Popper-Lynkeus's framework (Martinez-alier 1987).

had followed this framework, which had influenced Marx in his analysis of labour power.

1.4.2.3.1. Energy, Entropy and Economics in Agriculture

A Romanian mathematician with a doctoral thesis on Statistics (1930), and an early interest in agrarian economics, Nicholas Georgescu-roegen had published *The Entropy Law and Economic Process* in 1971. He was one of the founders of the emerging discipline of Ecological Economics, and a staunch critic of the orthodox economic discipline over its mechanistic outlook.[95] With the thermodynamic 'revolution' in Physics, Georgescu-roegen argued, it was important to move out of the mechanistic dogma, as 'the significant fact for the economist is that the new science of thermodynamics began as a physics of *economic* value and, basically, can still be regarded as such. The Entropy Law itself emerges as the most *economic* in nature of all natural laws' (1971: 3; emphasis as in original).[96]

The entropy law, or the second law of thermodynamics, was argued to be all pervasive: even if one living being may evade the entropic degradation of its own structure, for the whole system it was inevitable.[97] While acknowledging Alfred Marshall and physical biologist Alfred J Lotka, Georgescu went on defining economic development in terms of 'development proper' and 'pure growth' in entropy terms, before declaring that the 'economic history of mankind leaves no doubt about this entropic struggle of man' (1971: 294). In particular, relative

[95] In particular, he had blamed Jevons and Walras, the founders of modern economics for creating an 'economic science after the exact pattern of mechanics, [...] [which] can neither account for the existence of enduring qualitative changes in nature nor accept this existence as an independent fact [...] [as it] knows only locomotion, and locomotion is both reversible and qualityless' (1971: 1). The corresponding economic process 'is an isolated, self-contained and ahistorical process—a circular flow between production and consumption with no outlets and no inlets, as the elementary textbook depicts it' (1971: 2).

[96] Kåberger and Månsson (2001: 172), both physicists, commented:

> One of the most important contributions of Georgescu-roegen was his attempt to change the systems view of economics from this conventional (monetary) circular to the (partly physical) throughput one [...], thereby bringing economists and economics back towards reality. In particular, whereas the conventional models of the economic system were without connection to the physical world and thereby unconstrained by the laws applying there, the models with the economy as a throughput system have considerably less freedom of action, implementing some of the physical and other constraints that apply in society.

[97] In general, the total entropy of any system will not decrease other than by increasing the entropy of some other system. Hence, in a system isolated from its environment, the entropy of that system will tend not to decrease. It follows that the entropy of a system that is not isolated may decrease. In mechanics, the second law in conjunction with the fundamental thermodynamic relation places limits on a system's ability to do useful work.

scarcities of the two sources of low entropy, the solar radiation and the earth's own deposits was argued to be having a very strong connection with the balance and general direction of economic development. While solar energy was more associated with husbandry, minerals were with the industry (1971: 297). At the same time, partnership between man and the nature in the agriculture was distinctly 'more stringent and more subtle' than the other, for three reasons.

First, as nature dictates the schedule of agricultural activity, doubling the amount of labour used with same 'material funds' may not double the product flow. Second was the impossibility of stocking solar energy at a rate desirable by human beings due to the limits determined by the gradient of the sunrays on the earth's surface and the global position in the solar system.[98] Third, the subtle ways in which nature assists the farmer imply that the 'process' in agriculture must be followed rigidly as per the 'blueprint', unlike industry where certain margins are permitted.

Georgescu-roegen joined many of his predecessors in bestowing centrality to the agriculture sector in the development process,[99] and was particularly critical of the practices that eliminated draft animals as a source of power as well as manure, and replaced them with the oil-fed 'mechanical buffalo' and the chemical fertilisers. This had resulted in a replacement of power source from sun's radiation to 'an additional tapping of the stock of mineral resources in the earth's crust' (1971: 303). Incidentally, the highest estimate of terrestrial energy resources was argued to be rather meagre: less than the amount of solar energy received during four days (Ayres 1950: 16).[100] Thus, technological progress that had resulted in a shift from this abundant source of low entropy to a relatively scarce one, was nothing but 'the degradation of man's dowry of low entropy as a result of his own ambitious activity that determines both what man can and cannot do' (1971: 305).

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98 '[A]griculture teaches, nay, obliges man to be patient—a reason why peasants have a philosophical attitude in life pronouncedly different from that of industrial communities' (1971: 297)

99 For details, see part 3: Entropy and Development in Chapter X: Entropy, Value and Development (1971: 292–306).

100 Eugene Ayres, 1950, Power from the Sun, *Scientific American*, 183, 16, cited in Georgescu-roegen (1971: 304).

1.4.2.4. *Energetics in Human Society—Nature Exchanges*

The unification or convergence of ecology and economics continued through multiple routes: the one rooted in thermodynamics took place through the concept of social metabolism, as noted earlier.[101] The metabolism is regulated on the one side by physical processes based on natural laws and on the other, institutional norms governing the division of labour and distribution of wealth, etc. In Marx's writings, Stoffwechsel or metabolism appeared ever since the *Grundrisse*. In *Capital*, it was used for conceptualising the breakdown in humanity's relationship with nature: 'Capitalist production [...] disturbs the metabolic interaction between man and nature, i.e., prevents the return to the soil of its constituent elements consumed by man in the form of food and clothing; hence it hinders the operation of the eternal natural condition for the lasting fertility of the soil' (1954a: 474). This separation of human society from nature is what Foster (2001) had termed as 'metabolic rift', a concept intrinsically connected with the flow of nutrients in the soil. This separation had been argued to serve as the basis for 'capitalism's fundamental form of valuation' (Burkett 2003: 160).

Foster (2001: 240) found Nikolai Bukharin as one of the early followers of Marx and Engels, to take forward Marx's concept of metabolic interaction between human beings and nature. 'Chapter 5: The Equilibrium between Society and Nature' of Bukharin (1921/1969), had elaborated the type, nature, extent and dependence of the interrelationship between human society and the 'external nature' or its environment, in terms of 'energy income' and 'energy expenditure'. This interrelationship, arguably, is identical to the method of energy balance analysis.

Human society, like any system, exists in a non-empty space, i.e. within an 'environment', that ultimately determines all its conditions. Human society—

[101] Social metabolism brings together just not two but many other disciplines in dialogues with each other. 'There is a common ground between social history, economic history and environmental history, between ecological economics and political ecology, between sustainability science and environmental sociology' (Martinez-alier 2009: 62).
See, Fischer-Kowalski (2002) for a transdisciplinary history of the concept of metabolism, covering biology, agronomy, ecology, social theory, cultural & ecological anthropology, social geography, and geology. Fischer-Kowalski and Haberl (2007) addressed transitions in the use of energy and materials, patterns of human time-use, and economic changes by combining elements of human ecology, environmental history, and ecological economics, to explain the past and project the future possibilities.

environment relationship determine the alterations in the system as well as the fundamental direction of its growth (progress, rest, or destruction). The process through which such deterministic interaction takes place is through 'abstractions' and eventual appropriation of energy from nature by the human society: 'without these loans it could not exist' (Bukharin 1921/1969: 107). Further, this 'abstraction of energy from nature, is a *material* process [...] [and] [t]his material process of "metabolism" between society and nature is the fundamental relation between environment and system, between "external conditions" and human society' (Bukharin 1921/1969: 108). Such contact takes place through the process of human labour: '[b]y work, energy is transferred from nature to society; and it is on this energy that society lives and develops (if it develops at all)' (Bukharin 1921/1969: 89–90). Clearly, the higher is the amount of such appropriation, the greater will be the societal growth. Marx had explained this process as follows:

> [...] Labour is, in the first place, a process in which both man and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature. He opposes himself to Nature as one of her own forces, setting in motion arms and legs, head and hands, the natural forces of his body, in order to appropriate Nature's productions in a form adapted to his own wants. [...] At the end of every labour-process, we get a result that already existed in the imagination of the labourer at its commencement. [...]
>
> The elementary factors of the labour-process are 1, the personal activity of man, i.e., work itself, 2, the subject of that work, and 3, its instruments.
>
> The soil (and this, economically speaking, includes water) in the virgin state in which it supplies man with necessaries or the means of subsistence ready to hand, exists independently of him, and is the universal subject of human labour. All those things which labour merely separates from immediate connexion with their environment, are subjects of labour spontaneously provided by Nature. (Marx 1954a: 173–4)

In Bukharin's framework, production involved 'expenditure of human energy' to extract energy from nature. Such extracted energy is appropriated by the society through the process of consumption, which became the basis for further expenditure, and this 'wheel of reproduction being thus constantly in motion' (Bukharin 1921/1969: 110), recalling once again the idea of the Physiocrats. In this interaction between society and nature, when society applies its human labour energy, it also receives a certain quantity of energy from nature.[102] It is this '*balance* between expenditure and receipts' that is 'the decisive element for the

102 Just as the savage must wrestle with Nature to satisfy his wants, to maintain and reproduce life, so must civilised man, and he must do so in all social formations and under all possible modes of production. [...] Freedom in this field can only consist in [...] rationally regulating their interchange with Nature, bringing it under their common control, instead of being ruled by it as by the blind forces of Nature; and achieving this with the *least expenditure of energy* and under conditions most favourable to, and worthy of, their human nature. (Marx 1954c: 820; emphasis added)

growth of society' (Bukharin 1921/1969: 112). The three cases with varying working time to cover the society's most rudimentary needs that Bukharin (1921/1969: 112) had discussed, made the importance of spending lesser and lesser time to produce the identical quantity of objects amply clear. '

Yield or 'productivity of social labour' thus determined the growth (or retrogression) of the society. This was stated to be equal to the quantity of product per unit of working time, say, a year and represented the relation between the quantity of product obtained and the quantity of labour expended (Bukharin 1921/1969: 113). Alternatively, productivity of social labour represents the 'relation between nature and society [...] expressed in the relation between the quantity of useful energy turned out and the expenditure of social labor' (Bukharin 1921/1969: 114–15). Materially speaking in quantitative terms, productivity of labour is concerned with three things—the products obtained, the instruments of production (the 'crystallized labour') and the productive forces (the 'living labor') (Bukharin 1921/1969: 115).

Living labour equalled the 'direct expenditure of working energy' (Bukharin 1921/1969: 115) which arguably could be made to correspond to the food calorie intake. On the other hand, for the instruments and other materials, energy analysis may be employed, to arrive at a *balance* similar to the one that Bukharin had pointed to ninety years ago.

1.5. Energy in Economic System

Energy is present in all processes and there are no substitutes for it. It is a unifying concept for all materials, in terms of their thermodynamic potential. Energy Analysis traces the changes in thermodynamic potential of materials in quantitative terms, while they pass through successive stages of process(es). For thermodynamicists, energy content is an inherent property of the system, including all living systems, as the latter are dependent on an adequate supply of energy and materials to support life-sustaining processes.

Thermodynamic laws indeed explain the physical constraints on ecological processes. In ecological thermodynamics, the fundamental principle remains in terms of materials *cycling* in ecosystems, with energy *flowing* through them. All energy that powers life (except nuclear and geothermal energy) began with the sun and takes place in direct (as in the case of photosynthesis) or transformed form (as in the case of food intake). At the end, the energy flowing through living things is ultimately lost as heat (from movement, metabolism, and decomposition) and radiation.[103] Whenever heat is converted into work, increase in entropy or order that takes place, is known as negentropy.

Importance of energy in the economic system arose due to its appearance as a commodity, an input or an intermediate good in the economic processes. Indeed, the physical properties of energy became significant in the economic relations. To quote Kenneth Boulding (1973: 121), '[t]he critical question is: why is energy necessary to sustain or to increase affluence—affluence in this case considered as an indicator which increases when an individual moves from a less preferred to a more preferred condition or state?' While, affluence is measured here by both stock (wealth) and flow (income) concepts, its increase through more use of energy inputs had accompanied the twin problems of pollution and exhaustion.

There is ample historical evidence on how the absence of human prudence on the face of apparent abundance of energy and other natural resources had led to the

[103] As it is well known, first law of thermodynamics state that heat is neither lost nor gained, and the second law defines the manner in which negentropy is consumed when a non-spontaneous process works

decline of civilizations.[104] However, there is a vast difference between the present exhaustible fossil-fuel based mode of resource use and the earlier ones built on essentially renewable and inexhaustible energy resources. For the 'bottled sunshine', not only its availability but also the knowledge about its efficient uses, assumes greater importance now. However, its recognition among the economists had been rather late, in contrast to the other disciplines as stated earlier. For instance, consider the sociologist Roger Cottrell who had written in 1955 about the possibility of energy putting a 'limit on what man can do'.[105]

1.5.1. Energetic Response to the Energy Crisis

The field of environmental and resource economics that had started in US and Europe grew rapidly since the early 1970s. In 1970s and most of 1980s research was highly concentrated on two issues of valuation of the benefits of environmental amenities and the costs of pollution control, and the design of and choice among policy instruments, essentially within the framework of and following the method of welfare economics. The role of physical–biological perspectives inside environmental economics were humble to say the most (Røpke 2004:302).

Ideas floated since 1970s by pioneers of ecological economics, like Georgescu-roegen and Herman Daly, resulted in the emergence of a new field of energy studies, primarily as a response to the energy crisis. However, the relationship between the energy and the economy from the biophysical perspective took off rather rapidly since the end of 1970s, as noted earlier. Researchers were from many disciplines including physics, engineering, systems ecology and also economics. A parallel development was of industrial ecology: of note is the chapter on 'Application of Physical Principles to Economics' in Ayres (1978) that had brought energy efficiency and negentropy into focus. The common point of attention was the depleting fossil fuels.

> [...] You can't understand the last two hundred years of human history without understanding energy. We could have accumulated vast amounts of capital, but it wouldn't have done what it has done for us, had it not exploited

[104] For the resource perspective, see, Chew (1999) that analysed 'political, economic and ecological relations circumscribing the dynamics of the reproduction and decline of two socioeconomic organizations (Mesopotamia and Harappa) during the Bronze Age'.

[105] He was stated to be 'the first to demonstrate that economies with access to energy sources with a large energy surplus have greater potential for economic expansion and/or diversification than those with access to lower quality fuels' [Cutler Cleveland in forward to Cottrell (1955/2009)].

> fossil fuels. Energy is what you need to do work, and doing work is what economics is about. (Michael Common, quoted in Røpke 2004:303)

In the face of rapidly exhausting fossil fuel resource, it became important to locate possible enhancements in efficiency in the use of this scarce factor and development of its renewable alternatives. By the early 1990s, fossil fuel had marked its presence in the operationalisation of sustainable development principles, floated by pioneering ecological economists like Daly and Costanza (1992: 44). Among others, Kenneth Boulding had theorised the role of energy as a 'limiting factor':

> The most important limiting factor is the one that is *most* limiting, that is the one that actually limits the process. Sometimes this may be energy, sometimes materials, sometimes space, sometimes time. [...] Which of these four limiting factors in fact limits the process is an empirical matter, and varies from process to process. (1992: 239–41; emphasis as in original)

Boulding (1992: 241) argued further that empirical discovery of these limiting functions poses a severe problem, with their heterogeneity adding onto it. Heterogeneity of the 'contributive factors' indeed had become so much 'as to be almost as worthless as earth, air, fire, and water as factors in the theory of production' (Boulding 1992: 243).[106] Earlier, Duckham and Masefield (1970: 21) had already considered the possibility of energy and moisture regimes as one of the limiting factors that may reduce the number of actual systems than the ecologically possible ones. But technological optimists like Huettner (1982: 1142) were ready to challenge the 'unacceptable but also arbitrary' assumption of considering energy as the ultimate limiting factor with the argument that technological change could very well be 'the ultimate limiting factor or argue that other resources could be depleted before energy exhaustion is reached'.

> [...] There are, in fact, some good reasons for considering available energy the ultimate limiting factor. It is the only input that is both necessary for all productive activities and impossible to create internally or recycle. It must be supplied from outside the system and can only be dissipated internally. The same cannot be said for the other "intermediate" factors of production, land, labor, capital, and technology. Technological change is certainly an important characteristic of our economic growth, but it is no more independent of direct and indirect energy costs than any other component of the economy. [...] We can expect technological change to help us adapt to new energy sources, but it cannot create available energy. (Costanza 1982: 1143)

[106] The conventional economic or contributive factors of land, labour and capital are all mixtures of limiting factors in this framework—space, soil, materials and solar energy input in the case of land; time, human energy throughput and nutritive materials throughput in the case of labour; all the limiting factors in the case of capital.

However, notwithstanding the complexity involved in identifying the limiting factor at various spatio-temporal coordinates,[107] two facts stood out vis-a-vis energy, Boulding (1992: 244) concluded, even while acknowledging the difficulty in proving it in empirical terms. First, over the course of the biological evolution, energy had not been the limiting factor, but it was the space or the materials, and different discoveries like the fire, agriculture, fossil fuel, had helped the human beings to expand their 'niche'. Second, like in the past, only a very small fraction of the flow of solar energy was being utilized by the biosphere, and given the imminent exhaustion of fossil fuel, it has become necessary to find its substitutes along with more efficient utilization of solar energy and regulated use of the fossil fuel itself. Finally, available evidence more than conclusively proved that for the production processes using more of fossil fuel energy sources, energy will be the first limiting factor.

Among others, Cleveland et *al.* (1984: 892) declared that 'a physical analysis of economic production provides realistic assessments of the problems we face and some of the needed characteristics of any plausible solution'. The advanced argument was two-fold, focussing on the physical interdependence of capital, labour and natural resources: first, for a differential treatment of fuel and mineral resources among the factors of production owing to their non-substitutability with reproducible capital and second, importance of 'free' or low entropy energy to maintain and upgrade all organised structures including capital and labourers.

1.5.2. Energy in Agriculture

There are three primary reasons for energy use in agriculture attaining importance over the last 40 years or so. First, with respect to the negative externalities including greenhouse gas emissions; second, the falling efficiency of the 'modern' farming systems, that is, relation between energy input and output, in an absolute as well in relative terms vis-a-vis traditional ones; and third, share of the exhaustible energy sources in total input.

As noted in 1.4.2.3 above, from the very beginning, energy and economics linkage had been applied mostly in agricultural systems. Post energy crisis,

[107] Over the historical modes of resource use, energy has played a very distinct role in the evolution of society, in terms of the sources which it could access and the ways they could be utilized. See, Chapter 1: Habitats in Human History in Gadgil and Guha (1992) for details.

methodological issues became more important resulting in formalisation of a variety of methods, that included energy accounting, energy balancing, energy budgeting and energy costing. The subsequent vast literature that began with the classic paper by Piementel et *al.* (1973) was quickly followed by many at the international arena (Stanhill 1974, Lockeretz 1977, Mitchell 1979, Pimentel 1980a, Stanhill 1984, Fluck 1992, just to mention a few). These studies were conducted at different scales (individual plots, district, State or the country), of various inputs (individually or groups or in combination), of a variety of practices, or of individual operations.[108] There still exists, however, considerable diversity within each of these methodologies. Conflicting assumptions across methods, over aggregation, quantification, as well as handling of inputs, especially labour (Norum 1983) as well as unsettled questions over its nature, scope, boundary of analysis, research questions, accounting nomenclature, treatment of inputs, interpretation of results, and limitations (Jones 1989: 340) have remained. Each of the difficulties, however, can be addressed with a careful handling, while retaining the basic nomenclature.

For Common (1995: 209–212), energy analysis may provide the useful information, to be used with standard economic data, for public policy decisions. In particular, it had been advanced as 'one useful way of thinking about sustainability issues' (Common 1995: 198). One of the three reasons advanced in favour of energy analysis included the advantage of this method in 'making plain what is implicit but not readily apparent in the economic data, and can suggest new perspectives', especially in the food production systems. In fact, it was particularly favoured in relation to the understanding of current and historic conditions (Common 1995: 211), for its timelessness dimension.

One may note that, efforts in India in this regard were not negligible, yet scanty. Bhatia (1977) was the first attempt that captured consumption of energy in Indian agriculture from various sources and changes in the pattern over 1951–71. More importantly, it compared bullocks as a source of power vis-a-vis tractors and irrigation pumps. Attempt by Moulik et *al.* (1990) to make a forecast of energy demand for agriculture in India included evolving a methodology of estimation based on disaggregated energy-input data (based on direct and indirect sources

[108] Exception is the time-energy studies, that predate energy-agriculture writings by many years. Consider for example, Wirths (1956) or Hermann (1875).

for crop, agro-climatic zone, and farmer category). Accordingly, State-wise crop-wise energy per hectare (MJ/ha) was projected. Indian Council of Agricultural Research (ICAR) had conducted an All India Co-ordinated Research Project (AICRP) on 'Energy Requirements in Agriculture Sector' (1971–2002). Apart from various interim research digests (Mittal, Mittal and Dhawan 1985; Singh, Bakshi and Singh 1988), journal articles and books (Singh and Mittal 1992), the synthesis report was published as De (2005). Ramakrishnan (1992) had a chapter on energy budget under *jhum* cultivation practiced in North-eastern India.

Literature in Indian social science journals are represented by Chopra (1992) in *Indian Economic* Review, Prakash and Mohammad (1997) in *Geographical Review of India*, an issue of *Indian Journal of Agricultural Economics* (1998) with 'Economics of Energy in Agriculture' as a subject, and Singh and Saran (2004) in *Indian Journal of Economics.* Among social scientists, Parikh (1985) and Parikh and Kromer (1985) in *Energy* remained the only notable contribution on agricultural energetics. Interestingly, none of the authors in the section on 'Impact of Agricultural Development on Ecology and Environment' of *Indian Journal of Agricultural Economics* (1987) mentioned energy! Similarly, neither the author of 'Agriculture and Environment' in *Handbook of Agriculture in India* (2007: Oxford) nor the editor of this volume found energy to be important enough to be discussed. Neither did the editors of the 27 volume *State of the Indian Farmer: A Millennium Study* (2004: Academic Foundation). On the other hand, there had been a steady flow of contributions from the community of Indian natural scientists in internationally renowned journals like *Agro-ecosystems*, or *Agriculture, Ecosystems & Environment, Agricultural Engineering International, Energy Policy* and the like. One of the objectives of this work is to fill such a gap in the agricultural energetics, from the social sciences as such.

1.5.3. Impact of Land Constraint on Energy

Conforti and Giampietro (1997) had examined the comparative importance of constraints in land and labour endowment for energy balance in agriculture, assessed at the level of national crop production systems. Relations between output/input energy ratio of agriculture,[109] average labour productivity,[110] and land productivity[111] were explored over a 75-country sample taken from FAOSTAT-PC data bank using a cluster analysis procedure (into five groups), through a cross-section equation that explained output/input ratio in terms of intensity of land and labour-food-energy throughputs, for averages of two years (1990–1991).[112]

Expectedly, India was found along with developing countries of Sub-Saharan Africa, South Asia and Latin America, characterised with highest output/input ratio, high share of labour force in agriculture (>50%), and homogenously small endowments of arable land/farmer. Output and input per farmer and per hectare, expectedly again, was found to be lowest among all groups, notwithstanding wide differences over per hectare energy input and outputs among the countries in the cluster (1997: 240). Though the conclusion remained tentative and limited, which was acknowledged, due to the use of 'aggregated data, aggregated conversion factors and simple statistical tools', the results did suggest that a land constraint, with respect to the total population size, rather than labour constraints, tended to be associated with comparatively higher energy requirements in agricultural production.

In other words, increase in 'emancipation' from land shortage of agricultural production could be seen from the increased payment in terms of biophysical cost, namely fossil fuel energy. The latter was found to be connected with the negative environmental impact, be it from soil erosion or depleted water table,

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[109] Output as the food energy in crops and input as the commercial energy embodied in technical inputs.

[110] Food energy produced per hour of labour allocated to agriculture.

[111] Food energy output per hectare of cropped land.

[112] Variable included, output/input, arable land/farmer (in ha), output/farmer (in GJ), input/farmer (in GJ), output/hectare of arable land (in GJ), input/hectare of land (GJ), workforce in agriculture (in GJ), while crops were cereals, starchy roots, pulses, oil crops, sugar crops, stimulants (coffee, cocoa and spices), fruits and vegetables with completely excluding animal products for the complication of apportioning agricultural products between food and feed.

resulting increases in the biophysical cost. Clearly, either type of biophysical costs is not explicitly taken into consideration in the usual economic analyses.

Exothermic converters of energy[113] had enabled the pre-industrial societies to eliminate the power bottlenecks. Further, increased reliance on stock exploitation, in contrast to that of a fund, following the concepts used by Georgescu-roegen,[114] had eliminated the land bottleneck, together with the use of renewable energy inputs. As a result, massive switches from animal and human labour power to machine power, added to by increase in use of fossil fuel had brought increase in economic productivity at the end of eighteenth century, most notably witnessed during the second agricultural revolution (Conforti and Giampietro 1997: 231).

However, such 'technical change' which induced dependence on fossil fuel use, also implied the absence of any real 'emancipation' of production from natural resource base, which is particularly true of agriculture. Indeed the threat to food insecurity that rise in price of fossil fuel had extended, underscored the connection between increase in land productivity and intensification of fossil fuel use. The environmental consequences of such agricultural activities that are heavily dependent on technical inputs, jeopardised the viability of yield increases

113 Devices or machines that convert energy inputs into useful energy outside human bodies.

114 A fund, like the Ricardian land with 'original and indestructible powers', labour power or capital equipment enter a production process and (ideally) comes out without any 'impairment of its economic efficiency' and thus is expected to be perfectly maintained during the process. A fund is not a stock, with the *timescale* of accumulation or decumulation being vastly different. A stock of 1 kg of rice is a stock that can distributed between 5 persons in one single instant or to a single person over 5 days. A fund, in contrast, like a certain quantity of labour power, cannot necessarily be used at a particular point of time. While all stocks follow accumulation or followed by decumulation in a flow, not all flows like electricity involve a rise or fall in a stock (Marzetti 2009). Alternatively, flows can be seen as the connections between the economy which is an open subsystem of the larger ecosystem that contains and sustains the economy: the flow of material throughput that include source-side flow of raw material and sink-side flow of wastes, while originates from the stock, ecosystem services originate out of the fund. A stock can function as a fund, say, a forest, resulting in a different kind of flows: material throughout like *kendu* leaves, and also various climate-stabilising services (Malghan 2010). However, the ability of the a forest, to provide valuable services in its role as a fund depends on a particular configuration of the stocks that make up the forest. Even the natural regeneration rate of the constituent stock is dependent on the structure of the underlying fund-configuration. For example, a captive plantation with the same standing-stock of timber as a forest but with diverse species regenerating at a different rate provides different levels of micro-climate stabilisation service. The fund service, however, is not a physical flow like the throughput derived from the stock-function of the ecosystem. These essentially are very small 'rates of flow', and were termed as *service flux* to distinguish ecosystem services (as a fund-function of the ecosystem), from resource flows (as a stock-function) (Malghan 2010). Fund services are different from flows, as the former is expressed in terms of substance x time, while the former is defined in terms of a substance/time.

in the long run. The central point of concern has been that the consumption of fossil fuel energy has risen faster than its production (Martinez-alier 1987), clearly pointing to the unsustainability of such practices in the long run (Conforti and Giampietro 1997: 232). In the language of Mayumi (2001b), the land problem reflects the bias of 'efficiency of type 2' (or ratio of output per unit of time, without any consideration to the amount of inputs to obtain the output) over the 'efficiency of type 1' (or ratio of output to input, without consideration of the time required to obtain the output). Alternatively, it is speed of entropy that poses important problems for the course of development

1.6. Approaching the Sustainability of Agriculture

> [...] [S]torage of energy through work really only takes place in agriculture; in cattle raising the energy accumulated in the plants is simply transferred as a whole to the animals, and one can only speak of storage of energy in the sense that without cattle-raising, nutritious plants wither uselessly, whereas with it they are utilised. In all branches of industry, on the other hand, energy is only expended. The most that has to be taken into consideration is the fact that vegetable products, wood, straw, flax, etc., and animal products in which vegetable energy is stored up, are put to use by being worked upon and therefore preserved longer than when they are left to decay naturally. So that if one chooses one can translate into the physical world the old economic fact that all industrial producers have to live from the products of agriculture, cattle raising, hunting, and fishing—but there is hardly much to be gained from doing so [...]. (Engels 1968b)

Indeed, this 'old economic fact' warrants repeated examination in all countries that allows such accumulation of energy through the bio-physical route and more so, in the light of growing food prices across the world and the secular decline of per capita food and nutrient consumption in India, especially among the farming households. It may be noted that it is the cultivators who are responsible as economic agents for exchanges between human society and its environment, the part of the nature that serve as the source of materials, energy and also as a sink for the waste. Even if we leave aside the depletion and/or degradation of natural resource base, groundwater contamination from leaching and competitive withdrawal, pesticide residues in food, vegetables, and breast-milk, and adverse health impacts due to harmful exposure to chemicals, there are enough purely 'economic' reasons for birth of the term 'agrarian crisis'.

Sen and Bhatia (2004: 42) had warned that 'economic state of the average farmer, who is generally a small or marginal cultivator in most parts of the country' was far from 'reasonable'. A series of committees and commissions were set up, reports were commissioned, action plans were announced, and occasional aid packages for the distress areas by the State and Central governments were advanced.[115] Together, even intrinsically, these efforts can indicate the nature, extent, and seriousness of such a crisis.

The evidence was ample enough to prove beyond the reasonable doubt that (un)sustainability had been playing a contributory role somewhere. The usual suspects include agro-ecological aspects of crop production, and economic aspects of farming. Temporary relief in the form of debt waivers, could only postpone the crisis, at the most. While it may be difficult to establish the exact chain of causality for this phenomenon, nevertheless it is certain that walking along a few less travelled paths has become necessary to get closer to the truth.

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The New Oxford Dictionary of English defines sustainable as 'able to be maintained at a certain rate or level'. Merriam-Webster defines 'sustainable' as (1) capable of being sustained and (2) of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged. Other dictionaries provide multiple meanings of the term sustain as 'keep going', 'maintain', 'support' or 'endure'. Likewise, sustainability means 'the ability to sustain something'. Sustainability is being applied to many situations and contexts over multiple scales of time and space, from total carrying capacity of the planet earth to a very local one like that of a farm. Due to its multiple applications and meanings in different context, sustainability is often perceived as nothing more than a feel-good buzzword with little substance.

Schaller (1993: 91) argued that popularity of the term 'sustainable agriculture' arises from its general appeal 'not only to people interested in an environmentally beneficial and healthful farming but also to those concerned with its economic and social dimensions'. At the same time, as a concept, this phrase pointed towards 'not only a destination for agriculture but particular farming practices

[115] National Commission on Farmers (2004), Commission of Farmer's Welfare (2004), 'Suicide of Farmers in Maharashtra' (2005–06), Report of Fact Finding Team on Vidharbha (2006), Report of the Expert Group on Agricultural Indebtedness' (2007), 'Farmers' suicide and debt waiver: an action plan for agricultural development of Maharashtra' (2008), just to mention a few.

that could move agriculture toward that destination'. Such a definition is not only imprecise, but it also helps in understanding the ambiguity and controversy accompanying similar terms that capture some of the dimensions of sustainability, as commonly understood, namely, 'organic', 'biological', 'ecological', 'reduced-input', 'low-input', 'regenerative', or 'alternative agriculture'.

> [...] As a destination, sustainability is like truth and justice—concepts not readily captured in concise definitions. Nor can sustainable farming practices be defined easily, simply because no one can ever know precisely and finally which farming practices may be the most sustainable in every location and circumstance. (Schaller 1993: 91–92)

A detailed critical engagement with the notions of sustainability, or sustainable development or sustainability of agriculture certainly is beyond the present scope, but it may be sufficient to state that in the debate human labour/labourer was not given its due importance. This is rather strange given the list of issues that this debate has addressed so far.[116] Radicals on the one side of the debate, as usual, have been arguing for redesigning of agriculture while status quoists have been calling for a fine-tuning of the existing agricultural practices. Central to this debate are the issues of profitability of sustainable farming, howsoever defined within this supposedly agro-environmental framework and the adequacy of food production under such a system, apart from the matters of scale neutrality, supply of adequate non-chemical inputs, price of such products, or even the certification programmes. However, what Schaller (1993: 96) had identified, a number of challenges remained:

> [...] As one observer has put it, when you consider the energy inputs and costs in the distribution as well as production of food, you must ask harder questions. [...] To what extent does sustainable farming increase the well-being of rural people and communities? Do rural communities and institutions enhance or impair the ability of farmers to adopt sustainable practices? Beyond that, what is the connection between agricultural and rural sustainability and the rest of society?

A typical contribution from the agro-ecological side includes biodiversity, resource efficiency, productivity and economics, resilience, etc. as well as ecologically based soil nutrient management and participatory plant breeding with focus on livestock, livelihoods and innovation (see, for example, Snapp and Pound 2008). On the other hand, those who focus on labour concentrate on labour intensity, livelihood, displacement due to HYV technology, market for off-

[116] Crop rotations that can break pest cycles and restoration of soil nutrients, supply forage and harvest feed; raising livestock for supply of manure and power; biological, mechanical, and other non-chemical methods for controlling insects, weeds, and diseases; soil and water conservation techniques with better scientific knowledge, to include just a few.

farm employment, etc. (see, for example, Tripp 2006). There is hardly anyone connecting the labourer and the soil. Index of *The Earthscan Reader in Sustainable Agriculture* (Jules Pretty, 2005) does include a variety of terms[117] but not labour or labourers. Red and Green perspectives are perhaps at loggerheads for being too close to each other along with myopic visions.

1.6.1. Sources of Data and Brief Description of Field of Study

As indicated above, this work evaluates farming practices in the State of West Bengal, using the method of energy analysis, following the functional approach, in a comparative static framework. Temporally different datasets of *Studies in the Economics of Farm Management* (FMS) of 1956–57 and Comprehensive Scheme for Studying Cost of Cultivation/production of Principal Crops (CCS) 2004–05 were used.[118] 1956–67 was the third year of the triennial 1954–57 that FMS had covered in the State of West Bengal, which had resulted in better quality of data, 'in the light of the experience of the first and second years' investigations' (1959: preface). On the other hand, 2004–05 was a normal year, as the yield data revealed.[119] This dataset belongs to a series which has not been made public. Since 1986–87, it had been released only for research purposes, under certain conditions.[120] 2004–05 was the latest normal year, and it was the same year in which *Nutritional Intake in India: 2004–2005* (NSS 61st Round, July 2004–June 2005) had also taken place.

Practices in 1956–57 have been considered as 'organic', which by definition is true, and corroborated by the FMS reports through the absence of any direct chemical inputs. On the other hand, 2004–05 provides a variety of practices,

[117] Agroecology, biodiversity, genetic modification, intercropping, monocropping, organic crop production, energy consumption, environment, farmers, farming systems, fertilizers, health, insecticides, pesticides, soil erosion, water supply and even network could find their places.

[118] The former is a published source and was subjected to intense 'Farm Size and Productivity Debate' among a number of economists a few decades ago. The latter was obtained from Bidhan Chandra Krishi Vishwavidyalaya (BCKV), Kalyani University, West Bengal with due permission from Department of Economics and Statistics, Ministry of Agriculture, Government of India, Krishi Bhavan, New Delhi. From the original *.bin format it was converted into *.prn format, which is read by any data management software.

[119] In 2004–05, West Bengal stood sixth in the state-wise yield rank for paddy at 2574 kg/ha, and accounted for the highest share in total area under paddy in the country (13.79%) and production (17.9%) (Table 4.6 (b) in DES 2007a).
Table A.3.1.10 shows that the harvested percentage was at least 95% for 90.29% (3099) plots, with 86.97% (2985) recorded 100%. 6.17% of plots reported harvested percentage between 75% and 94%, while only 7 plots had recorded complete loss.

[120] The particular dataset must be at least three years old and it should have been used by the CACP in its reports (Sen and Bhatia 2004: 328).

from modern chemical based to those using only farmyard manure, without chemical pesticides and carried out under rainfed conditions.

Like its predecessor FMS, CCS collects data on all aspects of farming, including inventory of land, buildings, wells and tanks, livestock, machines, record of daily operations, wages, crop production, all kinds of human labour, bullock labour, machine labour, changes in inventory, land improvement work, animal and machine expenses, etc. on the basis of parcel, plot and seasons. This dataset had been argued to be suitable for 'Farm Energy sources, availability, use and economics' (CSO 2008: 42).

1.6.1.1. *Cost of Cultivation Survey dataset for West Bengal 2004–05*

Directorate of Economics & Statistics, Government of India has been presently collecting round the year information from 8000 operating holdings across the country, through state research institutions, under CCS.[121] In West Bengal, presently 600 households are covered under this scheme, 10 each for 60 *tehsils*.[122] Like FMS, it follows three stage stratified random sampling, with *tehsil* as the first stage sampling unit, a cluster of villages as the next stage and an operational holding in the cluster as the final and ultimate sampling unit. For the purpose of providing representation to all the areas in the states, samples were selected from all the agro-climatic zones, as defined by ICAR.[123] The state falls under six agro-climatic zones, offering diversity, apart from various types of soil, variety of farm sizes, and irrigation practices. Data are collected from the same households for every three years. For the 'crop complex' during 2002–05 cycle, selected *tehsils* were distributed against five agro-climatic zones as the following:

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[121] After beginning in 1970–71, initially it had continued along with 'Studies in the Economics of Farm Management in India' (FMS). Latter was discontinued after 1972–3.

[122] A.k.a., *taluk* and *mandal or* sub-districts, which is usually is an administrative unit, comprising several blocks.

[123] In India, three agro-climatic/agro-ecological parallel classifications exist, prepared by three different Central government bodies: (1) Agro Climatic Regional Planning Unit, Planning Commission, New Delhi, (2) Indian Council of Agricultural Research (ICAR), New Delhi under the auspices of National Agricultural Research Project (NARP) with soft loans from International Development Agency, World Bank and (3) National Bureau of Soil Survey & Land Use Planning (NBBS&LUP), Nagpur of ICAR. These efforts had continued parallely for some years. In table A.1.7.1, all the classifications have been approximately tallied against selected *tehsils*. While table A.1.7.2 provides the comparative basis, table(s) A.1.7.3–A.1.7.5, capture basic descriptions against specific regions/zones under each classification.
See, S. 10.20 in Planning Commission (1996: 402—403), Ghosh (1991a, 1996), Singh, N B (2006), and Vaidyanathan & Sivasubramaniyan (2004), for the Agro Climatic Regional Planning Project, Planning Commission; see, Sehgal et *al.* (1992: 125—127), Ghosh (1991a), and Singh (1991), for ICAR (NARP); see, Sehgal et *al.* (1992: 12—26), for NBSS&LUP.

9 (II–terai), 14 (III–old alluvial), 17 (IV–new alluvial), 10 (V–red and laterite) and 10 (VI–coastal saline), leaving zone I (hill) unrepresented.[124] Table A.1.7.6 contains the lists of villages under each of the blocks classified as a separate tehsil,[125] along with the agro-climatic zone (ICAR-NARP) that the concerned agencies followed.[126]

As green revolution packages had made a relatively late entry in the State, two kinds of seeds, local and improved, had been used. Fertile soil, with adequate water from rainfall or aquifer, and ample sunshine enabled triple cropping in many parts of the State. For example, it was common to find aman paddy, the kharif crop, boro paddy, the rabi crop and aus paddy, the summer crop. The distribution of plots against tehsil, crops, and seasons may be noted from table 1.7.1.

Farmer level field data, collected through investigators and supervisors in a specified schedule, was compiled at the State institution according to a specified format before processing it for the Central Analytical Unit at DES, for analysis and subsequent generation of the cost estimates to be used by Commission of Costs and Prices (CACP).[127] While there are justifiable reasons to question the validity of data, in the absence of a better source, we can rely on this to get an idea of the intricately woven picture of the farming operations in the country (Sen and Bhatia 2004: 328).

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124 Within a single agro-climatic unit, however, significant differences in climatic factors may result in difference in vegetation and soils, and consequently in a variety of agro-ecosystems: in such cases, an agro-ecological region is carved out of an agro-climatic zone. Definitionally speaking, 'an agro-climatic zone is a land unit in terms of major climate, and growing period which is climatically suitable for a certain range of crops and cultivators. An ecological region is characterised by distinct ecological responses to macro-climate as expressed in vegetation and reflected in soils, fauna and aquatic systems' (Sehgal et *al.* 1992). Clearly, a single agro-ecological zone may lie over two adjoining states, districts or blocks notwithstanding the administrative boundaries. This poses a significant hurdle for the success of planning programmes that invariably assumes homogeneity across a unit.

125 Of the 60 tehsils, two blocks had more than one tehsil: Moynaguri had tehsil no.s 7 and 9, while Haripal had 25, 27, and 28.

126 It may be noted that a suffix 'A' with the table number denotes its location in the appendix; this nomenclature has been followed throughout the text.

127 For a review of use of CCS data by CACP and other government organisations see, 'Use of Data by the CACP' in Sen and Bhatia (2004: 325–8). This volume also provides an excellent review of the Scheme. Also see, CSO (2008) and Ram (2001) apart from various Committees set up for the review of various aspects of the cost of cultivation data starting with Mitra Committee (1967) to the Vaidyanathan Committee (2011) [Government of India, 1967, 1980, 1990, 2004, 2005].

Table 1.7.1: Distribution of plots across Tehsil, Crop and Season

Tehsil No.	Season 1			Season 2								Season 3					Row Total
	Paddy	Rest	Total	Paddy	Potato	Mustard	Wheat	Vegetables	Sesamum	Rest	Total	Paddy	Sesamum	Jute	Vegetables	Total	
1	37	-	37	18	-	10	-	-	-	12	40	-	-	13	-	13	**90**
2	32	-	32	-	-	-	-	-	-	-	-	-	-	-	-	-	**32**
3	30	1	31	5	-	-	-	9	-	9	23	-	-	14	-	14	**68**
4	32	-	32	-	-	-	-	-	-	-	-	-	-	6	-	6	**38**
5	41	-	41	-	-	-	-	-	-	-	-	-	-	10	-	-	**51**
6	31	-	31	-	5	-	6	-	-	-	11	-	-	28	-	28	**70**
7	39	-	39	-	-	1	10	8	-	3	22	-	-	11	-	11	**72**
8	48	-	48	-	-	-	-	-	-	-	-	-	-	14	-	14	**62**
9	30	-	30	8	-	-	2	-	-	-	10	-	-	1	-	1	**41**
10	30	-	30	14	-	9	3	-	-	-	26	-	-	12	-	12	**68**
11	32	-	32	17	-	-	-	-	-	-	17	-	-	5	-	5	**54**
12	37	-	37	-	-	4	2	-	-	-	6	-	-	2	-	2	**45**
13	9	2	11	-	-	7	10	-	-	-	17	-	6	8	-	14	**42**
14	11	-	11	12	3	14	13	-	-	9	51	-	-	47	-	47	**109**
15	15	-	15	15	-	8	8	-	-	4	35	2	-	18	-	20	**70**
16	14	-	14	13	-	9	10	2	-	8	42	-	-	20	-	20	**76**
17	25	-	25	25	-	3	12	-	-	-	40	-	-	15	-	15	**80**
18	13	-	13	7	-	6	-	25	9	3	50	-	2	11	-	13	**76**
19	38	-	38	4	1	-	1	29	-	1	36	-	-	29	-	29	**103**
20	24	-	24	26	10	10	-	10	-	-	56	10	-	10	-	20	**100**
21	24	-	24	19	-	-	-	-	-	-	19	-	-	3	-	3	**46**
22	15	-	15	6	-	1	-	-	-	-	7	-	-	-	-	-	**22**
23	46	-	46	1	12	-	-	-	-	-	13	-	-	7	4	11	**70**
24	20	-	20	-	12	-	-	-	-	-	12	-	-	3	-	3	**35**
25	20	-	20	-	17	-	-	-	-	-	17	-	-	-	-	-	**37**
26	54	-	54	-	23	-	-	-	-	-	23	-	-	-	-	-	**77**
27	21	4	25	1	13	-	-	1	-	-	15	-	3	9	4	16	**56**
28	41	-	41	8	20	-	-	-	-	-	28	-	4	-	-	4	**73**
30	50	-	50	43	13	-	-	-	-	-	56	-	-	-	-	-	**106**

Contd...

Tehsil No.	Season 1			Season 2								Season 3					Row Total
	Paddy	Rest	Total	Paddy	Potato	Mustard	Wheat	Vegetables	Sesamum	Rest	Total	Paddy	Sesamum	Jute	Vegetables	Total	
31	49	-	49	30	0	-	-	-	-	-	30	-	-	-	-	-	**79**
32	32	-	32	1	10	-	-	-	-	-	11	-	9	-	-	9	**52**
33	29	-	29	12	12	-	-	-	-	-	24	-	-	-	-	-	**53**
34	51	-	51	0	17	-	-	-	9	-	26	-	-	-	-	-	**77**
35	38	-	38	3	-	-	-	-	-	-	3	-	-	-	-	-	**41**
36	36	-	36	8	-	-	-	-	-	-	8	-	-	-	-	-	**44**
37	-	-	-	37	-	-	-	-	-	-	37	5	-	-	-	5	**42**
38	-	-	-	33	8	-	-	-	-	-	41	-	-	9	-	9	**50**
39	34	-	34	11	-	-	-	-	-	-	11	6	-	-	-	6	**51**
40	39	-	39	1	-	-	-	-	-	-	1	-	-	-	-	-	**40**
41	31	-	31	6	-	-	-	-	-	-	6	-	-	-	-	-	**37**
42	45	-	45	-	-	-	-	-	-	8	8	-	-	-	-	-	**53**
43	43	-	43	-	-	-	-	-	-	-	-	-	-	-	-	-	**43**
44	14	-	14	4	-	-	-	-	-	9	13	-	-	-	-	-	**27**
45	36	-	36	13	-	-	-	-	-	-	13	-	-	-	-	-	**49**
46	61	4	65	-	-	1	-	-	-	10	11	-	-	-	-	-	**76**
47	29	-	29	2	-	-	-	-	-	-	2	-	-	-	-	-	**31**
48	49	-	49	-	-	-	-	-	-	-	-	-	-	-	-	-	**49**
49	27	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	**27**
50	28	-	28	17	-	13	10	-	-	-	40	-	-	-	-	-	**68**
51	42	-	42	4	8	9	7	-	-	2	30	-	-	-	-	-	**72**
52	31	-	31	8	5	5	9	-	13	-	40	-	-	-	-	-	**71**
53	41	-	41	6	-	-	-	-	-	-	6	-	-	-	-	-	**47**
54	36	-	36	-	6	7	9	-	-	-	22	-	-	-	-	-	**58**
55	38	-	38	1	-	1	4	-	-	-	6	-	-	-	-	-	**44**
56	14	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	**14**
57	43	-	43	-	-	-	-	-	3	-	3	-	4	-	-	4	**50**
58	48	-	48	-	22	-	-	-	-	-	22	-	-	-	-	-	**70**
59	57	-	57	-	-	-	-	-	-	-	-	-	-	-	-	-	**57**
60	40	-	40	16	12	1	1	-	15	-	45	-	-	-	-	-	**85**
Total	1920	11	1931	455	229	119	117	84	49	78	1131	23	28	305	8	364	**3426**

Source: CCS WB 2004-05, RT 230

Notes: Analysis in this work excluded tehsil no 29, and perennial fruit crops in all tehsils altogether. Details of distribution of vegetables into individual crops is captured in table A.3.2.6. Mustard includes rapeseed as well.

The choice of West Bengal is because of its significantly long history of food crop production. Further, the average farm sizes are smaller in comparison to most parts of the country, a part of the farm is usually kept for cultivation of food crops for self-consumption. Indeed, it is important to evaluate the efficacy of the land to the tiller, in terms of its ability to sustain the crop production. Finally, this State is one of the top producers of paddy, the cereal consumed by the majority of people in the state. It is also a well accepted physiological fact that this cereal contributes the most in the 'energy income' of the people.

> Even in reasoning upon some subjects, it is a mistake to aim at an unattainable precision. It is better to be vaguely right than exactly wrong. In the criticism of manners, of fine art, or of literature, in politics, religion and moral philosophy, what we are anxious to say is often far from clear to ourselves; and it is better to indicate our meaning approximately, or as we feel about it, than to convey a false meaning, or to lose the warmth and colour that are the life of such reflections. (Carveth Read, 1914, *Logic, Deductive and Inductive*, Fourth Edition, Simpkin, London, p. 351)

This chapter discusses the method followed in this thesis towards the measurement of surplus in energy terms. As noted earlier, there exist several strands within the 'energy theory of value'. Of which, the relevant one for the present purpose, considers 'value' as the use-value, following the Physiocrats. Indeed, the scope of the thesis is limited enough to leave the energetic basis of a 'theory of value' unaddressed.

> The difference between the *value* of labour-power and *the value created* by it — that is, the surplus-value which the purchase of labour-power secures for the user of labour-power — appears most palpably, most incontrovertibly, of all *branches of production*, in *agriculture*, the primary branch of production. The sum total of the means of subsistence which the labourer consumes from one year to another, or the mass of material substance which he consumes, is smaller than the sum total of the means of subsistence which he produces. [...] In agriculture it [surplus] shows itself directly in the surplus of use-values produced over use-values consumed by the labourer, and can therefore be grasped without an analysis of value in general, without a clear understanding of the nature of value. [...] Hence for the Physiocrats agricultural labour is the only *productive labour*, because it is the only labour that *produces a surplus-value* [...]. (Marx 1963: 46; emphasis as in original)

Like the 'pivotal point of Physiocratic theory' (Marx 1963: 45), this thesis assumes certain Calorie-norms towards quantifying the value of labour power in energy terms. Thus, with the given value of raw and other materials, and the value of labour power in energy terms, the surplus value in energy terms clearly consists of nothing but the return of the labour in excess of the sum of the materials and the labour power. Certainly, such value surplus will include the contribution of solar energy in particular, and will ascribe direct value to nature as well.

Again, for the Physiocrats,

> [...] the productivity of the earth enables the labourer, in his day's labour, which is assumed to be a fixed quantity, to produce more than he needs to consume in order to continue to exist. The surplus-value appears therefore as a *gift of nature*, through whose co-operation a definite quantity of organic matter — plant seeds, a number of animals — enables labour to transform more inorganic matter into organic. (Marx 1963: 55)

The inclusion of a 'pure gift of nature' was noted by Marx (1963: 54–55) in the discussion on the causes of the appearance of surplus value, in the context of Turgot's *Réflexions sur la formation et la distribution des richesses* (1766). The 'unbought elements' that the seller sold, as per the latter, included two elements: first was the unpaid value, while the second one was conceived as a 'pure gift of nature', the excess over the wage of labour. '[...] [B]ecause after all it is a gift of nature, it depends on the productivity of nature that the labourer is able to produce in his day's labour more than is necessary for the reproduction of his labour-power, more than the amount of his wages' (Marx 1963: 55). The 'gift' was made to the labour, or the one who cultivates the land. Marx (1963: 57) concluded that '*within the limits of agricultural labour*, the Physiocrats have a correct grasp of surplus-value', even while it was

> [...] explained again in a feudal way, as derived from nature and not from society; from man's relation to the soil, not from his social relations. Value itself is resolved into mere use-value, and therefore into material substance. But again what interests [the Physiocrats] in this material substance is its quantity – the excess of the use-values produced over those consumed; that is, the purely quantitative relation of the use-values to each other, their mere exchange-value, which in the last resort comes down to labour-time. (Marx 1963: 52)

Burkett (2003: 151) explained that 'the energy theory's search for a primary input is driven by its reduction of the question of value to that of finding some common measure of use value conceived apart from historically specific social relations of production'. This defines the scope and limitations of the thesis.

Section 2.1 describes the method of embodying the energy flows within an agro-ecosystem, in general terms, followed by the contours of the methods of energy balance analysis in section 2.2. Energetics of human labour and animal labour are discussed in section 2.3 and 2.4 respectively, along with the particular Calorie norm(s). Energy coefficients for the various material inputs and outputs are discussed in section 2.5, while section 2.6 explains the energy accounting of the machines in use and the associated materials. Finally, section 2.7 provides a summary of the Calorie norms/energy values for every type of inputs and outputs used in this thesis.

2.1. Energy Flow in an Agro-ecosystem

Agro-ecosystems are more complex than the other natural systems in many ways.[1] In agriculture, a proportion of the solar energy flow is diverted and managed to obtain food, timber and the other products useful to the human beings, directly or indirectly. Alternatively, in addition to the cycling of energy and materials, there are many human-manipulated processes, most of which are for 'modifying inputs and exports, but also affecting rate relationships within the system' (Loucks 1977: 173). While at one level, the humans could be seen as one of its natural constituents, interventions resulting from the economic and market processes, ultimately control its dominant characteristics. The causes include the governing 'economic system' determining the intensity of 'inputs and exports' and the 'economic viability or survival of the farmer-cultivator' (Loucks 1977: 173).

One of the other distinguishing properties of agro-ecosystems includes maximum harvestable (i.e. economic) productivity as a dominant goal, with associated perturbances (see, Loucks 1977: 174 for details). The analysis, causation and impact of such ecosystem stresses are beyond the scope of the present thesis, and so are the decision making and marketing processes resulting in a particular kind of economic behaviour on the part of the farmer-cultivator.

The maximization of harvestable output or the use-values of final products require the use of external 'support' energy inputs,[2] whose nature, composition and quantity are quite drastically different across agricultural systems.[3] Alternatively, '[b]ecause of the immunity of basic photosynthetic processes to man's influence up to date, the strategy of agriculture is to increase the proportion of primary production which is used by man by manipulation of

[1] An ecosystem is an arbitrarily defined unit in which there are distinct patterns of energy flow and chemical cycling (Mitchell 1979: 15). The agricultural one comprises a community of plants and animals (both domestic and wild), a collection of devices (buildings, machines, etc.) introduced by man, and the physical surroundings. (MacKinnon 1976: 278)

[2] While Sun's energy is virtually inexhaustible, freely available and generally beyond our control, the support energy is under our control, has a cost and is exhaustible. Latter consists of energy used by people and draught animals in their work, to manufacture farming tools and machinery, to power the machinery, to produce and distribute the fertilisers, pesticides, herbicides, plastics, etc., in food processing and to transport the produce to the consumer/intermediate producer.

[3] Man's attempts to alter the natural ecosystem through agricultural activities, have evolved over several centuries. Be it introduction of new techniques, or innovations, changes had been continuous, though at different rates per unit of time, accompanied by diverse patterns. However, a common factor had been the impact on the ecosystems: only to be increased by many times by the 'modern' innovations. (MacKinnon 1976: 278)

subsidy energy used' (Ryszlcowski 1984: 78).[4] Thus, some of the inputs are biological, originating within the system,[5] while the rest are non-biological with their origins outside,[6] resulting in a variety of types of non-uniform energy flows. These energy flows, have been arbitrarily divided into a) climatological (heat balance of environment), b) biological (flow of energy channelled by chlorophyll activity), and c) energy provided by humans to the system in order to obtain specific agricultural goals (Ryszlcowski 1984: 90). The external support energy inputs, be it biological or non-biological, performs an enabling function to capture a greater proportion of the solar energy flow.[7] It follows that *any* Energy Analysis (EA, hereinafter) will aggregate the external support energy flows. This thesis uses EA as a generic term for describing a variety of different methodologies, unless otherwise specified. They include energy accounting, energy analysis, energy balancing, energy budgeting as well as energy costing.

There are four types of ecosystems as per Odum (1975):[8]

A. Solar Powered—(1) independent solar powered, (eg. open ocean) and (2) nature subsidized (in terms of nutrient) solar powered ecosystems, (eg. flood plains.[9]

B. Fossil Fuel controlled—(3) fossil fuel subsidized solar powered, (eg. agriculture and aquaculture), and (4) fossil fuel powered, (eg. industry).

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[4] Increases in the energy output from per unit area of ecosystem due to human cultivations had prompted Giampietro and Pimentel to term such quantity of harvestable biomass as 'return of human investment' (1990: 258) or 'energetic return for human work' (1992: 14).

[5] Say, energy spent in site preparation, a common operation, allows plants to capture more sunlight without any competition from the weeds, but this energy is not directly combined in the plant.

[6] For instance, energy spent in production and application of fertilizers do not result in addition of fertilizer nutrient molecules to the plant, but it enables the plant to make better use of the available solar energy so as to convert a higher proportion of the 'incident' energy into the yield component.

[7] Neglect of this crucial difference between the flow from external energy inputs and solar energy can result in confusion. See, Jones (1989: 344) for a few examples of this methodological error.

[8] E P Odum, 1975, *Ecology: The link between the natural and social sciences*, Second Edition, Holt, Rinehart and Winson, New York; cited in Mitchell (1979: 16).

[9] See, Pandya and Pedhadiya (1993) for example, who had performed an EA of an ecosystem in Kadiyana village (23.1° N, 71.2° E), 105 km north of Rajkot, in 1987–1988 to empirically verify the existence of 'natural subsidized solar-powered ecosystems' in almost self-sustaining villages (Mitchell 1979). Following the study of four compartments, namely, crop subsystem, human subsystem, animal (livestock) subsystem, and non-crop subsystem along with five sub-compartments of storage that included food grains, fodder, fuel, dung and milk, the study had agreed with Mitchell (1979) 'for the existence in India of such a village ecosystem as a self-sustaining natural subsidized solar-powered ecosystem' (Pandya and Pedhadiya 1993: 174).

However, such a classification remains applicable only for the more industrialised countries, as the subsistence agriculture in less industrialised countries is mostly operated with little or no fossil fuel input, but largely with the direct solar energy. Hence, Indian agriculture in its entirety, can neither be classified under 'natural' systems, nor can it be clubbed together with the Western agriculture. In may be noted that, the 'traditional practices' have been argued to be 'the best base on which to develop effective production systems with minimum fuel subsidies and the survival of human populations depends on the evolution of solar-powered agro-ecosystems that are stable and more productive' (Mitchell 1979: 19). On the other hand, it has also been claimed that a system with a massive fuel-subsidy and faulty nutrient cycles, like the Western agriculture, cannot sustain the human population in the Indian agro-ecosystems.[10]

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Harper (1974: 1–2) had pointed that even before the introduction of the concept of the 'ecosystem', both agriculture and forestry had been concerned with the practical management of ecosystems. The only difference was that they simply had not been studied quantitatively (Loucks: 1977). Be it the minimally intervened rangelands or the highly intensive systems that had involved in 'battery production and factory farming', the common factor was the extraction of resources from an ecosystem and directing them away from the cycles that characterise the most natural systems (Harper 1974: 2).

[10] See, also Biswas and Biswas (1976) who had argued on the aftermath of the World Food Conference (Rome, 1974) that in its emphasis on the extension of the North American type of highly energy-intensive agricultural practices to increase the yield in the other parts of the world '[t]here is a very danger that, in our efforts to increase food production in the short run on a crisis basis, we may adopt strategies which are self-defeating in the long run' (1976: 197). To the authors, the inefficiency of these agricultural practices are such that the same amount of resources that was 'necessary to support on inhabitant of a more affluent country can support on average five citizens of developing countries such as Bangladesh, Uganda or Columbia' (1976: 197). Ryszlcowski (1984: 78) had noted that the global increase in yields, especially of the major cereal crops, since the World. War II, due to new technologies, energy and matter inputs and economic incentives, though unprecedented in the history of agriculture, had begun to level off by the beginning of the 1970's and thus subsequent increases in crop production were largely of the extensive kind. It was argued that the application of the 'means of high-energy crop production technology' was developed without sound ecosystem knowledge, and mostly by detection of positive correlations between inputs and outputs. Such '[l]ack of understanding of component ecosystem processes, which tie inputs to outputs, is probably the main obstacle to further big yield increases. It seems, therefore, that further energy intensification alone would not produce spectacular effects in developed countries' (Ryszlcowski 1984: 78).

Indeed, in agriculture, energy and mineral resources are deliberately channelled out of one area into another and in addition, it commonly creates 'leaks' in the otherwise self-maintaining systems. This is beyond the migration of resources in natural ecosystems which remain essentially self-sustaining. For example, most intensive forms of agriculture may lead to a loss of soils and mineral resources due to over-cropping, or a loss of minerals by leaching. The dustbowls of the 1930s in the US referred to earlier, are examples of the first type. Such ecological events take place 'particularly when a natural biomass that has maintained a large bulk of nutrients in a living cycle is suddenly reduced by large scale deforestation to a low biomass with a much reduced storage capacity' (Harper 1974: 2). It follows that, for continuous cropping, such 'leaks' had to be constantly filled, through organic or inorganic fertilizers. However, these are applied 'not simply at a level sufficient to make up losses but at rates designed to maximise crop production' (Harper (1974: 2). Indeed, such interventions, more often than not, do not correspond with the ecosystem functioning, and the excess nutrients are often leached into the neighbouring ecosystems.

These interventions with the objective of economically efficient food generation, constitute an act of design, and include a process of selection, involving particular types of components and techniques.[11] The complexity originates from the behaviour of the farm's various biological components, interactions with the natural community of organisms, and the effects of extensive, unpredictable disturbances from the local environment (MacKinnon 1976). Historically, the first and the most basic objective of the 'farmer-designer' had been to design the farming system so as to adapt to its environment. Indeed, if such a system could meet the farmer's demand for food, there was little motivation to change. With industrialisation, matters changed, urging and incentivising the farmer to produce a food surplus that could give the maximum monetary profit. 'General acceptance of this economic objective gave rise to an intensive search for farm systems which provided high levels of production per unit of land, labor and capital' (MacKinnon 1976: 280). No doubt, such motivations had resulted in the innovations and inventions towards achieving food security. However, in recent

[11] Incidentally, though such design concerns systems which are more complex than say, engineering systems, usually the role of the farmer as a designer is not commonly recognized. One of the reasons is that such designing had been carried out mostly on an informal and intuitive basis, and certainly lacks the formality of Western Science.

times, concern about the environmental effects of modern farms and their efficiency in the use of limited energy and materials had prompted further revision in the farm design objectives. Arguably, for locating or identifying the appropriate system designs, energy-material analysis could be of much use.

Indeed, the multiple objectives of designing a 'modern' farm may include (a) effective operation over a range of output levels, (b) continuous generation of a supply of high quality food in spite of the perturbances in the system, (c) efficient use of energy and materials, and (d) minimal adverse effects on its environment. Accordingly, a set of acceptable designs can be located, for which the overall measures of system performance may remain within the specified limits. The indicators may include, among others, the ratios of energy flows within specified temporal markers, e.g. energy output divided by solar energy, support energy or the fossil fuel energy input (MacKinnon 1976). Certainly, no single set of performance measures, including the limits on their respective range of values, could be applicable to all the situations; a suitable set must be chosen according to the type of production system and the local conditions, including the social considerations and not just the economic ones (MacKinnon 1976). At the same time, from a long-term viewpoint it is essential for the agriculture to function with the maximum efficiency in energy-material use along with a well-defined, acceptable level of ecological impact. Certainly, the evaluation of energy flow and matter cycling in the agricultural landscape can serve as a natural base for elaboration of farming optimization principles that takes into account the economic effects and protection of the environment (MacKinnon 1976, Ryszlcowski 1984).

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Following Lindemann, the flow of energy can be observed by looking at a 'compartment', which can be a single trophic level or any of its components. A compartment, by construction, takes energy from a common resource base and its use can also be specified as a set of outputs. While by the first law of thermodynamics, the total input and the gross output shall be identical, due to the near impossibility of measuring all the outputs of an organism at a trophic level, weights of the organisms are measured before converting them into energy units. Coefficients are obtained in the laboratory, which are used to convert the field level data on biomass and activities into Calories (Mitchell 1979: 28). The energy balance analysis follows an identical taxonomy.

The role of a compartment in an ecosystem has been defined by the ways through which one compartment is linked to the others. Accounting of energy flows represents such relationships; the input and the expenditure for a compartment forms the energy budget, while output defines the links with the other compartments (Mitchell 1979: 21). In algebraic terms,

> Energy received – unassimilated energy that is either lost or not absorbed
> = the portion of the energy that can be assimilated
> = energy used in growth (or change of mass, calculated in Calories terms) + metabolism (measured as the release of carbon dioxide or the uptake of oxygen).

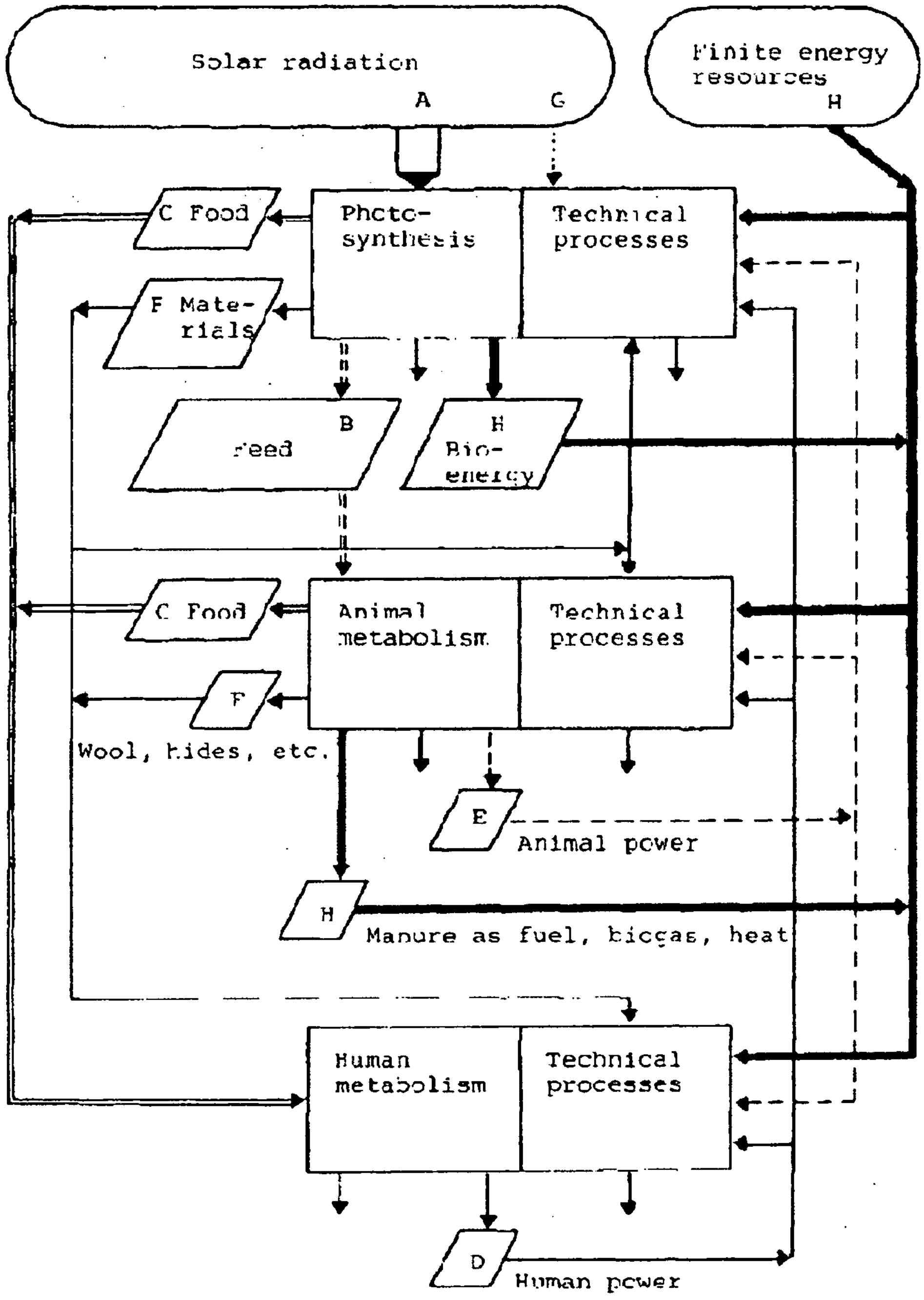
However, some of the non-biological inputs in agricultural systems, like a stone fence, cannot be expressed in calories. Further, for the external inputs like the fertilizers, chemicals and the irrigation, instead of the food calorie, energy of the fossil fuel needed to produce them is measured. Nevertheless,

> [...] problems of the non-equivalence of fossil fuel Calories with food Calories or protein Calories with fat or carbohydrate Calories are refinements that may be set aside in the construction and testing of energy budget for its precision. They become crucial issues in the interpretation and use of an energy budget [...]. (Mitchell 1979: 28–30)

Notwithstanding the enormous diversity of practices in India that include slash-and-burn, continuous paddy and 'every possible form of solar powers agriculture', a general model was proposed by Mitchell (1979: 31). For the kind of energy balance analysis that this work has undertaken, energy flows in a closed system producing goods and services for human consumption are arguably more relevant (see, figure 2.1.1).[12] Here energy flows are divided into eight groups according to the utilization of the energy (Norum 1983: 3).

[12] An open system is the one that exchanges energy and matter with its environment. A closed system exchanges energy but not matter with its environment. An isolated system exchanges neither energy nor matter with its environment. Examples are individual organism, earth and entire universe respectively.

Figure 2.1.1: Energy flows in a closed system



Legends:
(A) solar radiation utilized in photosynthesis;
(B) feed for animals;
(C) food;
(D) human muscular power;
(E) animal muscular power;
(F) materials of biological origin (timber, vegetable fibres, wool, hides etc.);
(G) solar radiation utilized in technical activities (natural drying of feed food and materials, etc.);
(H) energy from finite energy sources and from biological processes used to maintain the technical processes in the system.
Note: Short arrows ending freely imply loss of heat and energy content.
Source: Norum (1983: 3)

There exist three groups of biological processes: photosynthesis, animal metabolism and human metabolism. Human controlled activities are mainly consisting of the technical processes that are connected with the biological activities, so as to improve the latter.[13] The tillage, the fertilization, the irrigation, the harvesting, and the care to the livestock, are some of the examples.

> [...] Labour is, in the first place, a process in which both man and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature. He opposes himself to Nature as one of her own forces, setting in motion arms and legs, head and hands, the natural forces of his body, in order to appropriate Nature's productions in a form adapted to his own wants. (Marx 1954a: 173)

Given the importance of the low entropy energy as a limiting factor, the goal of energy conservation warrants consideration of the scarce resource requirements of the alternatives, along with their yield in goods or services and the possible positive and negative environmental effects. Clearly, the two flows termed as H in figure 2.1.1 are of primary interest in this regard.

Policy interventions or the 'strategy' warrants much greater and better communication, coordination and collaboration among the social and natural scientists to realise such a possibility. It may include, among others, a clearer picture of the relevant biological and technical processes, a set of the feasible alternatives and their respective physical consequences, and the possibility of improvements in the technology to achieve the chosen option. At the same time, it is important to question the guidance offered by the conventional economic analysis that has maintained the production of food as an essentially economic activity, in terms of the allocation of the scarce resources of various kinds (energy, labour, land, and materials). This indeed had created serious social and environmental problems, calling for new approaches to the problems of planning and managing the agricultural activities. A possible way forward is to combine the concepts and the principles from the sciences of energetics, ecology and cybernetics, so as to provide the basis for an alternative to the current methods of farm performance evaluation, with energy serving as a physical measure.

[13] Apart from those mentioned earlier, they also include other technical processes intended to meet the demands of human consumption other than the food. In the more industrialised countries, resources spent on the latter, are significant (Norum 1983: 4). As an illustration, consider the per capita material and energy consumption of the United States.

2.2. Energy Analysis: assumptions, prospects, limitations

The basic taxonomy of the energy balance analysis (EBA) employed in this thesis resembles that of EA in many respects, with the important exception of the living labour, among others. The closest one among the variations among the EA methods is the energy 'process' analysis. A brief review follows.

The central question that EA had to face at the very beginning was about its value addition potential. 'What is it that EA can provide in decision making and resource allocation which economic analysis can not do equally well or better?' (Nilsson and Kristoferson 1976: 27). Alternatively, '[w]hat information will EA provide us with that will improve our understanding of a particular problem?' (Jones 1989: 353). A workshop, titled Energy Analysis and Economics by International Federation of Institutes of Advanced Study (IFIAS) at Lidingö, Sweden, 22–27 June 1975, engaging twenty-seven economists and scientists from 10 countries,[14] had prepared a summary of recommendations. The latter included the nomenclature, method of analysis and the definition of terms for energy (process) analysis [Appendix 1: Guidelines for energy analysis in IFIAS (1978)]. Among others, the workshop included a rejection of the energy theory of value 'not because it is impossible to design such an allocation mechanism, but because such a system does not adequately describe the complex environment within which human choices are made' (Nilsson and Kristoferson 1976: 27).[15]

Considering the increasing recognition of the limits of low entropy energy resources in the contemporary times, EA was conceived to be pregnant with the potential to become a powerful tool for policy making, as it could quite effectively complement the economic analysis (Slesser 1978: 1). In particular, it was argued that, whatever adjustments the economists undertook in order to get the market

[14] IFIAS had conducted the first workshop in 1974 in Sweden for establishing the conventions and methodology of what used to be known then as Energy Accounting (Nilson 1974). Report of the workshop, that involved representatives from industry, universities, business and government, was widely accepted (Slesser 1978: 8).

[15] The workshop had also resulted in an agreement between the two disciplines over its use as a descriptive tool for the physical assessments towards establishing the physical and ecological limits for the economic processes. Limits were of two kinds—(a) a maximum one certain activities and (b) a minimum one, in a thermodynamic sense, for all process transformations, chemical, electrical or mechanical. In addition, the workshop had agreed on certain potentialities of EA: 'a. Assessment of existing and future technologies; b. Designing predictive economic models, especially for long-range planning; c. Describing the energy consequences of various societal policies; d. Establishing new and useful ways for the estimation of natural resources; [.. and] g. Providing a "missing link" between economic and physical descriptions of human activities'. See, Nilsson and Kristoferson (1976: 28–29).

price under imperfect conditions, energy analysts could offer a more precise alternative in comparison (Slesser 1977: 259).

2.2.1. Energy Analysis—energy flow to embodied energy

EA is a 'systematic way of tracing the flows of energy through an industrial system so as to apportion a fraction of the primary energy input to the system to each of the goods and services which are outputs of the system' (Chapman 1976: 1). IFIAS had defined it as 'the determination of the energy sequestered in the process of making a good or service within the framework of an agreed set of conventions' (Nilsson 1974: 222; deemphasised). Alternatively, it is the use-value of a product or a service in energy terms, as noted earlier.

Based on the First Law of Thermodynamics, or the principle of conservation of energy, its methodologies required the calculation of the different types of 'embodied' energy. Such capturing of the energy sources requires tracing the flow of the energy through the relevant system, and thus involves the entire life-cycle of the product or activities 'from-cradle-to grave'. As the production of any energy requires various inputs, which in turn requires energy for their production, this latter 'embodied' energy 'subsidises' energy output, and the society receives only the difference between the produced energy and the energy required in producing the inputs, or the 'net energy'.[16] In other words, conceptually, it is identical to the direct and indirect labour embodied, towards measurement of the surplus value, as noted earlier.

2.2.2. A few Methodological issues in EA/EBA

EA, as such, involves a number of methodological issues, and debates over many of them are yet to be settled, including the one on the system boundary.[17] At the same time, this 'heterodoxy' leaves ample scope for relaxing the specific assumptions or to 'mould' the method, as per the context, contours and content of

[16] It is defined as the 'amount of energy that remains for consumers use after the energy costs of finding, producing, upgrading, and delivering the energy have been paid' [H T Odum, 1973, 'Energy, Ecology and Economics', *Ambio*, 2, pp. 220–227, cited in Huettner (1976: 102)].

[17] Consider for example, a kilogram of chemical fertilizer, for which the 'energetic cost' may include the making of its packaging, its transportation to the shop or the percentage of product lost in the distribution chain. It is also interesting to note that there is no agreement even on the name for such a problem: it had been called 'partitioning problem' by IFIAS in its first workshop, and others call it 'truncation problem' (Conforti and Giampietro 1997: 235). These differences obviously make it impossible to reasonably compare the results across studies based on different assumptions, which often remain unspecified.

the research problem, while retaining the basic taxonomy. The methodological issues can be classified under three broad heads following Jones (1989: 340): (a) nature, scope and system boundary, (b) accounting nomenclature, and (c) implications and limitations.

2.2.2.1. *System Boundary*

System boundaries in EA can be drawn at different levels, according to the objective, taking a cue from the ecosystem approaches. For the crop production systems, it is usual to limit the upstream boundary at the farm gate, while at the downstream it is extended up to the production of the supporting energy inputs. However, there are variations in the 'level of regression'. Take for example, the space requirements for a particular farming system, which may vary, even for a well-defined set of inputs and outputs.[18] In this thesis, it is only the area under cultivation of the crop in question, except the grazing land for some of the animals.

EA of an ecosystem is carried usually on the (ecologically) stable ones, with a clear demarcation of the energy flows. Here, the system boundary is set at a level that includes solar energy and all other support energy inputs. Inclusion of the Sun's energy however creates a number of problems, as the incident solar flux or the rate of solar energy flow in a given area is independent of the use of energy in the corresponding agricultural system. The application of the supporting energy inputs, can only increase the proportion of the trapped solar energy, but not its flow, as noted earlier. Thus, the inclusion becomes irrelevant. At the same time, locational characteristics of the production systems or the agro-climatic zone appear as a variable.[19] The second problem is that of scale, as the inclusion makes the support energy an insignificant component of the total energy flow.[20]

[18] Against, a kg of corn, one could consider only the area under cultivation, or, the area of fallow land required by the productive process adopted by the farm, or, that required to produce the external inputs, if any, or, the space of wild ecosystem needed to preserve the stability of the agro-ecosystem (Giampietro, Cerretelli, and Pimentel 1992b: 451).

[19] 2004–05 dataset provide agro-climatic zone specific information. 1956–57 provides the specific location of the survey areas.

[20] The energy contained in Photosynthetically Active Radiation (PAR), the measure of solar energy, in temperate regions, is about 15,000 GJ/ha, which is around three orders of magnitude greater than all the fossil fuel energy inputs required by agriculture (Hulsbergen et *al.* 2001: 307).

2.2.2.2. *Data Requirements and Apportionment*

For the energy (process) analysis, at the practical level, the main constraint is the considerable amount of data and time needed to calculate these values (Jones 1989: 346). Most of the data and knowledge about the processes are only available at the field level, which is demanding to say the least. The datasets that this thesis has used conform to such a requirement, along with extensive interactions with farmers and enumerators for the 2004–05 statistics.

Similarly, apportionment of the joint production/consumption at the household level to each crop-plot combination was carried out through appropriate assumptions. For example, the joint material consumption and the depreciation of machines in use had been apportioned on the basis of the machine hours against relevant plot-season-crop combinations. All such assumptions adopted in this work are in line with the recommendations of the various committees set up by the Government of India,[21] to evaluate and improve the methods of the Cost of Cultivation Studies (CCS).[22] The only exception was the treatment of small implements, like sickle, *kadai*, crowbar, spade, bucket, etc. Embodied energy in each of them was so small that apportionment of depreciation resulted in meaningless values.

2.2.2.3. Methodological Issues over Treatment of Inputs

Importance of most of the methodological issues arose due to the requirement of the uniform treatment to the variety of the primary inputs. It may be illustrated with the treatment of human labour in relation to the other inputs, like animal labour and machinery, following Punti (1988). Consider the energy balance of the activity of harvesting carried out by a machinery and by human labour in two contiguous plots, with the assumption that the remaining activities are conducted in an identical manner. In the calculation of the EROI (energy output/energy input), numerator remains the same, by construction, while input differs between the machinery with oil and the human labour. Different methodological assumptions over the energetics of human labour, can result in a number of possibilities. Zero energy cost as in the industrialised systems will show the plot

[21] Mitra Committee (1967), Sen Committee (1980), Hanumantha Rao Committee (1990) and Alagh Committee (2006).

[22] Appendix A–D contains selected aspects of CCS: a general review, the key terms and definitions, the cost concepts, and the methodological issues respectively.

with the human labour to be much more efficient. Further, value of the food necessary to get such energy to work, may not also be correct for comparing with its substitute, the oil fed machinery. Food can account for 'only the cost of the "oil" for the "human machine", but not the consumption of energy necessary to build up this "machine"' (Punti 1988: 81). A possible way out, is the use of the Marxian concept of 'reproduction of labour power', that takes into account the cost of the reproduction of the capacity to undertake the useful work. Certainly, the valuation of human energetics, using the value of the embodied and process energy in the goods and services consumed by the labourers and their dependents, provides a socio-economic dimension, in the otherwise mechanical approach in the analysis. While in modern societies such costs may include food, clothes, housing, transportation, health, education, security, training, etc., in this work, only the food has been included, as noted earlier.

Further, as for the machinery, higher intensity accompanies increases in the labour used and the material consumed directly as well as for repair/maintenance, apart from the accelerated depreciation, in case of the living inputs, the recommended dietary allowance for more intense activities will be higher than for less intensive activities.

It is possible to conceive an increased health expenditure as a response to the more intense activities by the living labour, like maintenance costs for the machinery. Nevertheless, it becomes conceptually difficult to consider anything analogous to the depreciation to account for the prior fixation of flows. At the same time, it is possible to consider the days of 'work' and 'rest' separately for living inputs, like in a machine. Dividing the total Calorie ingested during the average lifetime, say, for a pair of bullocks who were not engaged in *any* 'work' may provide the daily average against the 'maintenance' (or days of rest). On the other hand, corresponding to every type of intense work an increment can be added. The total Calorie intake during the period of activity can be calculated accordingly.[23]

[23] See, for example, Rao (1984).

However, for the human labourers, the usual route is through the 'bomb caloriemeter',[24] where the basis of measurement is the individual days, and not the average of lifetime.[25] It is virtually impossible to state which of the methods are better. However, the data limitations permitted only the latter route.

2.2.2.4. *Level of Aggregation*

While 1956–57 data is on the basis of size-class, the 2004–05 data are on the basis of plots. The latter however, also provided size-group characteristics of the household in question managing the plots. It may be noted that a single household may cultivate in multiple parcels, or, fragments. Again, each parcel could be divided into multiple but contiguous plots. Certainly, the level of aggregation for the analysis could have been either of the three: household, parcel or the plot. Number of fragments in 2004–05 was significant, especially for the households with a smaller cultivated area, similar to 1956–57 (see, table 3–9, in DES 1956: 51). Multiple fragments of land under the management of the same household, with greater distance between each other, certainly influence the scale of operation for the farmer. In other words, increase in the number of fragments have two effects, given the total area of land as constant, as a whole in one particular village. First, is the limitation on the technological possibilities, and second refers to the increase in the invisible costs, primarily of labour.[26]

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24 It is used in measuring the heat (or the enthalpy) of combustion of a particular reaction.

25 But the past labour that is embodied in the labour-power, and the living labour that it can call into action; the daily cost of maintaining it, and its daily expenditure in work, are two totally different things. The former determines the exchange-value of the labour-power, the latter is its use-value. The fact that half a day's labour is necessary to keep the labourer alive during 24 hours, does not in any way prevent him from working a whole day. Therefore, the value of labour-power, and the value which that labour-power creates in the labour-process, are two entirely different magnitudes; and this difference of the two values was what the capitalist had in view, when he was purchasing the labour-power (Marx 1954a: 188).

26 Field survey revealed that in the populous districts of Nadia and undivided 24 Parganas, distance between the parcels were less. Similarly, in the smaller and densely populated districts of Howrah and Hooghly, otherwise distant parcels had been brought closer through the exchanges between their owners due to the efforts on the part of the Government. Again, in a diverse district of Bardhaman, where multi-cropping is rather common, parcels under the management of the same household are not very distant to each other, on average. It may be noted that these are the districts that produce most of the foodgrain in the State. On the other hand, in the southern districts of Midnapur, with less population density, distance between the parcels was significant to warrant consideration of time in the movement of inputs between them. This fact usually is not captured even in the primary surveys. However, single cropping was rather common in these districts.

Further, 1956–57 data were made available for 8 pre-defined size-groups on the basis of the area under the household. In contrast, it is 5 size-groups in the 2004–05 data. However, the latter dataset enabled classification of households into groups with area under the household identical to the 1956–57 one, for facilitating the inter-temporal comparison.

2.2.2.5. *Actual Use versus Adoption of Norms*

This thesis has used the energy/calorific norms against the specific inputs, available in the literature. Main sources were Mitchell (1979) and Pimentel (1980a) with occasional improvisations demanded by the production specificities. While coefficients in Pimentel's *Handbook* had become the *de facto* norm for the energy studies in the more industrialised countries, Mitchell's coefficients had been used in the tropics (for example, Han et *al.* 1985 that had studied the advanced collective farms in north China).

It may be mentioned here that for the human labour, consideration of the actual consumption, using the actual wages and the corresponding Calorie values, as is done for the enumeration of the persons below poverty line in India could have sketched a picture closer to reality. However, rather than exploring such 'actual' surplus, this work has restricted itself to the use of norms against each type of activities for the human labourers for two reasons. First, translation of nominal wages to Calorie values has a number of limitations, including the neglect of intra-household disparities in the distribution of food. Further, the level at which wages were to be considered, namely village or the average of the district or the State, is still an unresolved issue despite a number of Committee reports on the method of fixation of the minimum support prices. Second, the presence of a negative energy surplus against the households or the plots will reveal that the value of the labour-power is more than the value created by it. Such conclusions, which are of great importance, can never arise if we take the actual consumption of those engaged in labouring. These cultivations will be deemed as unsustainable.

2.2.2.6. *Limiting the Scope of Energy Balance Analysis*

Land and time remain outside the scope of the energy balance analysis. The fundamental physical relationship between energy and land stems from the fact that the latter can serve as a solar energy collection surface. However, the rent for the land is unlikely to reflect this energetic connection unless under very specific conditions of unlimited supply and uniform quality of land. For this difficulty in calculation, the energy value of the land is usually ignored. On the other hand, it is possible to calculate the energy required to intensify the production on unit area basis and thus the cost of increased intensity in an indirect manner. Number of hours per plot for all the agricultural operations, as supported by the 2004–05 data, used in this thesis has considered it.

Arguably, while the conventional EA does not differentiate between the renewable and the non-renewable resources, a unit of measure, other than the Calorie, to differentiate the speed of consumption of the stock of resources can address it. For instance, for renewable resources, the ecological cost could be determined by the period of time necessary for a natural recovery (See, Punti 1988: 84–85, for details). However, this work has not considered these aspects.

2.2.3. Limitations and Advantages of Energy Analysis

One of the valid criticisms of EA is the neglect of second law of thermodynamics or the differences in the levels of entropy across inputs. In principle, this could have facilitated the assessment of the maximum amount of work achievable in a given system across the energy sources. At times, therefore, employment of an exergy analysis[27] along with the traditional first law energy analysis is recommended (see, Hammond 2004, for example). Indeed, while the notion of the energy balance had historically emerged for the components of a process, mainly to ensure the adequacy of supplies of the heat exchangers and the utilities, in relatively recent times, the exergy has become as important as the material balance. However, no adjustments have been done here against the differences in energy quality across sources. Indeed, such 'corrections' are difficult to apply in a

[27] 'Exergy' is the available energy for conversion from the reservoir with reference to a specified datum. Higher the quality of an energy source like electricity, higher will be exergy, because it can undertake more work. Thus, exergy analysis evaluates the actual design vis-a-vis the theoretical design in every step and locates the true energy use or lost work. Second-law analysis looks at each individual components of an overall process to find the causes of such lost work.

work like this. Its incorporation might make it more complete, but it is unlikely to alter the general conclusion.

Admittedly, an indicator like EROI, which is used in this thesis, may lead to a misallocation of non-energy resources, and thus requires careful interpretation. Further, the relationship between the external energy inputs and the agricultural products is not a simple input-output relationship, but represent quite distinct energy flows. Notwithstanding the fact that both the flows are measured in a common unit, it does not imply that they are equivalent.

At the same time, energy balance analysis (or EA) can identify the energy related constraints For example, it can be used to find out the dependence of the agricultural systems upon the finite fossil fuels. Indeed, 'energy analysis is one useful way of thinking about sustainability issues' (Common 1995: 198).

While acknowledging the fact that there are 'not-inconsiderable' costs of obtaining information for the EA, the most benefitted will be the economists who often face energy related situations 'where existing economic approaches cannot provide all the answers' (Jones 1989). Apart from the use of EA in the longer-term national-level planning rather than as a guide for the day-to-day decision-making, a suggestion was made for making fairly general comparisons, using this technique, rather than for analyzing the specific concerns. The reason is that the results of the studies of individual systems are likely to be dependent on the techniques chosen, and hence will be subject to the limitations and the differences across the methodologies.[28] Thus, '[t]he use of a fairly simple analysis to support broad-brush comparisons would seem preferable to detailed refinement of energy requirement estimates' (Jones 1989: 352–3). While the choice of methodology remained flexible depending on the purpose of the analysis, it was emphasised that the choice should be confined to the minimum acceptable complexity of analysis.

[28] For example, comparison between two systems at a broader level for assessing the effect of a regulatory control on the use of fossil fuel in agriculture may use some values obtained by applying a particular methodology. However, the comparison is unlikely to the dependent on the usefulness of such values (Jones 1989: 352).

For future research in EA,

> [...] it is better to start by asking what we are looking to use the technique for and what information will EA provide us with that will improve our understanding of a particular problem? Only when we have established this can we assess whether any of the methodologies available are appropriate to an analysis of the problem'. (Jones 1989: 353)

At the same time it was argued that '[EA] is [...] likely to play an important role (together with biochemical-ecological analysis of production and consumption systems) in postcapitalist society—that is, in a socioeconomic system dedicated to a sustainable, all-round human development in coevolution with nature rather than an ecologically unsustainable process of competitive capital accumulation' (Foster and Burkett 2004: 40).

2.3. Energetics of Human Labour

In the literature on the human labour in agricultural energetics, one may find a host of assumptions. For example, while comparing the crop production systems from four stages of ecological human history, Leach (1976) had taken 6–7 MJ/day, as the food energy needed to maintain human activity during the working hours.[29] On the other hand, Pimentel et *al.* (1973) had taken per hour energy requirement as the energy content of the worker's weekly food consumption that translated into 18.24 MJ/day corresponding to an eight-hour working day. Again, Slesser (1973) had considered the 'energy for life support' as input for the human labour in 'intensive systems' that included heating of the house, running a car and the other energy uses necessary in a two-child family. It was taken as 84 GJ/year. Such diversity in the approaches for energy input by the human labour exists 'due to the existence of several space-time scales at which human labor can be described' (Giampietro, Bukkens and Pimentel 1993).[30]

Considering such differences, Jones (1989) had identified four approaches:

(1) the measures of human metabolic energy expended,

(2) the measures of the 'lifestyle support' energy requirement,

(3) the measures of the marginal energy requirement of employment, and

[29] This study was also cited in and used by Dasgupta and Mäler (1995) and Common (1995).
[30] Alternately, 'the definition of a particular boundary implies a choice of a hierarchical level at which human labor is described and assessed': for the field of work physiology it is the small spatiotemporal descriptions like 'individual' worker, while for the socioeconomic analyses it is larger spatiotemporal assessments, like the 'society' and for the EMERGY analysis , it is at the scale of the solar energy spent by the biosphere in providing the environmental services needed for human survival (Giampietro, Bukkens and Pimentel 1993).

(4) the use of a zero energy cost (as in industrial systems, noted earlier).[31]

Among the measures, the one based on the metabolic energy calculates the amount of energy (from food) required to sustain the labourer and her/his dependants. Here the treatment of the human labour is identical to that of the draught animals (for instance, Rappaport 1968, as cited in Punti 1988: 80 or what Podolinsky had done in the 1880s). Giampietro and Pimentel (1990: 263) had also argued that as the energy required for the production of replacement animals is included during the measurements of meat or milk production in agriculture, a similar approach may be employed for calculating the energy inputs for the human labour, i.e. inclusion of the children and the non-working force in all the human labour cost measurements.

However, conventionally the energy cost for the animals had been attributed to the energy content of their feed, owing to a fundamental difference between the animal and the human power with regard to the resource use. The number of draught animals is adjusted to the planned production and therefore the scarcity of resources becomes relevant in such a decision. Man's 'level of living' on the contrary, has to be met whether the work is done or not (Casper et *al.* 1974).[32] Therefore, the use of resources to meet the latter demands may not be a consequence of the particular production process and be irrelevant to the analysis. If, however, the exercise of work requires increased energy use not already included, it might be relevant to include such energy. Such an approach takes into account only the incremental energy required corresponding to the

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[31] For an alternative list see, Pimentel (1980: preface). Edwards (1976: fn1) had mentioned five possibilities: energy in food consumed (or its share, for allocating some intake to non-work activities), food energy plus energy cost of other goods and services required for the maintenance of the workforce (or its share) or zero. R C Fluck and D C Baird (1982 *Agricultural energetics*, AVI, Westport, Connecticut, pp. 100–105, cited in Punti 1988: 80) is an example of the second set, where energy cost of human work had been valued against consumption of food and energetic cost of all goods and services consumed by workers. Giampietro, Bukkens and David Pimentel (1993: 231) had provided another list: the metabolic energy of the worker during only the actual work, with or without the resting metabolic rate; metabolic energy of the worker during the non-working hours; metabolic energy of the worker and his/her dependents; and all embodied energy, including commercial energy flow in the society.
Such difficulties in having a general agreement of what should be considered as 'embodied' in a particular input, can also be found in the treatment of energy in natural ecosystems' activity that is required by farming systems.

[32] D A Casper et *al.* 1974, Energy analysis of the 'Report on the Census of Production, 1968'. Research Report ERG 006, Energy Research Group, Open University, Milton Keynes, Great Britain, pp. 18–20, cited in Norum (1983: 6).

'work', over and above the 'maintenance' energy. This is due to the fact that, human and animal labour need energy even for the periods when they are not at work, unlike the machines. Martinez-alier (1987: 28–30) had advocated the inclusion of total energy expenditure of workers (food and non-food), towards human energy inputs, equivalent to the 'social reproduction' of workers that includes not only the 'physical energy to keep them in working order, but a variable historical element, which can be many times higher than the food and fuel energy physiologically needed'. Consequently, for him the 'basic sustainability principle of an agricultural society is that the energy from agriculture must be sufficient, at a minimum, to feed the agriculturalists and their families, and to feed the animals' (Martinez-alier 2011: 147).

Nevertheless, regardless of possible energy use tied up with work as mentioned above, 'labour is a resource of special importance that has to be measured in its own dimension by hours, not as energy input' (Norum 1983: 6). Arguably '[t]he choice of one or another method of measurement of the energetic value of the human work modifies to a great extent the energy balances of economic processes' (Punti 1988: 80). In the non-industrialised agricultural systems where the labour inputs are provided mainly in the manual form, calculation of this value has been argued to include not only the number of hours actually worked but also the energy needed to 'maintain' the labour inputs (Jones 1989), along with the considerations of additional energy requirements arising from the leisure activities. Energy value norm of human labour/labourer adopted in this work has attempted to address all these requirements.[33]

In the industrialized agricultural systems, almost all the activities are performed by the machinery, which in the other systems may require inputs of labour in the manual form/physical effort. However, that does not mean that the energy cost of labour is necessarily zero.[34] Some authors had excluded the labour energy

[33] At the same time, we have followed the conventional norm for the animal labour and have taken energy values of the feed or the norm as required by the context. However, in one of the many variations, this assumption was relaxed to include the total energy required for the animals.

[34] See, Jones (1989: 347–8) for a discussion on the improbability of a situation like this. In the 'lifestyle support energy' measure the energy requirements of all goods and services that are used to sustain a worker are attributed to labour energy costs. Following D A Casper, P F Chapman, & N D Mortimer (1975, *Energy Analysis of the 'Report on the Census of Production, 1968'*, Open University Energy Research Group Research report ERG 006, Milton Keynes, Open University), Jones (1989: 348) had pointed out the double accounting error in

altogether being negligible (Leach 1976; Chapman 1975; Slesser 1978), while some others had considered a nominal value equal to the energy used in the worker's muscles without making a distinction between the part that served to achieve the energy necessary for the labour activities from the one used in the leisure activities (Pimentel and Pimentel 1979: 34–35). Further, the energy consumed in processing the food and transporting it to the consumer had been left out usually. No doubt, this may have led to misleading results, because these costs may represent up to two thirds of the total energy consumed in the food production. Thus, their inclusion in the calculations could turn what was apparently an energetically viable system into a completely unviable one. Many critics of 'modern' agriculture argued that a large increase in the processing and transport of produce is inseparable from the 'modern' farming methods. In primitive agriculture, in contrast, the farmers grew a wide range of crops to satisfy most of the needs of their own community. Consequently, a large part of their produce was consumed locally. Though various Expert Committees on CCS had recommended suitable adjustments in the Minimum Support Price (MSP) for considering the transportation costs, in this work, only the energy consumed within the boundaries of the farm has been included.

Further, Jones (1989) had pointed to the two distinct roles of human labour that add to the complexities of measuring this input. Apart from the physical input of the human labour which is generally accounted for in the EA, there exists a control function for optimizing the biological system, towards the maximisation of the harvestable biomass. While the energy involvement in the former may be known with a relative ease, for the latter it is much less clear. Though there have been efforts to calculate the energy requirements of microelectronic control systems as a substitute for the information inputs provided by the human labour, 'even the most advanced control systems are a very long way from substituting for the information inputs of labour in agricultural systems' (Jones 1989: 349). The first IFIAS symposium (Stockholm, 1974) suggested two conventions depending on the system being studied: inclusion of human metabolic energy expenditure for the low intensity agricultural ones and exclusion of the energy cost of labour for being a very small proportion of total energy requirements in the more

'lifestyle support' measure. Also see, Fluck (1981) for an explanation in terms of 'feedback' of net energy output of a worker to sustain their wage-earning activities whilst the remainder is used to provide support for their family, and other non-employment activities.

industrialised economies. Such a distinction however does not address the information inputs, without which the labour energy requirements will take into account only the physical energy inputs and be a partial measure (Jones 1989: 349). Arguably, while the metabolic energy route may make sense in the primitive systems, in modern societies, the human work is beyond the physical sense, and involves managerial skill, technical knowledge and professional competence (Punti 1988: 80), apart from designing. Both the quality and quantity of information can indeed modify the flow of power (Giampietro and Pimentel 1990). This shortcoming remains valid for this thesis. However, against the managerial inputs, a fixed percentage of labour-hours have been added equal to 50 per cent of the seasonal hours provided by the family-head or the hired labourer, whichever is larger, in slight modification to the recommendations of the Hanumantha Rao Committee (1990: 5) (Government of India, 1990).

It may be noted that the use of inappropriate methodologies on human labour may result in paradoxical results. Consider for instance the general conclusion in the literature that the traditional agricultural systems are much more productive than the modern ones, with the example of Andalusian agricultural workers, used by Punti (1988). An assumption of 860 Cal as worker/day resulted in a technical efficiency of 15.22 in a traditional system and 2.43 in a modern one. Even by taking the energy consumption upto 25,000 Cal/day, traditional systems were found to be still more efficient. On the other hand, consideration of the total energy consumed by the workers and their families, in food, goods, and services, the results could be different. On average an Andalusian rural working class family with two children, in the mid-1960's, had an energy budget of around 20,000 kcal/day; thus, traditional system will still be more efficient. On the other hand, given that in 1970s, for an average US farming family, energy consumption was 100,000 Calorie/day, and also that the wages could support the consumption of 30,000 Calorie/day, the modern system would have appeared more efficient in energy terms, than the more labour intensive traditional one (Punti 1988: 83).

It may be emphasised here that, these 'paradoxical' results appear due to consideration of the required energy only on a daily basis. In other words, for a labour intensive system, the product of (more) number of days and (higher) energy/day is higher than the corresponding input for a 'modern' system: daily requirement may be higher, but number of days are much less in the latter. Certainly, a correct temporal basis is the length of the season, and not the daily one, as done in this thesis (see, chapter 3).

Thus, while it is admitted that all the inputs have an energy measure to account for their total value, 'the energy value of labor is quite unsettled, depending on the standard of living assumed' (Huettner 1976: 102). Similarly, David Pimentel in the preface of his (edited) influential *Handbook of Energy Utilization in Agriculture* (1980) had defended the decision to exclude the energy value of 'manpower' by pointing towards the difficulties posed by the variety of measurement methods. We may recall that, human labour provides the labour power (as in the physical sense) to the production system along with the information to channelize it in a particular direction.[35] It is true for all kinds of labour because in each, there is a mental (mind's activity) as well as a manual element (body's activity). For coordination between these two activities, human body also requires energy, apart from for performing the various tasks, physical, mental and intellectual. Besides, the energy is spent even when the human body is at rest (as opposied to the physical 'work').

We may also note that, what a labourer contributes in the production is nothing but the labour *power* in the physical sense: 'Labour-power exists only as a capacity, or power of the living individual' (Marx 1954a: 167).[36] This capacity is depreciated with wear and tear as well as non-use, just like a machine, and thus requires rest to recuperate itself, just like the soil. While there exists no definite mathematical relation between the Calorie input and output measured in Calorie (or, energy income and energy expenditure following Ludimar Hermann), it is

[35] For the moment, we are considering the individual labourer itself. At a different level, it is possible for the labourer to be informed by a decision maker, capitalist, manager, owner, landlord, etc but even then, while at work, the decisions are to be taken by herself.

[36] The issue of energy expenditure on the part of the labourer had appeared in writings of both Marx and Engels: 'Wages represent the "expenditure of energy" embodied in commodities, the production value' (Engels 1947); 'The low wages will correspond to the labourers' lack of energy' (Marx 1954c: 245); 'The lack of energy with which the labour is performed will correspond to the low level of the minimum wage' (Marx 1963, volume III: 301).

Interestingly Marx's notions of labour power and its connections with food Calorie and energy requirements in agriculture could be found, most unexpectedly, in Blaxter (1974: 401):

> The purpose of farming is to provide food for people of these islands. On average, each one of our population needs 2.5 Mcal of food each day. The energy required by Britain's population of 55.4 millions in 365 days can be calculated and this—with apologies to Karl Marx—is the power of the people—the energy they require as food each year.

made more complex by the physiological dimensions of the labourer, namely gender and age. Therefore, consideration of the energetics of human labour demands addressing labour power, wear and tear, physiological attributes of labourer, nature of work, and food energy, besides reproduction of the labour power itself. The associated conceptual framework, discussed below, was initiated in the late eighteenth and nineteenth century through research involving a number of disciplines: physiology, physics, anthropology, sociology, ecology and economics. We will begin with the attempt by Serhii Podolinsky to reconcile Marx's labour theory of value with the laws of thermodynamics (Burkett and Foster 2006: 109). In particular, it was to provide an energetic version of the accumulation of surplus labour. Conceptually speaking, he was a pioneer, but a methodological error in his approach lay in the fact that while matters related to humans are not independent of energy issues, they cannot be reduced to pure energetics either.

2.3.1. The 'Podolinsky business'

Serhii Podolinsky[37] had expressed his question as follows in the 'Socialism and the Unity of Physical Forces', 'a product of the revolution in the scientific understanding of energy in the early 19th century' (Foster and Burkett 2004: 36):

> In accepting the theory of the unity of physical forces or of the constancy of energy, we are also forced to admit that nothing can be *created* in the strict sense of the word, through labor and that consequently, all the usefulness of labor, the goal for which it strives, can be nothing other than a transposition of a certain quantity of forces. What is the manner in which these transpositions are produced? What are the best ways to apply human labor to nature in order to render a greater fraction of its forces profitable for the satisfaction of human needs? [...].
>
> According to the theory of production formulated by Marx and accepted by socialists, human labour, expressed in the language of physics, accumulates in its products a greater quantity of energy than that which was expended in the production of labour power of the workers. Why and how is this accumulation brought about? (Podolinsky 1881/2004: 61; emphasis as in original).

Noting the increase in entropy of the energy sources, following the then newly discovered second law of thermodynamics by Rudolph J E Clausius, and also that 'the distribution of these forces is not always the most advantageous for the living world's needs in general and for the existence of the human race in particular', he reformulated the question to find the means to 'produce certain modifications in

[37] The title of this sub-section has been borrowed from Engels (1968a); it was also used by Foster and Burkett (2004).

this distribution of solar energy, in such as way as to render a greater portion profitable to humans' (Podolinsky 1881/2004: 62). However, as most of the 'physical forces' on earth-though abundant-do not exist in a form that is conducive to achieving such a goal, or the 'nutritive, combustible and mechanical forces for work, the most profitable forms', his 'scheme' involved two elements:

> [...] first, the more or less free chemical affinity, represented in the form of nutritive substances of animal or vegetative origin, or in the form of combustible material; second, effective and available mechanical movement that can serve as an engine for the machines that work to the benefit or human beings (Podolinsky 1881/2004: 62–63).

Further, given that 'the energy radiated from the sun is more or less the only source of all the forces profitable to humankind', and that only a portion can be 'captured by the earth's surface *without rising its temperature*', certainly, 'by certain acts of will', humans could increase the quantity of solar energy accumulated on the earth and 'diminish the dispersed energy'.

> In cultivating vegetables in places where there were not any, or even where they existed in small quantities; by draining marshes, irrigating dry counties, and introducing a perfected system or cultivation; in applying machines to agriculture, and protecting cultivated plants and vegetables against their natural enemies; man can reach the first goal. In driving away and exterminating animals that are harmful to the richness of the vegetation, he works to reach the second goal. (Podolinsky 1881/2004: 64)[38]

The key lay, in the 'useful work': 'every expenditure of muscular work of humans or of animals that has as a result an increase in the solar power accumulated on the earth' (Podolinsky 1881/2004: 64, 66; deemphasised): 'We believe we are right then in affirming that scientific agriculture is the best example of useful work, that is, of work that increases the quantity of solar energy on the earth's surface'. (Podolinsky 1881/2004: 67)

Among the many forms of 'work', it was argued that, the only way 'to increase the quantity of energy on earth, [...] is to make the muscular labor of the workers more productive with the help of machines and of perfected processes, etc.' (Podolinsky 1881/2004: 67). In this context, he had introduced an 'economic coefficient' for the 'human machine' or the ratio of quantity of muscular work supplied by muscles and the amount of 'work [...] for the satisfaction of our needs' (Podolinsky 1881/2004: 67).

[38] Elsewhere he had written: 'It would be impossible indeed to establish mathematically the usefulness or harmfulness of different animals, by which we should mean their usefulness for the welfare of the human race' (Podolinsky 1881/2004: 66).

Based on his calculations of French, Spanish and Swedish agriculture between the second and the seventh decade of the nineteenth century, he had concluded that 'useful work can accumulate energy in greater proportion than the population increase', with the qualification on the production of luxury objects in 'developed capitalist' systems that leads to the 'gratuitous dispersion of energy rather than to its accumulation' (Podolinsky 1881/2004: 68–69).

The coefficient, arguably, was variable: for the savage, whose needs were almost limited to the nourishment, for which there was hardly any useful work, the coefficient was higher. On the other hand, for the civilised man 'the work produced by the muscular system [...] satisfies a greater quantity of needs and satisfies them on average much better'.

> What is the cause of this apparent contradiction? Since the economic coefficient of primitive man is greater, it is necessary to consider his body as a better organized machine than the body of civilized man; still, the latter produces more with his work. To find the solution to this problem it is necessary to return to the noted considerations of Sadi Carnot on *thermal machines,* that is, machines that transform heat or other forces into mechanical motion. Man is also a thermal machine.
>
> According to Sadi Carnot, in order to be able to judge the degree of perfection of a thermal machine, one needs to know not only its economic coefficient , *but also its capacity to recycle the heal spent at work.* A machine having the capacity to reheat itself, making the heat spent at work rise toward its fire-box, would be a *perfect machine,* and only such a machine could provide a true conception of the transformation of heat and *vice-versa.*
>
> But, observing the work of humans, we see in front of us just exactly what Sadi Carnot calls a *perfect machine* (Podolinsky 1881/2004: 68–69).

Conceptually, Podolinsky was a pioneer, as far as the 'economic coefficient' is concerned. All the controversy arose due to his second assumption of the perfect machine: 'His real discovery is that human labour has the power of detaining solar energy on the earth's surface and permitting its activity longer than would be the case without it', while '[a]ll the economic conclusions he draws from this are wrong' (Engels 1968a).

Certainly, the assumption was contrary to the complex reality where human labour function in an away-from-equilibrium, non-isolated, non-closed system.

'Human economy' indeed is a dissipative system[39] constantly drawing upon energy and matter from the other sub-systems as well as using them as sinks for wastes.[40] This assumption made Podolinsky ignore the friction as well as 'inherently biochemical or metabolic nature of the human labouring organism and its interaction with the natural environment' (Burkett and Foster 2006: 114–5). Indeed, long ago, Liebig (1865) too had been critical of the concept of a perfect machine, particularly from the point of view of heat losses due to friction: 'For if a power could be annihilated, or, in other words have nothing as its effect, then there would be no contradiction involved in the belief, that out of *nothing* also power could be created' (1865: 388; emphasis as in the original).

Reading from *Plebe* in Italian, Engels had asked the most fundamental question: 'how can a given quantity of energy in a given quantity of food leave behind it a greater quantity of energy than itself?' (Engels 1968a). His answer was in line with the then newly discovered law of conservation of forces.

> [...] Assume that the amount of food daily necessary for one person represents an amount of energy expressed as 10,000 H.U. (heat units). These 10,000 H.U. remain forever = 10,000 H.U. and in practice, as is well known, lose in the course of their transformation into other forms of energy, through friction, etc., a part of their availability. In the human body this is even considerable. The *physical* work performed in economic labour can never therefore = 10,000 H.U. but is always less (Engels 1968a; emphasis as in the original).

However, for Engels, the physical labour was different from and always lesser than the economic labour. Out of the 10,000 HU, a portion will be lost due to heat and radiation and certainly cannot lead to '*reproduction* of the same 10,000 H.U., wholly or partially, in this or that form', he had argued. On the other hand, by employing the 10,000 HU, economic labour of man may result in the fixation of '*new* H.U. radiated to him from the sun, which have only this labour connection with the first 10,000 H.U.'. Further, such new HU could very well be 5,000, 10,000, 20,000 or 1,000,000 HU, depending 'solely on the degree of development attained by the means of production' (1968a: emphasis as in the original). These comments were however not on the 'usefulness' of the labour in agriculture, or the productive work, that Podolinsky had argued for.

39 A thermodynamically open system which is operating far from thermodynamic equilibrium in an environment with which it exchanges energy and matter.

40 As a result, the economic system, in the ecological sense, never returns to the starting condition.

While initially, Engels had been apprehensive on the suitability of the concept in the non-primitive agriculture or in industry,[41] but in 'the most primitive branches of production: hunting, fishing, cattle-raising, agriculture' (see, Engels 1968a), three days later, he had clarified:

> [...] To return once more to Podolinsky [...] that storage of energy through work really only takes place in *agriculture;* in cattle raising the energy accumulated in the plants is simply transferred as a whole to the animals, and one can only speak of storage of energy in the sense that without cattle-raising, nutritious plants wither uselessly, whereas with it they are utilised. In all branches of industry, on the other hand, energy is only *expended* (Engels 1968b; emphasis as in the original).

For Engels, the error in the 'energy reductionist' framework of Podolinsky lay in considering the role of man as a worker only in merely fixing the present solar heat and ignoring the squandering of past solar heat in the form of coal, ore, forests, petroleum etc., which is much larger (Engels 1968a).[42] For example, consideration of only the energy that is absorbed by the labour from the radiation of the sun, or the 'fresh cal', will ignore the complexity of accounting for the full effects of solar energy. It is a different matter that it is impossible to do so.[43] His overall conclusion was rather subtle: '[he] has strayed away from his very valuable discovery into mistaken paths because he was trying to find in natural science a new proof of the truth of socialism, and has therefore confused physics and economics' (Engels 1968a).

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[41] In contrast to cattle-raising, calculation was more complicated 'in agriculture, where the energy value of the auxiliary materials, manures, etc., also enters into the calculation. [...] The energy value of a hammer, a screw or a needle calculated according to the cost of production is an impossible quantity. In my opinion it is absolutely impossible to try and express economic relations in physical magnitudes' (Engels 1968a).

[42] In this connection, Martinez-alier (1987: 223) commented, 'Engels understood the principles of agricultural energetics though not of industrial energetics, and also [...] the differences between spending the energy stock in coal and using the flow of solar energy, and that he was far in advance of many later economists, sociologists and historians in his knowledge and interest in science'.

[43]

> Even in its own terms of calculating the "solar energy necessary directly and indirectly to produce" all commodities, the actual accounting of embodied energy is very incomplete. It counts only solar energy entering into agriculture, forests, and fisheries. But solar energy obviously enters all production processes by providing light and heat. [...] How this enormous joint cost could be allocated among all its joint products [...] is beyond my imagination [Herman Daly, 1981, 'Postscript: Unresolved Problems and Issues for Further Research' in H E Daly and A F Umaña, eds., *Energy, Economics and the Environment*, AAAS Selected Symposia Series, Westview Press, Boulder, p. 169) cited in Burkett and Foster (2006: 118)].

As we had seen earlier, solar energy is not accounted for in an EA.

Podolinsky's other error lay in not considering the energy values of materials used, including manure, guano or even coal, which was recognised later.[44] Dasgupta and Mäler (1995: 2391) committed similar methodological error as well in the computation of carrying capacity of land in terms of how much land a family may need under specific agro-climatic and technological conditions.[45]

Notwithstanding the methodological error in 'the perfect machine', Podolinsky's basic conclusion remains valid and relevant for this thesis.

> [The] primitive man, with his coefficient of almost 1/6, is less perfect as a machine than civilized man with his coefficient of only 1/10. It is that primitive man profits only from the free gifts of nature, while the civilized man satisfies almost all of his needs with the help of his work and produces in this way an accumulation of solar energy on earth, whose quantity surpasses ten times the force of his muscles.
>
> [...]
>
> *As long as muscular labor supplied by the human machine is converted into an accumulation of energy necessary for the satisfaction of human needs, which represents a quantity in excess of the sum of the muscular work of the human machine, by us many times as the denominator of the economic coefficient exceeds the numerator;-the existence and the possibility of the labor of the human machine are guaranteed.*
>
> Every time that the productivity of human labor falls below the inverse coefficient of the human machine, there will be misery and perhaps a decrease in the population. Every time, instead, that the usefulness of labor surpasses this number, there will be an increase in well-being and probably an increase in the population (Podolinsky 1881/2004: 70; emphasis as in original).

His conclusion on the forms of production that could '*produce the greatest accumulation of solar energy on the earth*' (Podolinsky 1881/2004: 70) is worth noting. The primitive accumulation was found to be 'not yet cultivation' but 'based [...] only on the utilization of forces previously accumulated from the vital processes of nature'. Similarly, under slavery, it was found that a considerable proportion of workers are excluded from all the participation in the labour which

[44] See, Martinez-alier (1987: 49) and Foster and Burkett (2004: 40).

[45] The assumptions included dryalnd rice cultivation in a tropical subsistence economy using conventional techniques. Per hectare per working day input was assumed as 3 MJ, along with 130 person-days of labour time per hectare per year. Total annual energy input of 390 MJ resulted in a rice output of 1000 kg of rice per hectare or 15 GJ, or a net energy of 14.61 GJ. Assuming further that a family of 5 members required 5 persons x 2200 kcal per day x 365 days = 16.798 GJ) of food energy per year, it meant a requirement of 1.15 hectares of land to maintain an 'energy balance'. Incidentally, 2200 Calorie equals 9.2 MJ, and therefore it is unlikely that any input other than labour was taken into account in the calculation. Indeed this explained a supposed EROI of 15 GJ/0.39 MJ per hectare or 38.5:1, which is an impossibility. Further, the supposed 'energy balance' of the area of land for the family meant that the correct EROI was 1, and nothing more.

accumulates energy on the earth. In contrast, feudalism, though represented several elements of progress, productivity of labour was much lower than even what could be achieved at the end of the nineteenth century:

> The small plots of the serf are but parcels in comparison to the fields of the seigneur, which extend as far as the eye can see, and the time allowed for free work is but a brief recreation after the hard days labor done for the lord. (Podolinsky 1881/2004: 71–72)

On the other hand, the 'unhoped for results' that Capitalism could obtain was nothing but the result from the '*accumulation of the labor of generations of workers in the past, or of the present day workers' associations (cooperatives)*'. It 'does nothing more than throw, in times of crisis generated by it, thousands of workers onto the street' and in the process 'disperses a portion of the energy at the disposal of humanity, instead of increasing its accumulation on the earth's surface'. No new accumulation of energy on earth will be possible by it, 'without the indispensable co-operation of the expenditure of a certain amount of presently existing muscular labor'.

> It goes without saying that labor and production in common, through the association of the work forces, are more advantageous, regarding the accumulation of energy, than is individual work. Apart from the fact that the egalitarian association of the workers is the best means to profit in a reasonable manner from all the advantages of the division of labor, avoiding its deadly influence on the health of the workers and on their intellectual development, it is also the only system through which the machines become real organs for social organisms, instead of being, as occurs frequently under capitalism, destructive weapons in the hands of the privileged few that direct them against the proletarian majority. [...] Under the socialist system, by contrast [to the capitalist system], every mechanical or other improvements will have as an immediate consequence a decrease in the number of hours of work of all the workers and it will furnish them with time for new production, or indeed for education, for art, etc. (Podolinsky 1881/2004)

We may notice the focus on the number of hours of labour, as the sustainability question that we are addressing has a rather heavy bearing on it. Leaving aside the methodological problems, but following the concepts of Podolinsky, we may restate the question: under what circumstances the 'economic coefficient' is more than 1? Alternatively, how can we increase it and further, achieve the maximum value? What shall be the form of such production that can engage labour in productive work, at the same point of time achieve the benefits of division of labour?

2.3.2. Metabolic relation between Human and Nature

For Marx, the labour process itself constituted the main metabolic relation between the humans and nature; indeed, without labour, no material exchange can take place between them, which is essential for life to exist.[46] While the various exchanges of matter take place, in the process of being reshaped, stored, etc., an exchange of energy also takes place simultaneously. Indeed, human labour was argued to be a necessary and universal condition for the material exchanges between man and nature.[47] Natural forces are constantly helping human labour, engaged in production, but the outcome of the man-nature interaction is the production of use-values. A labourer can only change the form of the materials, and even in this process, natural forces are constantly helping the labour, Marx argued.[48]

2.3.2.1. *Labour, Labour-power, its Value and Energy from Nourishment*

Labour power represents the capacity for labour, a property of its owner, the labourer.[49] It exists only as a power of the living individual. For a given individual, its production necessitates her reproduction of herself or her

[46] 'Labour is, in the first place, a process in which both man and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature' (Marx 1954a: 173).

'So far therefore as labour is a creator of use value, is useful labour, it is a necessary condition, independent of all forms of society, for the existence of the human race; it is an eternal nature-imposed necessity, without which there can be no material exchanges between man and Nature, and therefore no life' (Marx 1954a: 50)

[47] The labour-process, [...] is human action with a view to the production of use-values, appropriation of natural substances to human requirements; it is the necessary condition for effecting exchange of matter between man and Nature; it is the everlasting Nature-imposed condition of human existence, and therefore is independent of every social phase of that existence, or rather, is common to every such phase (Marx 1954a: 173).

[48] The use values, coat, linen, &c., *i.e.*, the bodies of commodities, are combinations of two elements – matter and labour. If we take away the useful labour expended upon them, a material substratum is always left, which is furnished by Nature without the help of man. The latter can work only as Nature does, that is by changing the form of matter. Nay more, in this work of changing the form he is constantly helped by natural forces. We see, then, that labour is not the only source of material wealth, of use values produced by labour. As William Petty puts it, labour is its father and the earth its mother (Marx 1954a: 50).

[49] 'By labour power or capacity for labour is to be understood the aggregate of those mental and physical capabilities existing in a human being, which he exercises whenever he produces a use-value of any description' (Marx 1954a: 164).

'Labour-power exists only as a capacity, or power of the living individual. [...] Given the individual, the production of labour-power consists in his reproduction of himself or his maintenance' (Marx 1954a: 167).

'Man himself, viewed as the impersonation of labour-power, is a natural object, a thing, although a living conscious thing, and labour is the manifestation of this power residing in him' (Marx 1954a: 196).

maintenance, through means of subsistence, consisting of nourishing matter.[50] In this connection, Marx (1954a: 167; 1865) had cited *Leviathan*: 'The value or worth of a man, is as of all other things his price—that is to say, so much as would be given for the use of his power'; value of the labour as that of all other commodities, in his later works, had followed from this.[51]

For Marx, the quantity of labour necessary for the production of labour power determined its value. At the same time, '*value of labouring power* is determined by the *value of the necessaries* required to produce, develop, maintain, and perpetuate the labouring power' (1865: emphasis as in the original). Each of the elements requires separate consideration.

The maintenance necessitates the restoration of 'definite quantity of human muscle, nerve. brain, &c., [which] is wasted' during the work;[52] without such exercise, however, labour-power cannot become a reality, by definition (Marx 1954a: 167).[53] Such 'wear and tear' of the body, is beyond what happens in a machine. While physiologically, it is possible to consider human body as a thermodynamical machine, where heat is supplied and converted into motion, such an understanding is incomplete. Internal 'work' in the form of chemical changes are being performed every moment, intensity of which depends on the process of respiration and function of heat, irrespective of any physical 'work' (Engels 1883).[54] At the same time, the intensity of exercise of labour-power

[50] 'What Lucretius says is self-evident; '*nil posse creari de nihilo*', out of nothing, nothing can be created. Creation of value is transformation of labour-power into labour. *Labour power itself is energy transferred to a human organism by means of nourishing matter*' (Fn 1, Marx 1954a: 207; emphasis added).

[51] Thomas Hobbes, *Leviathan*, in Molesworth, ed., *Works*, 1839–44, London, volume III, p. 76.

[52] 'If the owner of labour-power works to-day, to-morrow he must again be able to repeat the same process in the same conditions as regards health and strength. His means of subsistence must therefore be sufficient to maintain him in his normal state as a labouring individual' (Marx 1954a: 168)

[53] 'By working, the latter [seller of labour-power] becomes actually, what before he only was potentially, labour-power in action, a labourer' (Marx 1954a: 173).

[54] In the context of physiological and thermodynamical notions of 'work', he had stated: 'In some places there even appears to be not a little desire to re-import the thermodynamical category of work back into economics (as with the Darwinists and the struggle for existence), the result of which would be nothing but nonsense. Let someone try to convert any skilled labour into kilogram-metres and then to determine wages on this basis!' (Engels 1883).

directly influences the 'wear and tear', necessitating additional maintenance and hence 'a larger income'.[55]

Given that 'wear and tear and death' results in the withdrawal of labour-power from the market at which it was brought, its replacement was required 'at the very least, and equal amount of fresh labour-power', on a continuous basis (Marx 1954a: 168). Thus, 'another amount of necessaries to bring up a certain quota of children that are to replace him on the labour market and to perpetuate the race of labourers', in addition to the one for maintenance (Marx 1865).

Finally, for developing one's labour-power, at times, some additional values are required to be spent, towards acquiring skills or training or special education. At the same time, in case of ordinary labour-power, this amount was found to be excessively small (Marx 1865; 1954a: 168–9).

Consideration of all the components provides us the value of labour-power in terms of the value of a definite quantity of the means of subsistence (Marx 1954a: 167). Notwithstanding the variations in the climatic and other physical conditions of the country of the labourer, and modes of satisfaction of 'natural' and 'necessary' wants, 'in a given country, at a given period, the average quantity of the means of subsistence necessary for the labourer is practically known' (Marx 1954a: 168).

> [...] The minimum limit of the value of labour-power is determined by the value of the commodities, without the daily supply of which the labourer cannot renew his vital energy, consequently by the value of those means of subsistence that are physically indispensable (Marx 1954a: 169).

2.3.3. Energy Income and Energy Expenditure

The value of the labouring power, determined by the (value of the) means of subsistence, is more than the amount of power exercised by the labourer and there are no definite mathematical relations between the two.[56] However, the

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[55] In this connection towards establishing the relation between increased expenditure and a larger income, in the footnote Marx mentioned that '[h]ence the Roman Villicus, as overlooker of the agricultural slaves, received 'more meagre fare than working slaves, because his work was lighter' (Marx 1954a: 168)

[56] The *value* of the labouring power is determined by the quantity of labour necessary to maintain or reproduce it, but the *use* of that labouring power is only limited by the active energies and physical strength of the labourer. The daily or weekly *value* of the labouring power is quite distinct from the daily or weekly exercise of that power, the same as the food a horse wants and the time it can carry the horseman are quite

value of the labour power, or the 'en[redacted] income' is connected with the power exercised, or the 'energy expenditu[redacted]following the work of German energy physiologist Ludimer Hermann, whic[redacted]parently was observed also by Marx and Engels (Burkett and Foster 2006: 121).

Elements of Human Physiology (1875) was based on the two biochemical processes within the body, namely, consumption of energy sources convertible into work (energy income) and labour's loss of energy when work is performed (energy expenditure). They were found to be connected with the nutritional and other metabolic functions. This relation could determine whether a given labour situation was at par or consistent with the healthy reproduction of the labourer. It was shown that the types and intensity of different kind of work required correspondingly different biochemical forms of energy income and that it also depended on the rest that the labourer had taken from the prior labour (Burkett and Foster 2006: 121).

2.3.3.1. *Food, Oxidation, Potential and Kinetic Energy*

Oxygen is one of the two constituent elements of 'energy income' of the body, food being the other, representing the nutritious substances. The latter includes inorganic elements like water and salt and organic elements designed to replace the oxidisable portions which are lost due to energy expenditure (Hermann 1875: 190–191). The purpose of

> [...] the ingestion of food was to repair the losses which the body sustained through the excretion of its inorganic, and the oxidation of its organic, constituents. The simplest relationship which can exist between the food taken and the body is, therefore, when the former is just sufficient to cover the expenditure of the latter, and so to maintain it at its *usual standard of weight* (Hermann 1875: 199; emphasis added).[57]

This connection between the physiological minimum for taking care of the losses sustained to the body due to the energy expenditure and a particular weight is important for the measurements of recommended daily allowance in food Calorie.

distinct. The quantity of labour by which the *value* of the workman's labouring power is limited forms by no means a limit to the quantity of labour which his labouring power is apt to perform (Marx 1865: emphasis as in the original).

[57] See, Hermann (1875: 200–201) for a discussion on connecting weight and sufficiency and insufficiency of food intake in maintaining it. For various impacts of insufficient and superabundant food on human body see, Hermann (1875: 202–214).

The body receives energy in its potential form, to be converted mainly through oxidation, into the kinetic form, that constantly transfers from its source body to the bodies existing in the medium outside and independent of it (Hermann 1875: 217). Two kinds of matter namely, atmospheric oxygen and oxidisable constituents are involved here that enter the body as food. Like energy, for matter too, expenditure is below its income, though for a different reason. In this case, the 'extra' is necessary for the existence and persistence of the body while difference in the case of energy serves the purpose of storing the energy, part of which is heat and the remaining is the yet to be unoxidised constituents (Hermann 1875: 215). The three forms of kinetic energy in which potential energy of the body manifests, namely, heat, electricity and mechanical work, can however be converted into a singular form. The converted amount could then be compared with the energy income, and one of components of the energy income, namely food, may aid us in exploring the quantum of minimum amount of nourishments for the reproduction of labour power.

2.3.3.2. *Heat as a Common Denominator for Energy Expenditure*

When the body is in a state of rest, all forms of energy are converted into heat, and it is transferred to the external world in this form only (Hermann 1875: 219). Indeed, here no action is exerted upon the mediums outside it, and the movements disappear within the body itself, in the form of friction and it results in nothing but heat. In particular, 'everywhere, a quantity of heat is generated which is equivalent to the motion, i.e. mechanical work, which disappears' (Hermann 1875: 219). Moreover, even the small quantities of electricity developed in the nervous and muscular systems also are converted into heat (Hermann 1875: 219).

In contrast, when the body is at work, an increased quantity of kinetic energy is developed within the muscles, and takes the form of mechanical work and additional heat (Hermann 1875: 219). While part of the mechanical work gets converted within the organism itself into heat 'by friction of the muscles and tendons within their sheaths' and 'by the movement of bones in their articulations', the remaining mechanical work results in the 'movement of various parts of the body in reference to one another', for 'moving the body as a whole through the medium which it inhabits' and for moving the bodies that exist in that medium (Hermann 1875: 219–220). Keeping all the transformations in mind, it was argued that 'the natural measure of the whole of the energies of the body is the amount of heat corresponding to them' which could well be expressed according to its mechanical equivalent, i.e. in the units of work instead of heat (Hermann 1875: 220).

Such measurement of expenditure of energy is done either by placing the subject under observation into a calorimetrical chamber adapted to the purpose, when at rest, or by placing it in a chamber with suitable instruments when at work. 'From the quantity of mechanical work thus estimated the equivalent number of units of heat may be calculated and added to the expenditure of heat as found by the direct method' (Hermann 1875: 221).

2.3.3.3. *Measurement of Energy Income*

The amount of energy income can be determined from (1) the amount of organic constituents of the food and (2) the heat which they develop on combustion. However, there are only a few of the alimentary substances for which the heat of combustion could be accurately determined. Thus, 'kinetic energy corresponding in a given time to the potential energy at the disposal of the body' are measured, followed by its comparison with the actual amount of energy given out (Hermann 1875: 221).

Given that the consumption of oxygen in a body equals the one received by it over a long period of time, and that 'every manifestation of energy is necessarily associated with a corresponding consumption of oxygen', it becomes possible to 'calculate the amount of energy which becomes kinetic' (Hermann 1875: 221). All the methodological problems, if any, in this method, could be resolved with appropriate assumptions, asserted Hermann (1875: 221–2).

Again, the amount of the necessary oxidation process for the 'minimum expenditure of its matter' by the body could be measured, to ensure the existence of the organism. 'The minimum exchange of matter is, [....] so to speak, conditioned by the minimum exchanges of energy required' while '[a]n increase in the activity of one of these processes [like oxidation] must necessarily lead to an increase in the other' (Hermann 1875: 223). Thus, it follows that the increased energy expenditure necessitates increased consumption of food.

What Hermann did through physiology, Grove (1874) had arrived at the same conclusion through chemistry. '[T]he amount of labour which a man has undergone in the course of twenty-four hours may be approximately arrived at by an examination of the chemical changes which have taken place in his body; changed form of matter indicating the anterior exercise of dynamical force' (Grove 1874: 203).[58] So was Leibig (1865: 391): 'When [...], a certain quantity of work is performed by heat, there disappears, with the mechanical effect obtained, a certain amount of heat [...] This quantity of heat become then the equivalent or value of the working power expressed [...]'.[59]

2.3.4. Labour-power, Intensity of Labour, Productivity and Food

To recollect, it might be possible to know the value of magnitudes of necessaries of life, at a given time and in a given society, for the average labourer that determines the labour-power. At the same time, the value of the quantity can be variable due to two reasons: variable expenses depending on the mode of production and the natural diversity, namely, the 'difference between the labour-power of men and women, of children and adults' (Marx 1954a: 486).

Certainly, '[t]he employment of these different sorts of labour-power, an employment which is, in its turn, made necessary by the mode of production, makes a great difference in the cost of maintaining the family of the labourer, and in the value of the labour-power of the adult male' (Marx 1954a: 486). Admittedly, the discussion on the changes in the magnitude of the price of labour-power, did not include these two factors (Marx 1954a: 486–496), but was based on the average adult male labourer.

58 Marx quoted latter portion of the last sentence in case III of Chapter XVII: Changes of Magnitude in the Price of Labour-power and in Surplus Value' (1954a: 493).

59 To sum up, following Anneliese Griese and Gerd Pawelzig (1997, 'Why Did Marx and Engels Concern Themselves with Natural Science?', *Nature, Society, and Thought*, 8(2), pp. 125–37: 132–33, as cited in Burektt and Foster 2006: 27):

> [...] [t]he exchange of matter by living systems, according to the physiologists' definition, remains for Marx what it is, neither watered down nor 'generalized', as is often done. Exchange of matter is taking up, reshaping, storing, and giving up of matter with an exchange of energy taking place simultaneously. This same content applies—and here lies the discovery of Marx—not only to living but also to social systems, insofar as social life is also actually life in the physiological sense, arising out of social life and developing further its material basis.

With this caveat, Marx had argued that given the assumption of (1) commodities being sold at their value, and (2) the price of labour-power is no less than its value, the relative magnitudes of surplus-value and of price of labour-power could be determined with the consideration of three elements:

> [...]
>
> — (1) the length of the working-day, or the extensive magnitude of labour;
>
> — (2) the normal intensity of labour, its intensive magnitude, whereby a given quantity of labour is expended in a given time; and
>
> — (3) the productiveness of labour, whereby the same quantum of labour yields, in a given time, a greater or less quantum of product, dependent on the degree of development in the conditions of production (Marx 1954a: 486–7).[60]

With constant working day or the magnitude of labour and productiveness, increase intensity of labour results in its embodiment in more products. While this increases the surplus-value, it may not necessarily imply an increase in the price of labour-power. In other words, there could be possibilities where the requirement of increased maintenance may not have been addressed due to less nourishment than what was due to keep the labourer healthy, i.e., by keeping the body weight stable. Such a possibility represents a further source of exploitation, including the possibility of self-exploitation illustrated by the negative energy surplus.

This may also happen under lengthy working day even while the productiveness and labour intensities remain constant.

> Up to a certain point, the increased wear and tear of labour-power, inseparable from a lengthened working-day, may be compensated by higher wages. But beyond this point the wear and tear increases in geometrical progression, and every condition suitable for the normal reproduction and functioning of labour-power is suppressed. The price of labour-power and the degree of its exploitation cease to be commensurable quantities (Marx 1954a: 493).

60 [P]roductiveness is determined by various circumstances, amongst others, by the average amount of skill of the workmen, the state of science, and the degree of its practical application, the social organisation of production, the extent and capabilities of the means of production, and by physical conditions. For example, the same amount of labour in favourable seasons is embodied in 8 bushels of corn, and in unfavourable, only in four. The same labour extracts from rich mines more metal than from poor mines (Marx 1954a: 47).

2.3.5. Taxonomies of Measurement

Wirths (1957) was among one of the first to compute the human labour costs through the human energy route.[61] Notwithstanding measurement difficulties,[62] human energy consumption per hectare was stated to be 3,600 Calories in ploughing with an 1-furrow horse-drawn plough, 1,100 Calories with an 1-furrow tractor-drawn plough, 1,100 Calories for strewing fertiliser and 130 Calories with a tractor-drawn stewing machine. Mondot-Bernard (1981) had carried a survey of workers of rural Mali, in 1977–78, for measuring their energy expenditure through direct and indirect observations.[63] Calorie requirements were calculated based on the weight, type of activities, gender and location and found to be varying in each respect though with different intensity.[64] Certainly, the Calorie 'norm' for any population reflects these differences.

On the question of intensity of work and gender, Giampietro and Pimentel (1990, 1992) had provided some explanations and illustrations using the level of applied power. The observation of uniform 'performance' of men and women in clearing the bush in the oft-cited study by Rappaport (1971) was based on the energy requirements per unit of surface area.[65] However, such an energy balance ignored the time dimension. For comparing the work 'performance', specification of power level was necessary and variations can be observed in terms of the energy expenditure per minute or the level of power delivery (Giampietro and Pimentel 1992: 261–262). In the activities that require high power level, men with a larger body size were bound to have an advantage. On the other hand, in repetitive work with low level of required power, women with a smaller body size and a slower metabolism, and thus less energy expenditure in terms of the work done per

[61] It had found about 1500 Calories/day as the requirement for the body at rest of an average grown man. Inclusion of energy required to digest the food, that varies between 5–10 per cent of the total number of Calories consumed, was stated to increase this number, along with 'performance' of labour. Estimates were made for light labour (up to 75 Calories/hour), medium heavy labour (75–150 Calories/hour), heavy labour (150–300 Calories/hour), and very heavy labour (more than 300 Calories/hour).
[62] Intensity of work was found to be varied across seasons and even during the day in the small farms, as a labourer had to handle all kinds of operations, with varying intensity, making the calculations difficult.
[63] Interviewer with a minute recorder and following the person through every activity for seven days and through half-day interviews based on questionnaire, respectively
[64] Energy expenditures for rural agricultural female labourer were found to be varying less across dry and wet seasons, but it was significantly different from the urban women, as the latter worked for less number of hours per day. In contrast, energy expenditure across seasons for men engaged in agricultural activities was rather large.
[65] R A Rappaport, 1971, 'The Sacred in Human Evolution', *Annual Review of Ecology and Systematics*, 2, pp. 23 –44 cited in Giampietro and Pimentel (1990, 1992).

energy input, will be in the advantageous position on the other hand (Giampietro and Pimentel 1992: 28; also see, Thomas 1897).[66]

Indeed, such 'gendered' differences in the power delivery had put men in the activities with high power requirements like tilling the soil in agricultural societies faced with energy constraints, while women had to be engaged with the time-demanding activities like weeding, picking, collection of wood, cooking and collection of water, but that required low power at the same time. There is no doubt that this 'energy saving' had intensified the traditional gender roles in the society, where men's work became valuable in energetic terms despite its shorter time duration.

There exist three approaches in the measurement of human energy expenditure: nutritional, physiological and ergonomic (Loake 2001). A nutritional model like that of WHO/FAO/ICMR calculates 'energy and protein requirements' with an assumption of unsustainable variations in weight.

> [...] The energy allowances recommended are designed to provide enough to promote satisfactory growth in infants and children and to maintain constant body weight and good health in adults. [...] In the case of energy, the input must equal to the output in order to be in *energy balance which corresponds to a steady state*. The logical extension of this concept is that if body weight and the level of physical activity of an individual are known or defined (and additional factors such as growth rate and special physiological needs of the individual mainly those associated with pregnancy and lactation are taken care of) then energy balance can be achieved at only one level of intake (ICMR 1990: 11; emphasis added).

Such a framework had assumed that a balance between the energy consumption and expenditure was a prerequisite to the bodily well-being. Accordingly, the energy requirement was customised in terms of weight for height in adults and height in proportion to age in children. Measurements were carried out with the help of BMR (basal metabolic rate), PAR (physical activity ratio) and PAL

66 Man's katabolism predisposed him to activity and violence; woman's anabolism predisposed her to a stationary life. The first division of labor was, therefore, an expression of the characteristic contrast of the sexes. War and the chase were suitable to man, because his somatic development fitted him for bursts of energy, and agriculture and the primitive industries were the natural occupation of woman. This allotment of tasks was not made by the tyranny of man, but exists almost uniformly in primitive communities because it utilizes most advantageously the energies of both sexes. The struggle is so fierce and constant that the primitive community which should let any energy go to waste would not long survive. (Thomas 1897: 62)

(physical activity level).[67] This method is arguably advantageous for estimating the nutritional requirements of populations and Calories needed by individuals and populations. However, it does not take into account the physical work capacity of the individuals (Loake 2001: 279), which is important for the sustainability of the labour-power.

Physiological model on the other hand addressed this shortcoming, by taking into account the maximum level of oxygen of VO2 Max by an individual, as a measure for her work capacity.[68] Finally, the Ergonomic model deals with the well being outcomes like musco-skeletal disorder and fatigues. The reason is that, even working at 35% VO2 max, human labourers could put in heavier doses of labour-power in bursts. As stated earlier, this is more prevalent among the male labourers. With more bursts, risks of injury and fatigue increases (Loake 2001: 280–1). Similarly measurements of oxygen consumed or carbon dioxide exhaled were used for estimating the metabolic energy used in different work activities. This approach had been in use for a long time (see, Hermann 1875 and Podolinsky 1881/2004). Using this approach, East African women were found to be spending on average 240 Calorie each day just for obtaining water for the household by walking and carrying the jar on their heads (Revelle 1976).[69]

2.3.5.1. *Recommended Daily Allowances of Indian Population*

The dietary requirements of the Indian population have undergone several changes since the recommendation of the Nutrition Advisory Committee (NAC) of the Indian Council of Medical Research (ICMR) in 1944.[70] In 1958, ICMR had revised the requirements for Calories and protein only,[71] followed by the

[67] BMR or the energy requirement for body maintenance is multiplied by a number that depends on the level of physical activity, including sleep. Latter is obtained as a weighted average of PAR.

[68] VO2 max is estimated from O2 consumption at a specified percentage of maximum heart rate, rather than directly due to operational difficulties and cost considerations. Further, it may be noted that VO2 max can be sustained only for short periods of time due to slow energy conversion rate for human beings. It is estimated that over a full working day, just 35–40% of an individual's VO2 max can be sustained (Loake 2001: 279—280).

[69] R Passmore and J V G A Durnin, 1955, 'Human Energy Expenditure', *Physiological Review*, 35:(4), pp. 801–840 and G F White, D J Bradley and A U White, 1972, *Drawers of Water*, University of Chicago Press, Chicago, pp. 93–107, cited in Revelle (1976: 969).

[70] They were based on recommendations of the Health Committee of the League of Nations, the National Research Council of the USA, the National Research Council of Canada, Medical Research Council of United Kingdom and data collected by Indian workers (Gopalan and Narasinga Rao 1971: 1; Narasinga Rao 2010: 1).

[71] V N Patwardhan, 1960, 'Dietary allowances for Indians: Calories and proteins', Special Report Series No 35, ICMR, quoted in Gopalan and Narasinga Rao (1971: 1).

recommendations from Nutrition Expert Group of ICMR in 1968. Apart from the recommendations on dietary allowances of Calories, proteins, fat, calcium, iron, vitamin A, thiamine, riboflavin, niacin, ascorbic acid, Vitamin B_1, folic acid and Vitamin D for different age-sex categories of Indians (table 22, Gopalan and Narasinga Rao 1971: 84), it had suggested balanced diets against gender, activities, and age (tables 23–26, Gopalan and Narasinga Rao 1971: 87–90).

Gopalan, Shastri and Balasubramanian (1971/1989) had presented coefficients of Calorie consumption (in cu, or consumption units) for various types of activities-age-sex, in multiples of consumption of an average male during a sedentary work (Table 2 in Gopalan et *al.* 1971: 9). It had classified various activities into heavy, moderate and sedentary: agricultural labourer was categorized as moderate, landlord as sedentary and wood-cutter as heavy. Further, the report had pointed out the need for taking into consideration the body weight and the age along with the activity to find out the energy requirements for individuals, as their recommendations were applied for the large group.

A major review was conducted in 1988 by the ICMR, which had introduced recommended dietary allowances with respect to body weight apart from the age-sex-activity classification as before (ICMR 1990). Finally, ICMR Expert Group on 'nutrient requirement and safe dietary intake' for Indians had prepared a draft in 2009. Various recommended dietary allowance for Calorie over the years has been reproduced in table 2.3.1.

ICMR (1990: 17), following the methodology of nutritional model stated above, under moderate activity, had considered sleep (1.0), occupational activity (2.8) and non-occupational activity (2.0) in terms of BMR units, for an adult man of 60 kg (2879 Calories) and adult woman of 50 kg (2223 Calories). Under sedentary activity, the numbers were 1, 1.7 and 2.2 in BMR units respectively. Given the distribution during a 24 hour day across the three activities, namely, 8 hours each (table 4.3 in ICMR 1990: 18), average BMR for moderate activity was found to be 1.9 and for sedentary activities, it was 1.6.[72] From the Calorie values under sedentary activity, requirements for moderate activities were extrapolated for the

[72] While the distribution among activities/sleep remains the same, intensity of energy use changed for both occupational as well as non-occupational activities.

persons aged beyond 59 years, and children below 18 years to obtain the Calorie requirements, by activity, gender and age (see, table 2.3.2).

Table 2.3.1: Recommended dietary allowance for the Indian population (in Calorie)

Categories of population	Type of activity	ICMR (1958)	ICMR (1968)	ICMR (1971) *	ICMR (1990) **	ICMR (2009)
Man (55 kgs)	Sedentary	2400	2400	2425	2424 (2376)	2318
	Moderate	2800	2800	2875	2879 (2822)	2727
Woman (45 kgs)	Sedentary	2000	1900	1875	1872 (1920)	1899
	Moderate	2300	2200	2225	2223 (2280)	2234
Children	0 months–6 years	120/kg – 1500	120/kg –1500	108/kg–1690	116/kg–1752 (1630) ***	92/kg–1350
	6 years–12 years	1800–2100	1800–2100	1950–2190	2075–2194 (1833–1965) ***	1691–2198 (2008)
Adolescents	Girls	2100	2200	2060	2056–64	2328–2070
	Boys	2500–3150	2500–3000	2450–2640	2447–2642	2748–3017

Notes:
* Reference weight for man and woman were 60 and 50 kgs respectively, as in ICMR (1990).
**Refers to persons in the age group of 18–30 years. The numbers within the parenthesis refers to persons in the age group of 30–59 years.
*** Number within the parenthesis refers to girls.

ICAR-AICRP (1971–2002) had considered 1.96 MJ, 1.57 MJ and 0.98 MJ per hour as 'energy coefficients' for adult man, adult woman and children respectively (for example, De 2005: 350). With the assumption of 8 hours of 'on farm' work, this resulted in 3,745, 3,000, and 1,873 Calories respectively, which were certainly much more than even under the heaviest of activities like stone crushing.[73] This is highly unrealistic, given the fact that the agricultural labourers were considered to be engaged in moderate activities. However, with 6 hours of work as the length of a working day, the numbers were 2,809, 2,250 and 1,404 Calories respectively, which were close to the energy requirements for male and female labourers belonging to 30–59 age-group engaged in moderate activity as recommended by ICMR (1990: 23). Technically, the AICRP may be correct, in terms of accounting.

However, it ignores the fact that the human body spends energy not only during the hours of 'work' but also during other times as well, only at a different rate. Such 'atomistic' understanding is reflected in most, if not all, of the literature

73 ICMR had put them as 3485 Calorie and 2854 Calorie per day for adult man and woman respectively engaged in heavy work, even after considering the period of rest (See, Narasinga Rao 2010: 2). On the other hand, ICMR (1990: 17), deriving energy requirements from BMR factors, following recommendations by FAO/WHO/UNU expert consultation had put 3788 and 2925 Calories for adult man and woman under heavy activity.

from the natural science disciplines on energy accounting in agriculture in India. In this view, human labourers are considered as just another input like seed, irrigation etc. Treating the agricultural production as a technological relationship is hardly useful for any social purpose, especially when it is the livelihood and not just the activity of the majority of rural population in this country. Indeed, this difference has resulted in multiple scales of sustainability, adopted in this thesis.

Table 2.3.2: Recommended daily allowances against sex-age-activity (in Calories)—a trajectory

Age-group	Age/ age range	RDA^			
		Female		Male	
		Sedentary	Moderate	Sedentary	Moderate
Children	1+	1078	N.A.+	1096	N.A.+
Children	2+	1190	N.A.+	1301	N.A.+
Children	3+	1310	N.A.+	1463	N.A.+
Children	4+	1458	N.A.+	1531	N.A.+
Children	5+	1643	N.A.+	1778	N.A.+
Children	6+	1750	N.A.+	1948	N.A.+
Children	7+	1858	N.A.+	2030	N.A.+
Children	8+	1792	N.A.+	2034	N.A.+
Children	9+	1848	N.A.+	2160	N.A.+
Children	10+	1907	N.A.+	2140	N.A.+
Children	11+	1956	N.A.+	2193	2604*
Children	12+	2032	N.A.+	2248	2670*
Children	13+	2037	N.A.+	2340	2779*
Children	14+	2066	N.A.+	2468	2931*
Children	15+	2065	N.A.+	2354	2795*
Children	16+	2070	2458*	2586	3071*
Children	17+	2061	2447*	2662	3161*
Adult#	18–30	1872	2223	2424	2879
Adult	31–59	1920	2280	2376	2822
Old	>60	1704	2024*	1976	2347*

Source: table 4.2, 4.7, 4.8 and 4.11 of ICMR (1990)

Notes:

^ While recommended dietary allowances is also a function of body-weight of a labourer, in the absence of such information in the either of the datasets, reference weight of an adult male has been adopted as 60 kg and of an adult female as 50 kg, as per ICMR (1990: 70).

* RDA under moderate activity was extrapolated using the 24 hour average of Indian adults, from sedentary activities in terms of BMR. While for the former it was 1.9, it was 1.6 for the latter. Admittedly, this was the formula for adults, and thus for children below 18 years the conversion formula could be different. But for any better alternative route identical conversion factors had been used.

+ Energy values for children aged below 11 were not calculated in moderate activity. Lowest age for persons with crop production as the major occupation (code: 101) was 11 and 17 for boys for girls respectively. However, for crop production as the minor occupation for girls the minimum age is 16.

For persons in the age group of 18 years, table no 4.7 (for adults) puts 2424 against 60 kgs against the sedentary activities for boys while table no. 4.11 (for children) stated 2677 Calories. Persons at 18 years were considered as adults following the legally defined and judicially accepted position in India.

On the other hand, Mitchell (1979: 84) had considered 2,440 and 1,900 Cal for adult male and female humans for maintenance with additional increments for work.[74] This thesis has opted for ICMR (1990) and the corresponding Calorie values have been included in table 2.4.2 above.

Further, as 'on farm' energy requirement considers not just the many hours in occupational activity but also for the whole day including sleep and non-occupational activities, per-day approach has been preferred over a per-hour one. Labour-hours had been converted to labour-day by using a working-day norm of 6 hours. Though the official position had been to consider 8 hours as the length of the working day time, only 6 hours of physical work takes place on average. This position gains strength as the collected data was based on the actual physical work, excluding the time for taking the lunch and a two hour rest period in between. Interviews with the enumerators in West Bengal for CCS supported this position.

While for the household labourer, Calorie requirements could be further fine tuned with the incorporation of age data provided in the CCS dataset, no such possibility existed for the hired labourers. Thus, 2,822, 2,280 and 2,795 Calories per day for men, women and children respectively had been assumed.[75]

To sum up, while for the household labour, Calorie values as in table 2.3.2 has been used in this thesis. For hired labourers, the corresponding values have been included in the paragraph immediately above.[76]

[74] 400 and 1,500 Cal per day for light and heavy in case of men and 300 and 1,100 Cal per day for women, respectively.

[75] These are the Calorie values for adult male labourer in the age group of 31–59 years, female labourer in the age group of 31–59 years and male children of 15 years respectively, under moderate activity, as shown in table 2.3.2.

[76] In 2004–05 dataset, there exists another category, 'exchange labour' for which a separate set of assumptions were taken, which will be discussed in the next chapter.

2.4. Energetics of Animal labour

Besides the position that milch animals enjoyed in the rural Indian traditions from the nutritional aspects of human beings, draft animals had been a dependable source of power in many States.[77] However, several authors had noted the decline in the number of animals and corresponding increase in the machines replacing them for power requirements (for example De 2005, the synthesis study of ICAR-AICRP 1971–2002). Naturally, a few secondary effects followed, in the form of the loss of manurial resources and the wastage of by-products used as feed: first had weakened the soil fertility, while the second had resulted in waste accumulation. Further, it may be noted that the fuel used in manufacturing, maintaining and powering the machines has high economic value along with a variety of alternative uses while for draft animals the 'fuel' is the straw and the fodder of lesser economic value and having very few alternative uses (Mitchell 1979; Rao 1984). Clearly, the individual farmer-cultivator seldom considers such social costs and benefits.

Table 2.4.1: Energy value of daily consumption of food for selected animals (in Calorie)

Name of Animal	Annual Maintenance (in 10^6 Calorie)	Daily Maintenance or Annual/365 (in Calorie)	Daily increment for light work (in Calorie)*	Daily increment for heavy work (in Calorie)*
Bullock of 300 kg	3.12	8,548	4,902	8,772
Bullock of 400 kg	3.95	10,814	6,461	9,661
Bullock of 500 kg	5.03	13,790	7,385	13,835

Note: * 10 hour per day work assumed
Source: Mitchell (1979: 84)

As discussed earlier, there exist two methods to capture the food energy requirements for animals, engaged in labour on the farm. One considers not only the metabolic cost during the work periods but also the entire annual feed given to animals was to be taken as the biological cost of their labour. This was 'the equivalent of using the sum of all the energy for maintenance, manufacture and operation of a machine rather than only the work output of a machine' (Mitchell 1979: 46). Table 2.4.1 captures the energy costs for selected animals used in Indian agriculture, following this method.

Thus, a bullock of 500 kg engaged in a heavy work will require 27,625 Calorie of feed and may produce 641 Calorie/hr x 10 hr = 6,410 Calorie of useful energy, corresponding to 43% of conversion efficiency. Engagement with the light work

[77] A bullock or a buffalo may produce an average of 0.75 hp/hr (range 0.5–1.0 hp or 320–640 Cal/hr) (Mitchell 1979: 46).

may prompt a reduction of efficiency to 15%. These ratios may reduce further once the consumption and production are taken on an annual basis. Conversion rates less than 5% are common (Mitchell 1979: 85).[78] However, it may be noted here that the main food source, straw, has hardly any alternative use and is of almost no value to humans.[79] The labour supported by straw thus is a net gain.

Singh and Mittal (1992: 8) like all the other studies under ICAR-AICRP had used 10.10 MJ/hr as the energy coefficient for a pair of bullocks of medium built, the most common form of animals providing power in West Bengal. On the other hand, Rao (1984) provided a much detailed and refined assessment of Haryana cattle, in terms of the Total Digestible Nutrients (TDN), separately for the days of work and the remaining ones, and warrants a separate explanation. 1 kg of TDN, for cattle was found to be equivalent to 4400 Calorie (18.4 MJ) and resulted in different digestions depending on the type of food. On good rations, about 70% was digestible, while in case of food consisting primarily of crop residues absorption was only about 40% of the gross energy, as recorded in a 'bomb Caloriemeter'. Noting the usual rate of wastage on the farm to be 5%, Rao (1984: 542) calculated the energy inputs of a bullock in its growing years and after reaching a stable body weight of 400 kgs at about 36 months.

On working days, bullocks were found to have fed 4.0 kg of TDN (73.67 MJ) and 3.15 kg of TDN (58.02 MJ) in the remaining days of rest.[80] The observations in the study, pertaining to the energy requirements of the entire life of the bullock, however, brought an interesting question. Calculations showed that an idle pair of bullocks required maintenance cost of about 555 GJ during the 3 years of growing up and 10 years of working life, implying 152 MJ/day on average, while the increment was 31 MJ as feed for working days.[81] Table 2.4.2 captures the range of energy values as found in the literature.

[78] Rao (1984: 542) calculated such 'efficiency' to be 8.6% when the bullock works every day.
[79] Admittedly, small supplements in the form of concentrates and cakes are required too, which in general are by-products from processing grain or pressing oil. These products also have hardly any alternative, except as animal feed and manure (Mitchell 1979).
[80] In Mitchell's calculation, heavy work for a bullock of 300 kg required (8772 + 8548) Calorie = 72.40 MJ/day.
[81] These numbers differ from the previous ones, precisely due to the differences in the accounting period. Whether the one that takes into account the entire past life and takes the daily average or the one with the daily marginal intake, is more correct remains an important philosophical question.

Table 2.4.2: Energy values of nourishments for bullocks		
Type of Bullocks	Energy values	Source
350–450 kg	2,412 Calorie/pair-hr	Singh and Mittal (1992: 8)
300 kg in light activity	13,450 Calorie /day	Table A.10 in Mitchell (1979: 84)
300 kg in heavy activity	17,320 Calorie /day	
300 kg in days of rest	8,548 Calorie /day	
400 kg in light activity	17,275 Calorie /day	
400 kg in heavy activity	20,475 Calorie /day	
400 kg in days of rest	10,814 Calorie /day	
400 kg in days of activity	35,193 Calorie/day	Rao (1984: 542)
400 kg in days of rest	27,714 Calorie/day	

An alternative method of calculation is through the actual feed. Admittedly, such an approach may overestimate the energy content of the inputs. Thus, in some of the scales (to be defined below), energy values following Rao (1984) had been considered, while in others it was the entire feed. Notably such a consideration includes nourishments required for animals like milch ones, and may correspond to the reproduction of the animal labour power. Energy values against the constituent elements in feed have been listed in Table 2.4.3. Admittedly, only the privately provided material has been included here, irrespective of the 'management' of animals.[82] At the same time, energy inputs of the human labour involved in the maintenance of animals had been included in the calculation.[83]

Arguably, this method leaves a scope for ambivalence. After all, consideration of other animals or dependents in the case of the living labour could correspond to the notion of 'reproduction of labour power' only in a loose sense. For a stricter analysis, a norm may be required that may relate the labour-power of today in terms of number of workers with that of a later date. For example, corresponding to the Calorie value of one adult female labourer, one may add that of a male and a child in the notional household. Thus, a coefficient, equal to the ratio of the total energy requirements of the three individuals and the energy value of the worker in question, for the provision of labour power on a sustained basis was required to be constructed. Admittedly, with two or more members of the same household, including working children, it will certainly be a more complicated matter. For

[82] Categories included 'Joint herding, village land', 'Herding, own land', 'Stall fed', 'Run free and fed', 'Herded and fed' and 'Run free, herd and fed'. Exception has been the green/dry fodder against which the specific assumptions have been included in table 3.2.2 below.

[83] Admittedly, for such labour, as well as that involved in maintenance of machines, no consideration was given for reproduction of such labour power. It was treated as an activity, which may not be true in reality.

reasons of keeping the calculations simple, such an exercise had not been conducted and left for future.[84]

Table 2.4.3: Energy values of constituents of feed (in MJ/kg)		
Item	Embodied energy (in MJ/kg)	Source
Green Fodder	**3.94** (3.14–4.33)+	Mitchell (1979)
Dry Fodder/Straw	**12.5**	ICAR-AICRP
Dry Fodder/Straw	**13.79** (11.84–15.15)	Mitchell (1979)
Grain	**14.7^**	Table 2.6.6
Mixed Feed	**25**	Assumed Cattle Feed, ICAR-AICRP
Mineral Salt	**10**	ICAR-AICRP
Oil Cakes	**18.15** (16.41–19.11)	Mitchell (1979)
Oil Cakes	**10**	ICAR-AICRP
Oil	**30**	Assumption based on Oil Seed
Gur, and Oil Seeds	**25**	ICAR-AICRP
Other Concentrates	**13.81** (12.31–14.36)	Mitchell (1979)

Notes: Energy value of the services (veterinary, mating, etc.) were not considered, and so were the herding charges or vaccines
+ Numbers within the parenthesis indicates the range, while the one outside is the average as per the respective source. This thesis has used the average values, marked bold..
^ Assumption was made on the basis of predominance of paddy, as shown in table 1.7.1.

In sum, so far as 'energy income' of the bullocks are concerned, 73.67 MJ/day was considered as the energy value of the feed per active day; on the other hand, the total energy value of the feed was computed using the same for its constituents as in table 2.4.4. Both the methods had been used in this thesis, to be explained shortly.

Finally it may be noted that besides providing power, dung and urine returns virtually all the useful chemical nutrients back to the system. Former is high in nitrogen, phosphorus and potassium, to act as the fertiliser. Value of these nutrients could also be measured in terms of its chemical energy content or in terms of fossil energy they save. Nutrient composition and energy content of dung and farmyard manure are presented in table 2.4.4.

Table 2.4.4: Energy values of dung (in MJ/kg)						
Material	In percent per unit of weight				Energy value	Source
	Water	N	P_2O_5	K_2O		
Fresh Dung	79	0.34	0.18	0.25	20.40	Mitchell (1979: 86)
Dung Cake	10	1.60	1.50	1.50	2.09	
Farmyard manure	25	0.50	0.30	0.60	1.74	
Farmyard manure (dry matter)	Not provided				0.30	ICAR-AICRP
Cowdung Cakes	Not provided				8.76	
Dung	Not provided				13.8	Parikh (1985)

[84] An alternative variation was to consider the average population proportions and to add corresponding number of dependent animals against those working on the respective plots (see, Norman 1978).

2.5. Material Inputs and Energy Values

Studies in the agricultural energetics usually consider uniform values for the embodied energy in the materials used, be it the seed or the varieties of pesticides or the farm yard manure (FYM). Except the fertilisers, homogeneity assumption has rather been a norm. A plausible reason is the absence of specificities in the secondary data. Both the datasets used in this thesis were no exceptions.

However, energy values do differ based on the production process as well as the content. To address such a requirement, efforts had been made to supplement the available data for 2004–05 with qualitative information collected from the primary datasheets, along with interviews with the selected enumerators and discussions with a number of academicians at Bidhan Chandra Krishi Vishwavidyalaya, Kalyani (BCKV) that had conducted the survey for the 2004–05 dataset.

2.5.1. Pesticides, Herbicides, Insecticides

Table 2.5.1 provides a summary of average energy values, of chemical pesticides, available in the literature. Interestingly, Conforti and Giampietro (1997: 234) had used average values constructed from Helsel (1992: 194–196) that provided energy values against each type of pesticides, namely, herbicides, insecticides, fumigants and fungicides, separately. Energy inputs for production of active ingredients of pesticides as provided by the latter reference along with those from Pimentel (1980b) have been listed in Table A.2.5.1.

Table 2.5.1: Average energy value of pesticides and herbicides

Generic Name	Energy Values	Reference
Pesticides	293 MJ/kg in developing countries; 418 MJ/kg in developed countries	Conforti and Giampietro (1997: 234)
Herbicides	147.82 MJ/kg	Mitchell (1979: 38)
Insecticides	101.18 MJ/kg	
Superior chemicals that require dilution on application	120 MJ/kg or 120 MJ/litre	ICAR-AICRP

Energy input for pesticides ranges from 57.8MJ/kg for methyl parathion to 458.5 MJ/kg for paraquat. The difference is owing to hydrocarbon feedstocks used and the amount of heat and electricity used in the manufacturing process. However, it may be noted that apart from active ingredients, there are other items like formulation, packaging and transportation of the product which also involve additional energy input, and can be up to 33% of the total energy input till the farm-gate where they were to be used (Pimentel 1992: 23). Among the alternatives, about 20 MJ/kg of additional energy is required to make pesticides into emulsifiable oils. Wettable powder, on the other hand, does not require any hydrocarbon directly, but considerable grinding and mixing uses about 30 MJ/kg. Granules require about 10–20 MJ/kg of additional energy. Packaging and distribution in general require about 2 MJ/kg of additional energy (Helsel 1992: 196). Table A.2.5.2 provides energy cost for production, formulation, packaging and transport of pesticides.

Supplementary qualitative information, collected through the discussions, mentioned above had been of two kinds: crop and *tehsil* specific Tables A.2.5.3 and A.2.5.4, contain a summary of the information obtained. Additionally information from the Insecticides Act, 1968 (46 of 1968), its schedule (as per Sec 3(e) of the Act), and Pesticides registered under the Act had been used to make the connection between the common names and its chemical equivalents. Further, the latter was linked with the information in table A.2.5.1 and A.2.5.2 to obtain plot-season-crop specific energy values against the variety of pesticides, given the monetary expenditure against each item and rates prevailing in the respective *tehsil*.[85] Importance of these steps arose from the fact that, despite being small in the physical sense, its embodied energy is considerable to attract a careful scrutiny. Pimentel (1992: 22) had stated 15 % to be the share of pesticides in the total energy use.[86]

Finally, as noted above, Dovring (1985: 80) had pointed to the underestimation of energy values by Pimentel (1980a), for not considering the indirect energy uses towards the production of materials, which however, was more applicable for the fertilisers. Again, there can be possibilities for the underestimation, given that the technological changes may have resulted in lowering of these values. However, there are reasons to question such a transition taking place in India, a less industrialised country, where technological changes take time to take place, in contrast to the more industrial ones. Keeping in mind all these considerations, this work has taken the highest one from the range of values against each of the pesticides.

[85] The respective assumptions will be explained in the next chapter.
[86] However, in West Bengal, 2004–05, the energy expenditure on pesticides was much lower. See, <scale A.xlsx> in the CD.

2.5.2. Manure/nutrients–inorganic and organic

Among the nutrients, only the nitrogen fertiliser accounted for nearly one-third of energy use in the 'modern' agriculture, claimed Pimentel (1992: 20). Besides, phosphorus, and potassium in general, sulphur, is required in the humid tropics. Like pesticides, the energy cost of production of nitrogen had also changed over the years: between 1945–1973 in USA, while it was 62.8 MJ/kg, in 1980, it was reported to be 87.9 MJ/kg (Pimentel 1992: 21). While energy directly required to produce a kilogram of nitrogen had decreased by about one-third, the equipment became more complex and larger in size, requiring more energy for its production (Pimentel 1992: 21); however, there are claims to the contrary pointing to the continuous decrease in the energy use per kg (Editors note in Pimentel 1992: 21fn).[87] Similar changes had been witnessed in phosphorus, potassium and lime as well, which however require much less energy in contrast to nitrogen. Between 1945–1973 in USA, energy input for P was 12.6 MJ/kg, while in 1980, it was found to be 26.4 MJ/kg. For K, against the identical temporal markers, it was 6.7 MJ/kg and 10.5 MJ/kg respectively. For lime, in 1980 energy cost had been 1.3 MJ/kg (Pimentel 1992: 20). Again, like pesticides, for the major nutrients, namely N, P_2O_5 and K_2O, there is not much difference in energy used for packaging, transportation and application (Helsel 1992: 182). While table 2.5.2 provides the energy value of the production of different individual nutrients, table A.2.5.5 captures the details of the variety of fertilisers of all the three types, apart from providing the indicative energy values for packaging, storage and transportation to the farm gate. However, the energy values for the compound fertilisers had to be derived; this will be explained in the next chapter.

Table 2.5.2: Average energy requirements for N, P_2O_5 and K_2O (in MJ/kg)

Nutrient	Embodied Energy only in Production (in MJ/kg)				
N	77.00	69.5	60.60	60	66.8
P_2O_5	13.96	7.7	11.10	14	11.7
K_2O	9.67	6.4	6.70	6	7.2
Sources	Mitchell (1979: 38)	Helsel (1992: 184)	ICAR-AICRP	Singh and Saran (2004)	Average

[87] Helsel (1992: 182–4) had also argued that in the then recent period, all types of N production process became energy efficient to the tune of requiring 1–5 GJ/t of N less than the time when production first started.

2.5.2.1. *Organic Manure*

The 2004–05 dataset provides specific information about FYM, compost and the green manure, besides the 'other organic'. Unlike its chemical counterparts, none of these items has a fixed content or a definite production process. For example, in FYM, water content as a proportion may vary from 25% to 50%, thereby making the calculation of energy values difficult. Similarly, 'other organic' also cover commercially produced branded organic manure, whose content may also vary for obvious reasons. More often than not, these products had been used as a substitute for dung/compost. One plausible reason can be the reduction in the supply of dung in the villages due to the substitution of animals by tractors, apart from the convenience in use. Table A.2.5.6 provides the summary information on the energy values against each of the items considered under 'organic manure', be it prepared within the farm, like, compost or, produced outside, commercially.

2.5.3. Other Macro- and Micro-nutrients

Macro- and micro- nutrients include lime, gypsum, zinc sulphate, boron, magnesium and sulphur. Their respective energy values have been included in table 2.5.3. However, in the State, the common practice has been to use the pre-mixed commercially produced micro-nutrients, like the organic manure. Table 2.5.4 lists a few of them, which by no means is exhaustive, as the brand/common name varied from one district to the other.

Table 2.5.3: Energy input for macro- and micro-nutrients (in MJ/kg)

Type	Mining	Total
Lime	1.05	10.0
Gypsum	1.08	10.0
Sulphur	3.0	
Zinc sulphate	6.9	20.9
Boron	18.2	
Source	Helsel (1982: 184)	ICAR-AICRP

At the same time, many of these inputs were used in miniscule quantities: say, plant growth hormones like Fitonal or Minaculan consisting of triacontanol 0.05%, is used at the rate of 1 ml/1 litre of water. Thus, corresponding energy values were relatively very small, if not insignificant. However, its application is labour intensive, often carried out with the mechanical sprays. Such energy costs had been considered, within the manure application, as appropriate micronutrients are spread on the soil alongwith.

Table 2.5.4: Constituents of selected commercially produced composite micro-nutrients			
Name	Constituents	Rate of application	Price
Zinc Sulphate Monohydrate	Zinc 33%, Sulphate 15%	5 kg/ acre	₹ 35/ kg
Tata Tracel Grade II	Zinc 8%, Boron 0.05%	7 kg/ acre	₹ 60/ kg
Multiplex (of M/s Multiplex Fertilizers Pvt. Ltd.)	Zinc 5.3%, Copper 2.4%, Managanese 5%, Molybdenum 0.01%	5 kg/ acre	—
Rutoz (of M/s Coromandel Agrico Pvt. Ltd.)	Mycorrhizal Fungi 27.55%, Naturally derived ingredients 25.75%, Humic Acid 28.70%, Cold Water kelp extract 18%	—	—
Sulfex (mainly for Mustard)	Sulphur 80% w/w	—	₹ 65/ kg
Boromin	Boron 10.5% w/w	1–2 kg/bigha	₹ 60/ kg

For the purposes of this work, following the discussion with the farmers, enumerators, and research staff, we had assumed crop specific 'other' micronutrients, like, zinc for paddy and boron for wheat, along with magnesium granules and other micronutrients for appropriate soils, as per the respective Agro-climatic zones. Latter followed the *State Agriculture Plan for West Bengal* (NABCONS 2010), and its background report (SoiL, undated). Specific values with respect to the 2004–05 dataset will be explained in the next chapter.

2.5.4. Main Products, By-products and Seed

Energy content of the selected products has been provided in table 2.5.5. Energy coefficients for seeds had been taken identical to the crop itself, as followed in the literature. Energy value of the by-products has been taken into consideration in 2.4.4 along with the energy values of other constituents of feed.

Table 2.5.5: Energy content of selected crops (in MJ/kg)				
Crop	Main product		By-products	
Paddy and Wheat	14.7	12.92–15.8 (14.43)	12.5	
Potato^	3.6	0.66–9.02 (3.42)	18.0	
Pulses (Gram, Masur, Lentil, Moong, and greengram)	14.7	13.16–18.05 (14.48)	10.0	
Sesamum, Sunflower, Mustard	25		10.0	17
Pea	430.6		10.0	
Chillies	191		10.0	
Vegetables	2		14.7	
Jute	11.8		20.0	
Tobacco	2#			
Source	ICAR-AICRP	Mitchell (1979)	ICAR-AICRP	Mitchell (1979)

Note:
^ For seeds, 1.5 MJ/kg was added, as per ICAR-AICRP. 5.05 MJ was assumed in total.
# Assumed.

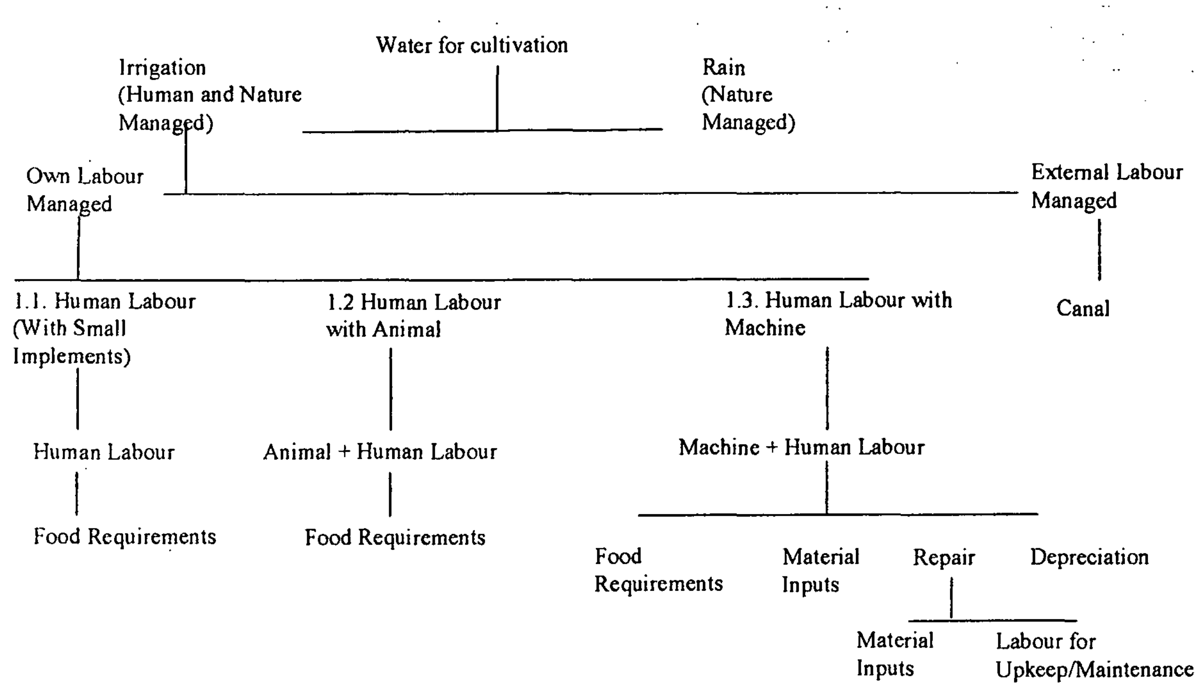
The energy values as used by ICAR-AICRP were used in this thesis.

2.6. Machines

For the machines, the two primary sources of energy are (human) labour and material. Labour use and material consumption takes place directly and also for upkeep/maintenance of machines. However, in addition to these flows, changes in the stock due to the depreciation of the machines were also to be accounted for. Case 1.3 in figure 2.6.1, explains the taxonomy of energy accounting for machine aided irrigation in particular, which is applicable for all types of machines.

Level of intensity of human labour, in case of maintenance of machines, or employed in association with it, unlike the case of direct participation in the agricultural activities, had been categorised as sedentary by ICMR (1990). Further, the discussion with the enumerators and staff members of CCS revealed that the machines required supervision at the most, and thus the labourer usually gets engaged with some other activity when the former is at work. It follows therefore that it is virtually impossible to segregate the two components of human labour between the two, namely, sedentary activity in association with the machines, and moderate activity otherwise. As a result, all the labour hours against farming had been considered at moderate intensity. Only those engaged with the maintenance of machines had been treated as under sedentary activity.

Figure 2.6.1: Typologies of sources of water during cultivation



2.6.1. Energy Values of Material Consumed

The type of machines, their features including age, power (HP), monthly material inputs for running, monthly repair (labour and material) cost, etc. for owned machines at the level of the household were available in the 2004–05 dataset. Accordingly, the energy value calculations were carried out for various materials consumed, directly or also for upkeep/maintenance, based on the coefficients available in the literature; they have been included in table A.2.6.1. Energy values for average consumption of material (both direct and maintenance), computed from data on use of all the owned machins, and has been included in table A.2.6.2.

While the dataset supported monthly consumption data at the level of individual machines against plots, annual consumption data against each machine were taken instead. This was done in order to minimise the possibility of errors in reporting, as they were based on the visual observations instead of an actual measurement.[88] For unused machines and equipments, however, no account was taken. At the same time, contractual arrangements for specific activities like threshing or watering against a fixed rate (either consolidated or per unit of land), had been reflected in the dataset only as a service, precluding the possibility of recording the physical aspects. While markets for these products had developed more rapidly in the last five years, they did exist during the year of study, reflected in the 'hiring charges for implements' and 'others' in the Record on Crop Physical Inputs and Payments, and was different from the 'Irrigation fees (canal charges)'.[89] No account could be taken for the irrigation expenditure, as what was reflected in the records was only the product of the rate per hectare and the area under such irrigation. It had no connection with the actual amount of water use.

2.6.2. Depreciation of the Embodied Energy in Machines

The social surplus, that this work has attempted to locate, is a flow, like income, but remains connected with the various stocks through the preceding depletion and depreciation along with the following accumulation. Arguably, for 'a precise accounting of the actual energy embodied in a specific stock of farm machinery

[88] Author is thankful to the research staff at BCKV for providing many advices like this.
[89] In CCS WB 2004–05, transactions in such services were distinctly conducted in the fertile block of Haripal (tehsil 25, 27 and 28) in Hooghly district and interestingly in the blocks of Manbazar-I (tehsil 54) and Jhalda-II (tehsil 55) located in red laterite zones.

for any given farming operation', the information required will be virtually unobtainable (Doering III 1980: 9).[90] Further, even if the actual embodied energy could be measured, its use per unit of the crop or the cultivated area, will vary with respect to time, depending on the degree of intensity of machine use, which in turn is a function of many factors, some of which falls within the control of the farmer-manager, while some others fall outside.

Considering all these limitations, this work has largely followed the energy values provided by Doering III (1980), which are based on US industry averages, for want of a source more relevant to the Indian situation. While for 'any detailed study it is necessary to refer to the original sources for specific values' (Mitchell 1979: 85), most of the studies in India, including the ICAR-AICRP, did not provide any justification for the ones used by them. Mitchell (1979) itself had used the values provided by Alvani and Chancellor (1975), where energy values were taken from the wheat production in California.[91] All the values, considered in this work, had been listed below, along with the discussion of specific inputs.

Doering III (1980) had combined the following three categories of energy use to arrive at the total energy associated with a piece of farm machinery (and also Mitchell 1979: 72):

1. Embodied in the materials used for the production of machinery,
2. Used at the point of manufacturing for treating, shaping and fabricating,
3. Embodied and fabricated in the parts for repair/maintenance during the useful life of machine.

Accordingly, embodied energy in various types of machines had been computed using the standard coefficients for the most typical type of machines used in the State, identified through the field survey. Table(s) A.2.6.3 and A.2.6.4 contain the energy values of selected material inputs towards production/installation of machines, and mass per length of selected items used in various irrigation

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90 Consider the following, as an illustration:

> In order to calculate the energy embodied in an engine block one would require information on the blast furnace used for the production of the steel involved, as well as information about the mining, transportation and refining of the iron ore, and other ingredients used in the steel making process. Beyond this, one would have to keep track of the machining and processing of the engine block itself in all intermediate process steps, as well as in final assembly and delivery (Doering III 1980: 9).

91 P K Alvani and W J Chancellor, 1975, 'Energy requirements for wheat production and use in California', American Sociology of Agricultural Engineering, Paper no. 75-1557.

structure. A.2.6.5 shows the derivation of energy values for each type of machines. Accordingly annual depreciation for own machines were calculated following the straight line method, in consideration with the various characteristics of the machines, like type, capacity in HP, age in years, and the remaining age in years.

2.6.2.1. *Taxonomies of Measurement of Depreciation*

Let the value in construction/purchase of the asset be V_o as calculated from above and at year t, it is V_t, with t taking the value from 1 to n. Considering uniform rate of depreciation r, $V_t = (1-r)^t \times V_o$. As t becomes large, $(1-r)^t$, and consequently V_t approach zero. Typically, use of the machine ceases much before V_t equals or even becomes close to zero. Doering III (1980: 11) assumed reliable life for farm machinery and buildings to be 82%. V_t/V_o attained 19% with r = 0.08, at t = 20. Such value of r gains strength as the average life span of all machines in the dataset was roughly 19 years, as captured by table A.3.1.7. Therefore, with t obtained from the dataset against individual machines, depreciation or the change in capital stock due to wear and tear for the t^{th} year was measured with the expression:

$$V_{t-1} - V_t = 0.08 \times (1-0.08)^{t-1}.V_o$$

2.7. Summary of Energy Values against various inputs and outputs

For human labour, Calorie values as in table 2.3.2 were used for household labour. For hired labour, they were 2,822, 2,280 and 2,795 Calories/day for men, women and children respectively. For animal labour it was taken as 73.67 MJ/active day in two of the scales; it was the entire feed, in the other two. For seed, main-product and by-products the values in table 2.5.5 have been used. Similarly, values in table A.2.6.1 was used for material consumed during use of machines. Table A.2.6.5 captures the embodied energy of various machines.

For the remaining inputs, namely, pesticides, fertilisers, organic manure and other soil nutrients, the values had to be derived from those available in the literature, as referred to above. Such derivations will be explained in the next chapter.

> The Method I take to do this, is not yet very usual; for instead of using only comparative and superlative Words, and intellectual Arguments, I have taken the course [...] to express my self in Terms of *Number, Weight,* or *Measure;* to use only Arguments of Sense, and to consider only such Causes, as have visible Foundations in Nature; leaving those that depend upon the mutable Minds, Opinions, Appetites, and Passions of particular Men, to the Consideration of others [...] (Sir William Petty, 1662, 'Preface' to *Political Arithmetick, or A discourse concerning,* -, in Charles Henry Hull, ed., 1899, *The Economic Writings of Sir William Petty*, Cambridge University Press, 2 volumes, vol. 1, p. 244; emphasis as in the original).

3.1. Sustainability of Agriculture

Sustainability, for the purposes of this work may be defined as the ability to sustain a process under consideration in general terms. The said process, for this work, is the *life* or the level of living of the human labourer in farming operations on the land under assessment. A few qualifications shall be in order, however. First, the farming operations under consideration are limited to those taking place within the farm-gate. The labour involved in activities within the management of the household, but not connected with farming are not included. Further, activities outside the farming household have been considered only indirectly, in extending some of the calculations. Second, while the land units under evaluation in this thesis had greatly varied characteristics and qualities, they have been taken as given and no attempt has been made to explain the differences in terms of past practices, ecosystem stress, and so on. Indeed, it is impossible to know about the past contributions of nature and labour separately towards the quality of land: '[i]t is indeed difficult to draw the line between the so-called endogenous soil differences and man-made differences especially since it is past investment in land which influences today's quality of soil' (Bharadwaj 1974: 15). Finally, while property relations are not taken into account in an energy balance analysis, as stated at the very beginning of the thesis, it may be noted that of the 2279 parcels or contiguous land (827.25 ha) cultivated by the 590 households under evaluation here, 2243 were 'owned and managed' (814.37 ha), while 20 were 'leased in' (5.01 ha) and 16 were 'leased out' (7.87 ha). Thus, for an overwhelming 98.5% of land was cultivated by its owner.[1] At the same time, owing to land distribution programmes of the State government and the fragmentation of land due to succession, there had been as many as 178 households (30% of the total) with less than 1 ha of net sown area.

[1] These percentages are based on net area sown. However, with such a distribution for NAS, the one based on gross cropped are is unlikely to be very different.

3.1.1. Level of Living

Arguably, it is possible for the human beings to have various levels of living or 'lifestyle support'.[2] Consider the contrasting examples of having a healthy life resulting from the consumption of recommended doses of food in balance with the intensity and duration of activity engaged in and a 'solitary, poor, nasty, brutish, and short' life, following *Leviathan*. However, the resulting choice over the particular level of living and its attainment requires a few qualifications.

Consider the distribution of food by the female members of the household favouring those working outside home and/or belonging to male gender across ages. There is well-documented evidence of these sacrifices.[3] This thesis will not take into account these favouritisms and its consequences on the sustainability of the life of each individual member of the household.[4] Instead, consumption of the labourer household has been taken at the aggregate, using the norm of recommended age-sex-activity based dietary intake in food calorie terms. The purpose of this thesis is to locate those households who are being able to meet these norms, though notionally, under different scales of sustainability, to be defined shortly.[5] Following such identification, corresponding units will be analysed along with the associated farming practice and the agro-climatic environment.

It is well established that many of the farming households do not have profit maximization as their objective function (Bharadwaj 1974: 5) but aspire to lead a 'decent' life. This is especially true for the small and medium farmers, primarily engaged in food crop production on the land under the management of the

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[2] These two phrases are often used synonymously. There can be many elements in the commodity basket that define level of living, which may appear to be without any corresponding support in *physical* terms. However, such mental or emotional support, always require indirect expenditure in physical terms.

[3] It is possible to link this distribution to the notions of fairness on the part of the women, which is a function of generations of custom, constructs and controls that the society has transposed into their moral positioning. Monetary earnings are only valued and thus their earners, be it those at present or the ones having future potentials.

[4] Such a position, however, does not challenge the assumption of rationality that we maintain on the part of all economic agents: altruism is just one manifestation of rational behaviour.

[5] Actual consumption data could have made the analysis more robust. Though this remains as a possible area of extension of this work, one must qualify that getting individual household member's consumption data is difficult if not impossible, even through the field observations. It is precisely for these difficulties, *Nutritional Intake in India* (National Sample Survey Organisation, Ministry of Statistics and Programme Implementation, Government of India), collects and publishes data on the basis of household, defined as 'a group of persons normally living together and taking food from a common kitchen'.

household, while supplying labour to cultivation managed by others, to make both ends meet. Stated differently, one of the intentions of this work is to assess the farming households in terms of meeting this rather simple goal.

3.1.2. Index of Measuring the Level of Life

This work takes food-calorie intake at the household level as the indicator for measuring the level of living. Indeed, it has been a common practice, to link mean per capita consumer expenditure by the household to food intake (NSSO 2007). However, for many, if not, most of the farming households, the bulk of consumption originates from the farm itself, which is not fully captured by the expenditure route. Food-calorie, on the other hand, does not suffer from similar disadvantages.[6]

Understandably, analyzing the level of living on the basis of a single ingredient of the basket of commodities may appear reductionist in approach. The term commodity here means not just the 'commodity space' but also the 'capability space' following Amartya Sen and Martha Nussbaum, and thus includes all the goods, services, associations, freedoms, dignity, social supports, and so on. We maintain that food is a necessary, if not the chief ingredient of such a basket, defining and deciding the level of living.[7] Thus, it would not be unrealistic to let the basket be represented by food itself because of the position that food enjoys. Admittedly, the assumption held here is that the food and other requirements of life do maintain a strong and positive relationship with each other. Further, rather than taking food, we have taken Calorie as the unit of measurement. This assumption finds support from the *Nutritional Intake in India: 2004–2005* (NSSO, 2007, NSS 61st Round) for the period July 2004–June 2005, which exactly corresponds to one of the periods under study in this thesis. For the three lowest MPCE (Monthly Per-capita Consumer Expenditure) classes in the rural West Bengal (Table 3R) the percentage of expenditure on food varied between 70.2% and 71.8% while that on cereals was between 35.5% and 38.2%. Further,

[6] Admittedly, actual food consumption, instead of the Calorie norms, that we have taken, would have the same problem as the one based on the expenditure.

[7] Consider Pachauri and Spreng (2004) for an alternative view: in 'Energy Use and Energy Access in Relation to Poverty', while criticising the conventional approach to poverty line on household income or consumption (total or food), as a 'static concept', the study had offered 'energy poverty line' or 'fuel poverty line' as an alternative. However, such standards were exclusive of access to food by human beings, but included only biomass, electricity, kerosene and LPG as energy needs of a household determining the well-being.

the consumption of cereals alone was responsible for 74.92–77.75% of Calorie intake (Table 4R), suggesting that the focus on the particular food crops that provided the bulk of the calorie intake in the state of West Bengal may be justifiable. Within this understanding, food consumption is a necessary and important component of the human well-being.

Food-calorie has also been used as a measuring unit for the estimation of poverty line in India. Similarly, scientific studies on human metabolism[8] use it as the unit for calculating the chemical energy that human body releases per unit of time. Further, a person's Basal Metabolic Rate (BMR) is also defined in terms of the minimum calorie requirement needed to sustain life, when at rest.

3.1.3. Alternative Scales of Sustainability

We propose four alternative and progressively stricter scales of sustainability. It may be noted that this variety is applicable only for the human labourers and the animals, and not for any other input. For the latter, the analysis is identical across the scales. The per acre algebraic expressions corresponding to these scales together with a numerical example to elucidate them will be presented alongwith.

Consider a certain practice on a land of a given area of 1 ha that involves engagement of only one labourer for 56 days during the Kharif season of 120 days. The male household labourer, aged 29, provides the requisite labour and he is not engaged in any other crop cultivation managed by others during the season.[9] Dependents include two female members, aged 26 and 17 respectively, who are not engaged in any farming activity, within or outside.[10] Cultivation also involved 10 active days of labour from the animal in the possession of the household. The household is not engaged with cultivation beyond the Kharif season.

For the moment, we also assume that the said plot is the only land in possession of the particular household. In section 3.3 below, we will illustrate the quantification of surplus for one of the 590 households with as many as 7 plots of

[8] Rate by which the human body produces and consumes energy and calories to sustain life.
[9] Some modification will take place in the assumptions later, to incorporate the wage-labour and hired out days.
[10] Specific ages were assumed *only* for the purpose of identification of the corresponding Calorie values from table 2.3.2.

land and that had cultivated in two seasons. The calculations for surplus, as will be shown, was made against every plot, under all the four scales, which was later aggregated at the household level, for the purposes of analysis.

a) Scale A, asks the following question—what are the input used, output yield and the resulting surplus in energy terms for this particular plot of land in a particular season? In this scale, human and animal labour input is defined exclusively in terms of the Calories to sustain these inputs according to the number of days for which they are employed/engaged. Alternatively, this scale evaluates the surplus of only the agricultural operations, and thus considers only the 'on farm' labour. Agricultural engineers usually follow this scale (for example, see, studies done under ICAR-AICRP), which reflects a rather mechanistic framework, like the mainstream economics. Agriculture is treated as an activity, in this scale. Indeed, for highly mechanised operations, results of this scale of sustainability will not be different from the other ones.

   Surplus in the scales of A, B and C is defined as,

   Surplus in scale i = Gross Output in scale i – Total Input in scale i, i=A, B, C, annual[11]

In terms of the illustration,

Gross Output in scale A =
Main product + by product, of 120 days

Total Input in scale A =
56 active days of nourishment for the adult male labourer @ 2,879 Cal per day
+ 10 active days of nourishment for the animal, @ 17,624 Cal per day
+ energy value of all material inputs used up in crop production during 120 days of kharif season.

[11] The annual one will be illustrated separately, shortly below, that accounted for both cultivating and non-cultivating periods within the agricultural year.

b) In scale B, the question is as follows: what are the input, output and surplus in energy terms, when the input must include the sustenance of the human labour, during not only the active days but also the days in which it is not employed during the season.[12] In other words, here, sum of the 'on farm' and 'off farm' labour of the labourer involved in the cultivation on the land during the entire cropping season, say, Kharif, is under consideration. Difference between the working time and production time in agriculture (Marx 1956b: 242—244) necessitates this scale. In contrast to the previous one (scale A), agriculture is considered as a livelihood, and includes contributions from the labour in its non-active days as well. Certainly, for more labour intensive operations, there will be considerable difference between the results of this scale with the previous one. Indeed, for a labour force mostly dependent on agriculture as a source of livelihood, or alternatively, without many other occupational opportunities, this scale is more relevant than the previous one. Further, following the difference between the terms activity and livelihood, in this scale, the farmer himself or herself is the designer, tiller, planter, cultivator, herder, harvester, picker, thresher, transporter, marketer, and so on; in the other case, different persons could have performed each of the activities.

In terms of the illustration,

Gross Output in scale B =

Main product + by product, of 120 days

Total Input in scale B =

56 active days of nourishment for the adult male labourer @ 2,879 Cal per day

+ 64 inactive/unemployed days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day

+ 10 active days of nourishment for the animal @ 17,624 Cal per day

+ energy value of all material inputs used up in crop production during 120 days of kharif season.

[12] Unemployed or inactive days for the animal during the season will be considered in scale C. Needless to state that, the nomenclature of 'active' and 'inactive' concerns only the direct involvement with the crop production.

c) The following question is asked in scale C: what is the surplus in energy terms, when the input include the sustenance of the human labour and the animal during the active and unemployed days of the season, along with the dependents of the labourer within the household for the duration of the season,[13] and the output include dung from the animal besides the main product and the by-product? In other words, scale C, considers the replacement of the labour-power. Even if scale B had considered agriculture as a livelihood, many other 'supporting' activities had not been considered, which take place outside the farm boundary, in a spatial sense. For the sustenance of the labour force as such, these 'non-activities' are necessary. Alternatively, while scale B had considered agriculture as a livelihood, it was still for the labourer alone and hence rather individualistic, and certainly not social.

In terms of the illustration,

Gross Output in scale C =

Main products + by products, of 120 days +

dung from the animals in possession of the household in 120 days)

Total Input in scale C =

56 active days of nourishment for the adult male labourer @ 2,879 Cal per day

+ 64 inactive days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day

+ 120 days of feed for animals in the possession of the household

+ 120 days of nourishment for the dependents @ (1872 + 2061) Cal per day

+ energy value of all material inputs used up in crop production during 120 days of kharif season.

Quite obviously, through the application of these three scales, we arrive at the progressively lower quantities of social surplus or the *produit net*, against given units of land cultivated by the household in question. In one of the variations of

[13] All animals in the possession of the household are considered in this scale and also in the annual one. For reasons of simplicity, in the illustration, only one animal was assumed, which could be engaged in the cultivation. In reality, one additional animal will be required (either hired out or in cooperation with the neighbour) for such an engagement. Further, milch animals do not usually participate in the cultivation, and as stated in 2.4 above, inclusion of their Calorie requirement in scale C will loosely correspond to the reproduction of animal labour-power.

the fourth or annual scale, we shall incorporate hiring out of the household labour as well as the animal in possession of the household. Subsequently, we will extend the illustration to incorporate wage labour.

d) The fourth or the annual scale asks the following question: what is the surplus in energy terms, when the temporal boundary for the 'inputs' and the 'outputs' is beyond the cultivating periods of the year? Here, the input not only includes sustenance of the household labour, the dependents and the animals during the entire season, but also during the non-cultivating period of the year as well. Similarly, the output includes dung produced during the non-cultivating period besides the cultivating period (the latter was considered in scale C), besides the seasonal main product and by product. This scale necessitates from the fact that the Calorie requirements of a particular cultivating household, must originate from the surplus produced by the same household during the only season when cultivation takes place.[14]

Let us now consider two possibilities, so far as the engagement of the labour (both human and animal) is concerned. The first corresponds to a situation where no hiring out takes place, for either of the two. In the other possibility, the labourer in question hires out labour, say, for 150 days in the crop cultivation managed by others, and in plots of land in someone else's possession. In the remaining 90 days, he has no direct involvement with any crop cultivation.[15] Likewise, hiring out of animal takes place for 20 days outside the Kharif season. In both the above cases, with all the remaining assumptions remaining unchanged, we may define the annual surplus, as the difference between the 'full and final annual gross output' and the annual 'input'.

It may be noted that the 'full and final output' is different from the sum of seasonal outputs. This is due to the fact that even if a household can be engaged in crop cultivation in as many as three seasons in the same plot of land, latter may remain fallow for some days within an agricultural year. This fact is based on the CCS 2004–05 dataset of West Bengal.

[14] Conceptually speaking, an alternative way to conceive this surplus as the ability of the farming household to support others in every occupation other than crop cultivation, during the same agricultural year when cultivation is taking place.

[15] But, can be engaged with some work involving crop produced in the past. For example, weaving basket.

Components of the annual Surplus in the first case where there is no hiring out of labour are as follows:

Full and final annual gross output =

Main product + by product, of 120 days

+ dung from the animals in possession of the household in 360 days

Annual Input =

56 days of nourishment for the adult male labourer @ 2,879 Cal per day

+ 304 (= 240 + 64) inactive days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day

+ 360 days of feed for animals in the possession of the household

+ 360 days of nourishment for the dependents @ (1872 + 2061) Cal per day

+ energy value of all material inputs used up in crop production during 120 days of kharif season.

In the other case *with* hiring out labour, components of the annual surplus are:

Full and final annual gross output =

Main product + by product, of 120 days

+ dung from the animals in possession of the household in 360 days

Annual input =

56 days of nourishment for the adult male labourer @ 2,879 Cal per day

+ 154 (= 240 + 64 – 150) days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day

+ 340 (= 360 – 20) days of feed for animals in possession of the household

+ 360 days of nourishment for the dependents @ (1,872 + 2,061) Cal per day

+ energy value of all material inputs used up in crop production during 120 days of kharif season.

Clearly, the difference between the two cases in the scale of annual sustainability arises due to hired out labour: 150 days for human labourer and 20 days for the animal. Employment elsewhere will also reduce the input in scale B and C as well. Assume that of the 150 hired-out days in the entire year, 30 falls within the Kharif season. The modified human labour input in scale B, will be as follows:

56 active days of nourishment for the adult male labourer @ 2,879 Cal per day

+ 34 (=64–30) inactive/unemployed days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day.

Further, consider the possibility of wage labour, during the Kharif season cultivation. For simplicity, let us assume that only one hired adult male labourer had contributed 16 days, and as a result it was 40 (=56–16) active days for the household labour. 2004–05 dataset had shown that on average, among the members of the households with crop cultivation as the occupation, an adult female and male labourer were engaged with 44 and 32 days of work respectively during the Kharif season with an average length of 120 days. Thus, on average, of the duration of the season, the number of active days was one-third, while the remaining two-third days were without employment. It follows that for every active day, there were two inactive days, within the season. As stated in 2.3.5.1 above, per active day Calorie requirements for the hired adult male labour was taken as 2,822 Cal; for unemployed days, 2,400 Cal per day was assumed.[16]

In the case of without hired out labour, the modified inputs against (only) the human labour in scale B is as follows:

40 active days of nourishment for the adult household male labourer @ 2,879 Cal per day

+ 16 active days of nourishment for the adult hired male labourer @ 2,822 Cal per day

+ 80 (=120–40) inactive/unemployed days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day

+ 32 (= 2 x 16) unemployed days of nourishment for the adult hired male labourer @ 2,400 Cal per day

In the second case, with 30 days of hired out for the household labour during the Kharif season, the modified inputs against the human labour in scale B is as follows:

[16] Following table 2.3.2, Calorie requirements per non-active days for male of 18-30 years and 31-59 years were 2,424 and 2,376 Cal respectively. The average Calorie value taken, approximates to the nearest hundred.

40 active days of nourishment for the adult household male labourer @ 2,879 Cal per day

+ 16 active days of nourishment for the adult hired male labourer @ 2,822 Cal per day

+ 50 (=120–40–30) inactive/unemployed days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day

+ 32 (= 2 x 16) unemployed days of nourishment for the adult hired male labourer @ 2,400 Cal per day

In scale C, or in the annual one, due to the modifications in the assumption on hired in and hired out labour, except for the changes as shown above for the labour engaged on the plot of land in question, every other component of the input will remain the same, and so will be the output. In the annual scale, with 150 days of hired out labour of the household labourer, the input will be as follows:

40 active days of nourishment for the adult household male labourer @ 2,879 Cal per day

+ 16 active days of nourishment for the adult hired male labourer @ 2,822 Cal per day

+ 170 (=360–40–150) inactive/unemployed days of nourishment for maintenance of adult male labourer @ 2,424 Cal per day

+ 32 (= 2 x 16) unemployed days of nourishment for the adult hired male labourer @ 2,400 Cal per day

+ 340 (= 360 – 20) days of feed for animals in possession of the household

+ 360 days of nourishment for the dependents @ (1,872 + 2,061) Cal per day

+ energy value of all material inputs used up in crop production during 120 days of kharif season.

Differences in the age and sex of the household labourers will be reflected in the per day Calorie values during active as well as unemployed days, following table 2.3.2. However, due to the absence of age-specific information in case of hired labourer, Calorie values will differ only with respect to sex. We will discuss this aspect in a more detailed manner in 3.2.3.3. below, along with the 'exchange labour', one of the two categories of hired labour.

It may be emphasised that for hired out days the assumption is that the Calorie 'earned' is just sufficient to maintain the energy balance of the household labour or the animal in possession of the household.

Energy balance analysis of agriculture in 2004–05 will be carried out through the following paths of enquiry (all the measurement of flows are in terms of energy units):

1. The surplus during the cultivated period, against gross cropped area (GCA), gross output (O) (cultivated period) and cropping intensity; surplus per hectare, against EROI (scale C),[17] cropping intensity and GCA.
2. EROI, against GCA, and gross output, in all the four scales.
3. The annual surplus, against GCA, and net area sown (NAS).
4. The rate of surplus value (in scale C), or the ratio of surplus and the value of labour power, against O, GCA, O per hectare and surplus per hectare.
5. The percentage share of various inputs, against GCA, per hectare output and per hectare surplus.
6. The percentage share of by-products in the output.

We shall be using two categories in addition: first, the size-group characteristics as defined by the Cost of Cultivation Scheme (CCS), the agency responsible for collecting the 2004–05 data and second, the agro-climatic characteristics of the land in question. There are five size-groups based on the area in posession, or the upper bound for the NAS: 0–1 hectare (1), 1–2 hectare (2), 2–4 hectare (3), 4–6 hectare (4) and more than 6 hectare (5). The size-group will serve as a proxy for the NAS; due to the possibilities of land lying fallow, NAS may be lower than the lower boundary of a particular size-group. The relevant agro-climatic zones were also five: terai (II), new alluvial (III), old alluvial (IV), red & laterite (V) and coastal saline (VI) (see, figure 3.1.1).[18]

Section 3.2 will describe the 2004–05 dataset. It will be followed by the quantification of the surplus in each of the four scales (section 3.3) with a selected household, as mentioned above.

[17] The ratio of gross output (O) and the corresponding input (I), both measured in energy units.

[18] As noted earlier, none of the 590 households was located in the agro-climatic zone I (hills).

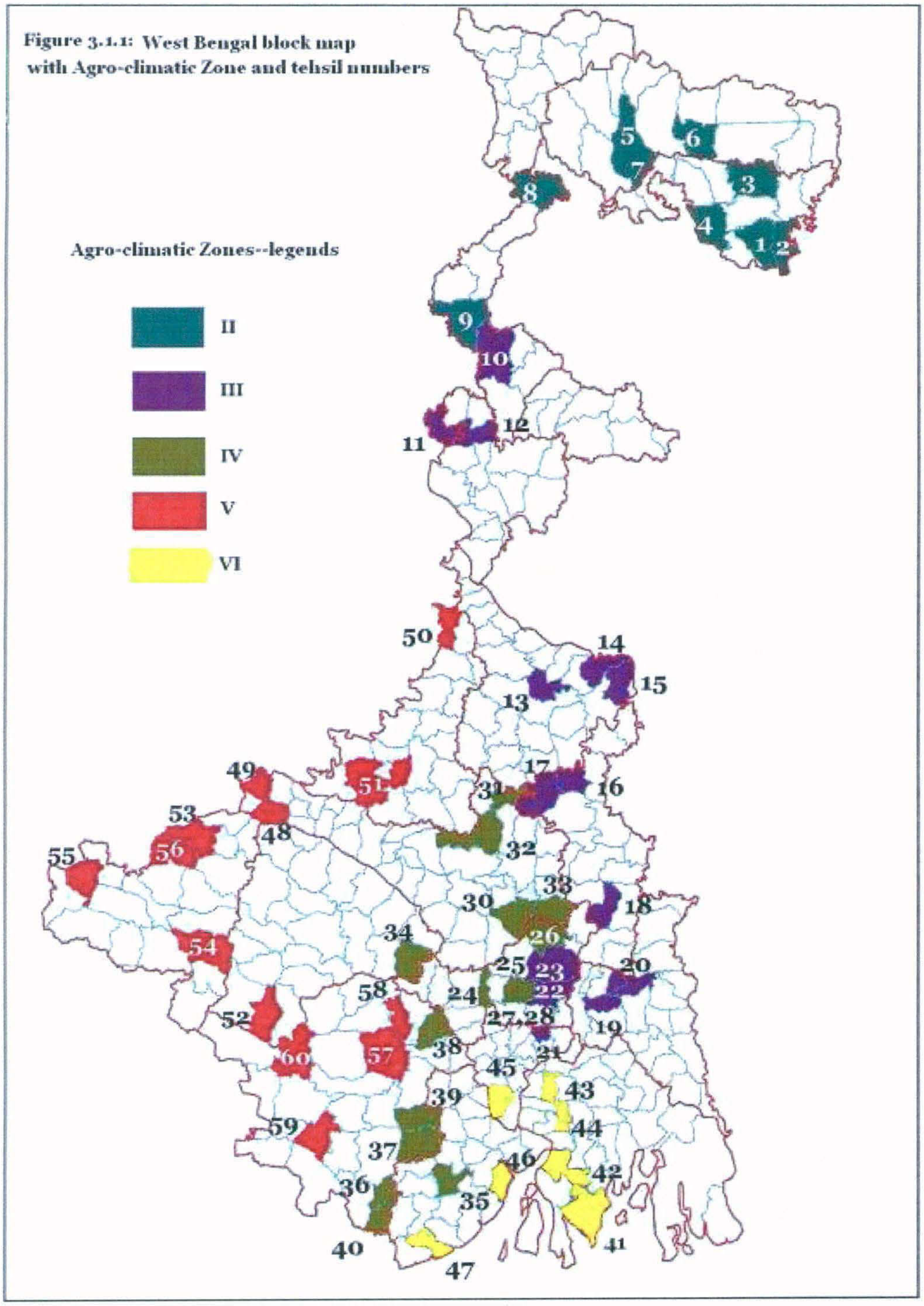

Figure 3.1.1: West Bengal block map with Agro-climatic Zone and tehsil numbers

3.2. Description of the 2004–05 Dataset

2004–05 dataset provided the various destinations (and the sources, as the case may be) for every input and output, that allowed capturing the physical dimensions even if no market exchange was involved. Such inclusion is quite unique. Usually it is not covered, including in the Chinese accounting systems for communes (Han et *al*. 1985: 235).

3.2.1. 'Record Types' and 'Data Fields'

The data are captured from the farms on the basis of 40 different forms for specific purposes. The forms are known as 'Record Types' (RT). Each RT included multiple Data Fields (DF). Of the 40 RTs in 2004–05 dataset, only 18 were used in the thesis (see, table A.E.1, for details). In fact, for some of them, only a few DFs had been used (see, table A.E.2, for details).

In particular, the price data had not been used, and so were those on credit, loan and the repayment by the household.[19] Transport and marketing operations were not considered also; nor was the building inventory or the ones describing only the payments of various kinds (without any information on the physical aspects). We have also assumed that during the cropping year the number of animals, human labour, implement, irrigation and all other assets did not change. Similarly, activities other than 'on-farm', or the 'Special Activities' following the Cost of Cultivation Scheme (CCS), have not been taken into account, except for calculating the number of hired out days.

Information obtained from the dataset were of two kinds: qualitative, like sex of the living inputs, as well as quantitative, like use of organic manure in physical units. For reasons of secrecy, identity of the villages or the households covered was not provided in terms of their location or name.[20]

The data on household members, animal inventory and their maintenance, and machine inventory and their maintenance were made available at the household

[19] The prices were used only for the verification of the data; to be discussed shortly.

[20] The primary datasheets submitted by the enumerators to the office of the CCS do contain the identity of the farmer and her/his household members, as well as the village, However, it is not included in the dataset made available in the electronic format. As a result, enormous information gets lost from the point of view of policy recommendations. Further, this poses a problem for using supplementary data from the other sources.

level. Some others were corresponding to the parcels, like land inventory. This had been one more reason for the apportionment of various kinds of joint consumption into the relevant plot-season-crop combinations, besides what had been stated earlier.[21] Finally, information on annual crops record, crop operation hours, crop physical inputs and payments and crop outputs were made available at the plot level.

The 2004–05 dataset was made available in the electronic format. List of codes against each RT and the corresponding DF has been provided in table A.E.3. The relevant part of the 2004–05 dataset, used in the thesis, is contained in <Core data for all TTFF.xlsx> file in the attached CD. The complete dataset is contained in <Raw data.xlsx> file.

3.2.1.1. *Treatment of data problems*

Problems in the data included mistakes in units (say, 1 or 3 instead of 13), entry in wrong data field, and mismatch between the data in primary sheets and electronic form. Among the more serious problems was the mixing of three categories of pesticides.[22]

Each of the RTs was checked for the anomalies, typographical errors, entries in wrong columns, etc. In addition, data were cross-checked at the level of each farm taking into consideration the other farms belonging to the same tehsil.[23] For one particular tehsil (no. 29) however, there were distinct problems, which could not be sorted out; thus, instead of 600, the number of households in our analysis is 590 (see, figure 3.1.1, for the location of the relevant tehsils).

[21] Materials used in machines, for example, were apportioned on the basis of machine hours in the relevant plots cultivated by the household. Similarly, Calorie requirements for the maintenance of labour in scale B were apportioned on the basis of the cultivated area of the relevant plots. It may be emphasised that such apportionment was necessitated by the plot-wise analysis.

[22] All of these are avoidable and can be corrected with little willingness on the part of authorities from state institutions to Economic and Statistical Adviser, DES to the political establishment. Notwithstanding these deficiencies, this source remains a goldmine for anyone interested to undertake any aspect of research on rural economy of India.

[23] For this purpose, rates of various materials were used.

3.2.2. Households, Parcels, Plots

The selected farming households have been found to be cultivating 2279 parcels altogether. In 2208, it was crop production. Further, while many parcels were divided into a number of plots, many plots also supported mult-cropping, and some plots also allowed multiple crops within the same season.

This had resulted into 3459 plot-season-crop (or PSC) combinations. 27 were corresponding to the perennial fruit crops (mango, litchi and banana) which were not considered. Of the remaining 3432, due to incomplete data, 6 data points were removed from the analysis. <scale A.xlsx> contains the information for these 3426. Further, there were 42 data points, against which no output data was available. However, the input data was used for apportionment of the material.[24] As a result, our analysis involved 3384 plot-season-crop combinations.[25] The description of the features of the crop production in the next section however will include all 3426.

Table 3.2.1: Distribution of household size

No. of members	No. of households
1	5
2	12
3	46
4	101
5	110
6	86
7	57
8	46
9	40
10	28
11	18
12	8
13	12
14	5
15	3
17	4
19	2
20	6
25	1
Total	590

3.2.3. Characteristics of the Crop Production Systems

This section will offer a brief review of the 2004–05 dataset, along with the assumptions that had been taken in absence of the supporting information.

3.2.3.1. *Members of the Household*

Size-distribution of 590 households has been provided in table 3.2.1.[26] Average family size was 6.54. 3860 members included 590 'Head of Household', of which 18 were women. 20 households were found to be having an attached male servant. Of them, 11 resided with the cultivator,[27] and were considered as a part of the household. The remaining nine were considered as hired labourers.

[24] In <scale A.xlsx>, numbers in the corresponding rows are marked with a strikethrough.
[25] It was 2387 plots, some of which had been cultivated multiple times. The file <annual sustainability> lists all of them, season-wise.
[26] RT 110 provided all the information on members of the household, and RT 120 did the same for servants.

Occupational categories included crop production, non-crop agriculture, non-agriculture on farm, and 'other work'. Further, 'major occupation' was differentiated from the 'minor occupation' in the dataset. Though this categorisation appeared to have a relationship with the 'percentage of time on farm', it was not definite.[28] Further, for identification of the human labourers belonging to household, we have not made any distinction between the 'major' and the 'minor' occupation, following the discussion with those involved with the CCS at Bidhan Chandra Krishi Vishwavidyala (BCKV), the agency that had collected the data.

Various characteristics of the members have been captured with table(s) A.3.2.1 and A.3.2.2. Table A.3.2.1 (f) shows that those with significant proportion of time 'on farm' had crop production as a major occupation.[29] On the other hand, 169 household members with crop production as a minor occupation mostly had spent significant share of their time off-farm.[30]

An overwhelming proportion (98%) of members stayed 100% of their time 'at home'. However, these percentages, like the 'on farm' ones, were collected only once at the beginning of the crop year, and expected to represent the perception of the household member (usually the head) providing the data, rather than the actual. In other words, under this circumstances there was no hard information on this aspect, and we had to continue with it. Admittedly, this is one of the limitations of our results.

The data on the 'percentage of time at home' were used only for the measurement of Calorie requirements of the dependents. For example, the seasonal Calorie requirement in scale C of a 15 year dependent girl living 80% time at home was taken as 80% of the length of the season in days @ 2,065 Cal per day, following

[27] Only 2 of them were involved in crop production, 5 in cattle tending, 2 in tractor driving, 10 in multipurpose work while the remaining member in 'other work'.
[28] There exists lack of clarity on the notion of 'percentage of time on farm' among the enumerators. For some, this was to do with time on 'own farm', while for others, it meant *any* farm. The problem in the FMS on this count of non-uniformity in categorization, that reflected the subjective judgment of the supervisor/enumerator was reflected in CCS dataset as well, even after half a century.
[29] Of the 1158 persons, 632 (55%) had spent at least 75% of their working time on-farm.
[30] 138 (82%) of them had spent at most 30% of their working time 'on-farm'.

table 2.3.2 above.[31] Similar modification was carried out in the annual requirement as well. However, for the earners with crop production as an occupation, 'percentage of time at home' was not taken into account. For example, irrespective of the percentage, the seasonal Calorie requirement of a 29 year male, working for 56 days in a season of 120 days, as in the example (in 3.1) above, remained as before, i.e. 56 days @ 2,879 Cal per day + 64 days @ 2,424 Cal per day, in scale B as well as C.

3.2.3.2. *Labour hour and corresponding Calorie Value in scale A*

Labour-hour data against the household head and servant were given separately.[32] Accordingly, the corresponding Calorie value was calculated using table 2.3.2, while converting the hourly data into number of days.[33] However, the labour data against the remaining household members, were available only on the basis of three categories: 'family men', 'family women and 'family children'. Thus, for the households with more than one labourer under a category,[34] it was not possible to attribute the Calorie value directly. Consequently, we have assumed that each of the members within a category had equal probability to contribute his/her labour. Thus, the total labour hours against a category was divided equally and this average was attributed to all the household members within the particular category.

Further, there were problems on the definition of an adult: in some cases, it was 18, while in some others it was 15.[35] However, given the small share of labour performed by children, this was of little significance. While the identity of the members of the household was known, it was not the same for the human

[31] This had followed the NSS (2007: 12) definition of household with respect to nutritional intake, that had excluded the members who stay outside: 'A group of persons normally living together and taking food from a common kitchen constitutes a *household*'. Only their duration of stay, if any, was taken into consideration. The word 'normally' was qualified to exclude the temporary visitors but to include temporary stay-aways. 'Living together' was given more importance than 'sharing food from a common kitchen' in drawing the boundaries of a household in case the two criteria were in conflict. However, in the special case of a person taking food with his family but sleeping elsewhere (say, in a shop or a different house) due to space shortage, the household formed by such a person's family members was taken to include the person also.

[32] DF 9 of RT 710 captured the number of hours for all categories of labourer. The type of activities was reflected in DF 8.

[33] We may recall that the length of working day was taken as 6 hours.

[34] To reiterate, 'work' here implies crop production only.

[35] Consider TTFF 4409, with only one male 16 year old member. Significant number of hours was shown against 'family-men'. Again, for TTFF 5105, with a 19 years old as the youngest, number of hours against 'family-children' was significant.

labourers under 'exchange' or against wage. This has resulted in a few more assumptions.

The average age of all male adult members of the households with crop cultivation as the occupation was 36 years. For male children it was 15 years, and for elders (above 60 years) it was 68 years. For female children, adult and elders, the respective average age(s) were 17, 35 and 71 years. Based on this, the age of the adult male hired labourer was 38 years, and for the adult female labourer, it was 36 years.[36] For the hired male and female children the respective age(s) were 15 and 17 years. Accordingly, the Calorie norms followed from table 2.3.2, as stated earlier.

For the 'exchange labour', that is, the hired-in labour against which corresponding hired-out labour takes place, between the owners of such labour, the above assumption for the hired labourer was modified to some extent. Provided that the household which had benefitted from the exchange labour of a given type, say, women, had members with crop cultivation as the occupation in the same category, it was assumed that the age of the labourer contributing such labour is identical to that of the corresponding household member. Else, the average age was assumed. In other words, for a household with a 27 year woman with crop cultivation as occupation, age of the female labourer contributing the labour in exchange was assumed as 27 years. For the households without such correspondence, it was taken as 36 years.

For the informational/managerial inputs, while in general, it was taken as 50 per cent of the seasonal hours provided by the household-head, there were instances where there was no contribution from the household head or even the other members.[37] In such cases, as a thumb rule, it was taken as 5% of the total labour hours. This number was arrived at after observing the labour-hour of the household head in the other PSC combinations. Further, this labour was taken as

[36] Given the Calorie requirements, as per ICMR (1990) was available only for an age-group, the specific age(s) were of no consequence. Further, due to unavailability of data on age of the hired labourers, we had no other option but to make such an assumption. No doubt, this excludes the elders from the purview of the hired labourers, which does not conform to the reality; this is especially true for small and marginal farmers.
[37] Some of them had considerable labour from the servants.

a moderate activity, while holding no distinction between intellectual, manual and the mental labour.

Calorie values against all types of labour were calculated following table 2.3.2, as in the case of household head or servants. Unit Calorie value(s) against all type of labour have been included in the sheet 'human labour-calorie' in file <Scale A.xlsx>. The total Calorie value(s) are included in the sheet 'total' in the same file.

3.2.3.3. *Calorie Value for Human Labour in scale B*

Following our definition, the Calorie corresponding to the non-active part within the particular season was to be added in this scale.[38] This is the 'maintenance cost' of the engaged labour. However, by construction, the requirement under this scale will be net of the labour engaged in crop production managed by others.

In our framework, it was the labour-power alone that could fetch returns to the labourer in question, so as to sustain herself or himself. There could be three possible sources of livelihood, within the agriculture: (1) working on the land under the management of the household; (2) working on the land commanded by others; and (3) being engaged in non-agricultural activities.[39]

To put it differently, of the multiple ways of earning the means of sustenance, crop cultivation could be just one way for the household. At the same time, the labour engaged on the crop cultivation precludes the application of labour on any other. Further, by virtue of the fact that a given cultivated area within the seasonal duration of crop cultivation could engage only the labour of type (1 and 2) above, the surplus generated from it was required to cover the nourishments for the labour so as to be engaged with the other types, namely, non-crop cultivation or non-cultivation (both included in 3). Certainly, the surplus was also required to take care of the maintenance of all the many types of exercise of labour power.

Arguably, there always remained the possibility of the labour from the household in question working on some farm other than the one under its command and

[38] See, 3.2.3.3.1 below, for the discussion on the length of the season.

[39] Again, within the first, one could be engaged with the non-crop production as well, even while working 'on-farm' in the spatial sense.

receiving the produced food in exchange. Food could also be brought from outside the farm, being produced on some other land, not within the purview of the present analysis. Certainly, in those cases, the requirement from the cultivated land under the command of the household will be reduced accordingly, by deducting the days of hired out labour on crop cultivation. After all, we were interested in the measurement of the *surplus* from the plots in question as the early classicists had imagined, and in exploring its ability to sustain the labour working on it.

For calculating the hired out days in crop cultivation we have included only the 'off-farm work', 'exchange labour', and 'other general farm'.[40] Hired out labour hour data, however, were made available on the basis of two categories, men and women, as in the case of data on the household managed crop cultivation, stated above. Again, like the previous instance, the total seasonal hired out labour hours were equally divided to all the members of the household, with crop cultivation as an occupation, for each category.[41]

For the 'maintenance cost' of the 'exchange labour' and 'hired labour', we had made some assumptions as stated in the illustration above while defining the four scales of sustainability. Besides the assumption of two unemployed days for every active day during the season, it may be noted that no Calorie was added for the maintenance of labour for management. For every inactive day, Calorie requirements were assumed as 2,400 Cal per male labourer and 1,900 Cal per female labourer respectively.[42] Identical assumption was held for other seasons as well.

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[40] Fishing was excluded, from the types of activity, included in CCS WB 2004–05.

Record type 733 that contained the hired out data, included month-wise information and not the seasonal one. July–November was taken as season 1, December–March as season 2, and April–June as season 3.List of other types of activities with hired out, has been included in Appendix E.

[41] This fact was exemplified by the multiple entries on a single month within a particular sub-category. Admittedly, while this assumption may appear stringent at this level, once we aggregate the surplus at the level of the household in scale C, overestimation and underestimations will cancel each other.

[42] Following table 2.3.2, Calorie requirements per non-active days for female labourers were 1,872 Cal per day and 1,920 Cal per day.

3.2.3.3.1. Length of the Season in scale(s) B and C

2004–05 dataset provided month-wise information on different agricultural operations against every PSC, and not the week-wise information. Accordingly, we had taken the middle of the month(s) as the temporal markers for delineating the season.[43] Arguably, rather than the conventional assumption of fixed temporal markers against the duration of the season, accommodation of this variation certainly was more useful.[44] Such variations have been captured in table A.3.2.3, constructed from the data on the crop'operation hours. It portrays the monthly 'incidence' of labour against the variety of operations across seasons.[45]

More specifically, the duration of season was taken from the middle of the 'preparatory tillage' month to that of the 'transportation on farm' or 'guarding', being the first and the last activities respectively, chronologically speaking. However, there were temporal variations even for the same operations, including the 'month-planted' between the plots under the management of the same household cultivating the identical crop within the same season. The longest plotwise length was taken as the duration of the season, for all the plots under the same household.

3.2.3.4. *Calorie Value for Human Labour in scale C*

In this scale, the Calories necessary for the replacement of the labour power were to be added, over and above the requirements in scale B. In other words, we will consider the necessary energy income for the dependents. Further, by construction, the Calorie requirements for the dependents were 'modified' with the individual member's 'percentage of time living at home'. Based on the seasonal duration, the table 2.3.2, the total Calorie requirements for the households were calculated.

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[43] For example, 'month-planted=6' was interpreted as June 15.

[44] In other words, instead of the usual assumption of July–November, November–April, and March–July as seasons 1, 2 and 3 respectively, as done by the CCS, we had taken seasons to be of variable length, though within a range. This assumes further importance from the division of season 2, as stated earlier. However, for separating the hired out labour days data, or to account for the dung from the animals of the households, we had to make separate assumptions regarding the length of season (see footnote 30 above).

[45] Apart from the time period differences, it may be of interest to note the spread of 'other' operations across seasons. While in the less human managed season 1, it could be found more concentrated towards the edges of the season, in season 2 it was distributed more uniformly through the entire period. Further, the number was also less in the 'more controlled' season 2 than the season 1, notwithstanding the lesser number of plots.

3.2.3.5. *Animal Labour*

Information on the animals belonging to the households managing the farms was collected from RT 310. Table(s) A.3.2.4 and A.3.2.5 portray some of the salient characteristics. Interestingly, all the reported animals were found to be within the category of 'owned and managed' and not in either 'taken in and managed' or 'given out, not managed'. However, there existed varieties in the management of animals, with implications on the sources of feed. This assumes importance from the point of view of Calorie calculations. In particular, certain assumptions were made regarding the respective sources of green/dry fodder and other inputs shown in table 3.2.2.

Table 3.2.2: Varieties of Management of Animals and sources of constituents of Feed

Management	Number	Percentage of green/ dry fodder provided by farming household	Percentage of other inputs supplied by farming household
Joint herding, village land	230	50	100
Herding, own land	335	100	100
Stall fed	356	100	100
Run free and fed	121	50	100
Herded and fed	563	50	100
Run free, herd, fed	17	33	100

For the purposes of scale A, only two of the 'purposes' for which animals were kept appeared relevant: power and mixed reasons.[46] Hourly labour data against animals for various activities, and origin (of family, exchange or hired), was made available in the dataset.[47] As by construction, labour by the animals were considered as an activity in scale(s) A and B, total energy cost was calculated by multiplying the number of hours (for all categories) and the per day energy values as noted in 2.4 above. i.e. 17,624 Cal per day.

3.2.3.5.1. Energy Value of Feed and Dung in scale C

In scale C, the energy value of the actual feed for the owned animals was accounted for. Consequently, the Calorie value of the labour provided by the animal in possession of the household, which was taken into consideration in scale A (and subsequently in scale B) was deducted to avoid double-counting. Further, the hired out labour hours were deducted from the consumed feed, pro-rata.

[46] Of the 947, against these purposes, three types of management, namely herding on own land (22.7%), stall fed (13.7%) and herded & fed (30%) accounted for almost two-third.

[47] In DF 27–29, of RT 710.

As captured by table A.3.2.4, of the 1622 animals in possession of the households, purposes of power, milk and 'mixed', accounted for 1588 of them. However, we had considered all 1622, in terms of their feed, dung, labour for upkeep and days of hired out. Further, as noted in the table 3.2.2, additional green/dry fodder was considered according to the type of management.

For feed, the annual consumption was apportioned on the basis of the duration of season for each household (or TTFF). However, the human labour for the upkeep was calculated, with July–November as season 1, December–March as season 2, and April–June as season 3, as was done in the case of hired out human labour.[48] Identical temporal demarcations were used in the case of hired out animal days and dung, as well.

Apportioning the days net of hired out, the seasonal Calorie value was obtained for feed and human labour for upkeep, which was added to the input. Similarly, the energy value of dung was added to the output. The consideration of these inputs and outputs resulted in 'full' seasonal input, 'full' output, and the 'final' surplus.

3.2.3.6. *Material Inputs*

On the basis of each PSC combination, monthly data were made available for all the direct material inputs:[49] seed, seeding, FYM, compost, oil cakes, bone meal, other organic, NPK fertiliser, lime, zinc sulphate, sulphur, other micronutrients, gypsum, herbicide, insecticide, fungicide, and hiring charges for implements. The sheet, <quantities> in the file <scale A.xlsx> contains all the quantitative information on directly used material inputs.

3.2.3.6.1. Crops, types of Seeds and Seedling

Data on the type of seed, i.e. local or improved[50] included information on all the 15 crops. However, the record on the 'Receipt and Disposal of important Crop products' (RT 610) captured only 6: wheat, paddy, potato, mustard and rapeseed, sesamum and jute. Incidentally, these six were the crops selected for the State of

[48] See, footnote 30 above.

[49] RT 712 made available the nature, type and extent of all material inputs, except for the machines (both direct consumption and maintenance), and the type of seed. While DF 7 mentioned the specific input (in codes), DF 12 recorded the quantity and DF 13, the unit.

[50] Included in RT 230.

West Bengal by the CCS in the triennium 2002–2005.[51] This focus often resulted in the systemic neglect of crops other than the selected ones, at every level, from the enumerators at the field to the DES. Thus, the conclusion derived from the CCS data on the crops other than the selected ones shall remain tentative only.

Distribution of the crops across seasons and varieties has been captured in table A.3.2.6 that reveals the predominance of paddy (2398 plots or 70% of the total 3426) followed by jute (305 or 8.9%) and potato (229 or 6.9%), besides the fact that the remaining 12 crops together could cover less than 15% (494).

Barring very few plots where seedlings were applied, in every other, seeds were used. Rates of seed use were clearly based on the tehsils, or the location of the plot, and there was hardly any variation intra-tehsil, within each crop variety.

3.2.3.6.2. Organic Manure

The dataset did not include the data on farmyard manure (FYM) and compost in 13 tehsils.[52] While such absence of use of organic manure may be possible in the coastal saline (zone VI) or the red laterite zone(s) (zone V), certainly it does not hold true for the other zones. Consider, the block of Moynaguri (zone II) that had two tehsils 5 and 7. It is expected that the pattern of input use will be very close to each other. However, in the dataset, while one had substantial use of FYM, for the other it was completely absent. For the remaining 6 tehsils in zone II without any reported use, however, it was difficult to establish the 'error', if any, as barring one, all of them had considerable use of inorganic fertilisers.

In general, there were two kinds of such PSC combinations. First, those with a considerable amount of inorganic fertiliser application, and second, those with some moderate amount closer to the plots that reported use of manure. Clearly, the second is a case of missing data on FYM. Rather than correcting such anomalies, we have continued with them. As we will see below, most of these tehsils were associated with large, if not impossibly high EROIs, pointing to the

[51] The number and type of crops had changed over time, however. For example for triennium 2008–2011, they were Paddy, Wheat, Rapeseed & Mustard, Seasmum, Jute, Potato and Lentil (7), with Lentil being added since 2005–2008 triennium.

[52] They were 6, 7 (both in zone II), 10, 11, 13, 14, 15, 18, 19 (all seven in zone III), 31 (zone V), 41, 44 (both in zone V), and 60 (Zone VI).

absence of some of the inputs. Due to this reason, the results against these tehsils will need to be interpreted cautiously.

Rates of manure use, were greatly varying.[53] It ranged between just 6 and 8,000 kg in physical terms (or just 12.5–30,000 kg/hectare). Interestingly, all the 57 plots that had applied at least 10,000 kg/hectare, were of the size between 0.02 and 0.51 hectare or 0.049–1.26 acres. The lowest size-group in FMS 1956–57 was also 0–1.25 acres.

Only in 5 plots, compost was applied with 100 kg each.[54] In the few plots, bone meal had been applied along with the FYM, as per the practice. In some plots, 'other organic' was applied, along with FYM also. Altogether oil cakes were applied in 151 plots (4–200 kg in absolute terms, or at a rate of 15–1000 kg/hectare, with an average of 138 kg/hectare), and in 101 of them, it was along with the FYM.

It was assumed that FYM contained 25% of water, and accordingly, 1.74 MJ/kg (or 415.6 Calorie/kg) of embodied energy was assumed, following table 2.4.4.[55] For composts, given the variability of its contents and the processes involved, leaf/crop residue and labour in addition to the base FYM, it was assumed to contain 3 MJ/kg of embodied energy. Oil cakes, as stated in table 2.4.3, were considered to contain 18.15 MJ/kg. Bone meals were assumed to contain 11 MJ/kg. For the 'other organic', it was assumed to be putrefied compost as in table A.2.5.6 with NPK ratio of 9:9:9, with an energy content of 12 MJ/kg.[56]

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53 See, column 'rate of manure use' in 'quantities' sheet in <scale Agriculturexlsx>.

54 There are definite reasons for questioning such a miniscule incidence of use of compost, in contrast to FYM. Certainly, it does not conform to the reality. Not only the nutritional and corresponding energy content of the two differ, there are many types of compost as well, even within the farmer-made ones. Perhaps such diversities were difficult to be captured in the 'modern' information systems. Other likely reasons for this absence includes the poor level of farming knowledge on the part of the enumerators and almost complete lack of scrutiny by their superiors. Finally, as the composts were mostly made of various 'freely' available natural components, no importance was attached to them. At the end, we may simply state that, this anomaly had put a downward bias to the inputs and therefore a consequent upward bias to the surplus.

55 The dataset (RT 712) revealed that in approximately 90 % case of FYM use, the source was the farm itself: either it was another component or another activity or storage.

56 Given the production cost of N, P and K (18,400, 3,335 and 2,310 Calories respectively; Mitchell 1979: 75), and content, the total was 9.06 MJ/kg. An addition of 3 MJ/kg for packaging and transportation, was made.

Among the specific nutrients, lime, zinc sulphate, gypsum and other micro-nutrients (OMN) were included. Table A.3.2.7 captures the use of specific soil nutrients across crops. Barring OMN, the rest were used in only a few plots, for which energy values were calculated, in accordance with the coefficients in table(s) 2.5.3 and 2.5.4 above. 10 MJ/kg was taken as the energy cost for its formulation, packaging and transportation for them. Table A.3.2.9 provides the list of nutrients that soils in different ACZs were found to have been lacking in recent times, so as to reveal the identity of the 'otherness' in the OMNs. Table A.3.2.8 provides the distribution of OMNs across tehsils and crops along with the average rates per hectare and the price. For the identity of the 'others', after all the information together, our conclusion is that it was either boron, or boron and zinc together. Against these two possibilities, estimated energy values were found to be 1.91 MJ/kg and 0.6 MJ/kg respectively, computed from table 2.5.4 above; on average 1 MJ/kg was assumed.

3.2.3.6.3. Inorganic Fertilisers

10 types of chemical fertilisers were found to be in use. A few of them were of compound types, for which the respective energy values had been derived, following Mitchell (1979: 76), and Singh and Mittal (1992: 9).[57] At the same time, for the fertilisers based on single nutrients, calculations were also made following the same method, as captured in table 3.2.3.

Table 3.2.3: Energy values of types of chemical fertiliser used (in MJ/kg)

Type (N-P-K)	Production*	Packaging⁺	Transportation⁺	Total
Type A (46-0-0)	30.72	1.20	1.84	33.75
Type B (18-46-0)	17.40	1.66	3.02	22.08
Type C (15-15-15)	12.85	1.05	1.65	15.55
Type D (0-16-0)	1.87	0.42	0.80	3.09
Type E (0-0-60)	4.32	1.08	1.20	6.60
Type F (10-26-26)	11.59	1.40	2.22	15.21
Type G (20-20-20)	17.13	1.40	2.20	20.73
Type H (20-0-0)	13.36	0.52	0.80	14.68
Type J (14-35-14)	14.45	1.53	2.59	18.56
Type K (28-28-0)	21.97	1.46	2.52	25.95

Notes:
* Based on average energy values from table 2.6 (2).
⁺ Based on average of values in proportion to individual nutrients from table A.2.6 (5).

57 The estimates of quantity of individual nutrients, has been provided in table 2.6.2.

Indeed, we had opted for those derived in table 3.2.3 to ensure consistency. Extent of the use of various types of fertilisers has been provided in table A.3.2.10.[58] This table also shows the extent of concurrent use of two or more chemical fertilisers. While it is possible to envisage situations, where a combination of fertilisers was necessitated by the lack of nutrients in soils, the trends indicated something more than that. There had been tremendous variations within the same crop, season and more notably, tehsil. It is beyond the scope of the present work to explore the reasons behind such actions on the part of the farmer-cultivator. An optimality exercise, keeping in mind the variations in the quality of the soil may reveal the extent of 'excessive' use of chemical fertilisers, if any, and may explore the association with negative energy balance for the cultivation as such. However, we may note that, the energy value of the inorganic fertilisers, in contrast to organic ones, against plot area (in ha), gross value of output (in MJ), parcel area (in ha), and CCS size-group, was much less.

3.2.3.6.4. Pesticides

As noted earlier, but for the few tehsils, qualitative information, i.e., name/contents of the pesticides used were not included even in the primary datasheets by the enumerators, despite there being provisions for it. A more serious problem was the almost complete disregard by the enumerators in noting the different varieties of pesticides, as the primary datasheets had records of identical names under herbicides as well as fungicides. Monthly consumption, in fact, had revealed a number of impossibilities like use of insecticides during the site preparation.[59] As a result, a number of assumptions had to be made, to be noted shortly below.

Table 3.2.4: Distribution of plots without pesticides use

Season	Paddy (in no of plots)		Potato (in no of plots)	
	No pesticides	Total	No pesticides	Total
1	1064	1920	N.A.	N.A.
2	77	455	39	229
3	4	23	N.A.	N.A.
Total	1145	2398	39	229

Source: RT 712, CCS WB 2004–05

Nevertheless, the available information, howsoever mixed up, had revealed a few patterns with important consequences for the analysis. Dataset

[58] As noted earlier, fertilisers were the only input, against which information was available on its contents, namely the proportion of the nutrients. It no doubt helped in a more precise estimation of the energy value, unlike for most other inputs, where supplementary information had to be used.

[59] If required, only herbicides or weedicides are used during the site preparation.

had pointed to the absence of *any* pesticides in a substantial number of plots. There were as many as 1145 plots for paddy (48%), and even for potato, there were 17% plots.[60] Distribution of these plots across seasons has been presented in a summary form in table 3.2.4. The seasonal pattern of pesticides use across tehsils for paddy and potato has been presented in table A.3.2.11.

The pesticides usage pattern was in broad agreement with the data on the 'problems'.[61] Distribution of the plots against insect damage across seasons and crops against different type of problems has been presented in table(s) A.3.2.12 and A.3.2.13. The former portrays the plots without any pesticides use, while the latter does the same for all the 2388 plots for paddy and 229 plots for potato. An overwhelming number, 87.31% (2085), of plots for paddy and 77.29% (177) of plots for potato did not report any of the listed problems.[62] It implied two things: first, the confirmation of the year 2004–05 as normal, and second, about the reasonable farming knowledge of the cultivators.[63]

Table 3.2.5: Assumption regarding the range of prices for pesticides

Price Range (in ₹/kg or litre)	Pesticide
15–60	Foratox 10G
63–110	Thimate 10G
150–195	Glytox
200–250	Diathion M 45
252–365	Durspan/Caroban
366–475	Sumidon
500–549	Hostathion
550–599	Thiodan
600–1150	Hinosan
1300–1960	Sencore
2200–4000	Confidor 200SL

Note: The price ranges were used only for identification for the particular pesticides

For the plots showing use of pesticides, supplementary information from what was available in the CCS dataset was used. We may recall here that, only scanty information could be made available by the primary datasheets or researchers at BCKV, as was reported in table(s) A.2.5.3–4. Discussion with the enumerators could reveal that, it was impossible to capture the enormous variety of products, known by their brand or the local names.[64]

60 Paddy and potato were the two dominant crops, and the most important from the point of view of 'energy income' of the human labour. Due to this reason, we had opted for limiting our discussion to these two, instead of including all other crops in this section. However, <scaleA.xlsx> file contains extent of use of pesticides for all crops.

61 As recorded in DF 18 of RT 230.

62 They included drought, flood, irrigation seepage, animal damage, insect damage, disease, wind, cyclone, and storm.

63 This was also corroborated by the data on the harvested percentage. It was at least 95% for 90.29% (3099) plots, with 86.97% (2985) recorded 100%. 6.17% of plots reported harvested percentage between 75% and 94%, while only 7 plots had recorded complete loss.

64 Further, many of the pesticides in use in 2004–05 simply had been discontinued by its producers/marketers later. Neither the enumerators nor the dealers of these products could

Further, as indicated earlier, precise categorisation among the three types of pesticides was not maintained in the dataset. As a result, for the measurement of the corresponding energy values a few assumptions had to be made.

As an alternative to the use of average values, we had used the prices only for the identification of the pesticides. For such a purpose, information on the crop-wise list of standard pesticides as used in 2004–05 in the State and their rates, captured in table A.2.5.4 was used. Range(s) of prices against selected pesticides were decided upon, in consultation with the researchers and field-staff at BCKV, which is shown in table 3.2.5. Accordingly, the pesticides were identified. The corresponding energy values have been derived in table A.3.2.14.

Admittedly, this procedure was rather crude, but despite enormous efforts on the part of the enumerators themselves as well as the research staff, no better method for identification could be found. However, we have also conducted an alternative calculation with the energy values as captured in table 2.5.1 following Mitchell (1979): 101.16 MJ/litre for the insecticides and 147.82 MJ/litre for the herbicides and fungicides. Calculations based on our assumptions were found to be having on average 49.61 MJ (11,870 Calorie) lower energy value, in absolute terms, per PSC, than the one based on the average values. We had opted for retaining the one with lower numbers, which may have contributed to a downward bias in the energy value of the inputs and thus an upward bias in the surplus. For the sake of completeness, both the calculations have been retained in <Scale A workfile.xlsx>. It may be noted that the percentage share of pesticides in total inputs was extremely small. Thus the extent of bias, if any, will be very small.

3.2.3.7. *Machines and Implements*

Distribution of the 'irrigation facilities' among the 2279 parcels has been provided in table 3.2.6. Specific characteristics of such 'irrigation structures' and the other machines at the level of the farming household (i.e. TTFF) have been presented in table A.3.2.15. They included shallow well other than masonry *kutcha* or masonry *pucca*, tubewells, pumping sets, oil engines, electric motors, submersion pumps, tractor, powered cart and power tiller. Table A.3.2.16 provides the distribution of containers, implements and tools at the household level.

in fact recall a number of brands like Obsum or Metaitt 10G, documented in the primary datasheet.

However, ownership of a structure/machine or implements/tools did not necessarily mean its use for each of the seasons, crops and plots; indeed, any use at all. In other words, these data, at best, could only point to the presence of assets but not their use, which is crucial for the present analysis. We may recall that the non-use of any asset resulted in its exclusion from the purview of the EA.[65] For this reason, we had taken machine-hour data as an evidence of the use of machines against each of the plot-season-crop combinations.

Table 3.2.6: Distribution of irrigation facilities across parcels

Type of Facility (code)	No. of parcels
No Irrigation (0)	977
Well (399)	1
Tubewell (499)	582
Tank (599)	32
Canal (699)	189
Pond (799)	55
Canal & Tubewell (802)	144
Tank & Well (803)	1
Other (999)	298
Total	2279

Source: RT 210, CCS WB 2004–05

On the other hand, most of the implements and tools had been ignored, even if they were *in use*, for two reasons. First, many of them were made of naturally available resources like branches of tree, bamboo, logs etc., or with very little material resulting in a miniscule annual depreciation in energy terms. Further, the apportionment of the energy value to the relevant PSC combinations yielded meaningless amounts. Second, many, if not most of the implements, like tins, buckets, baskets, and mugs, served the dual purpose of domestic use as well.

3.2.3.7.1. Material Inputs

Seasonal machine use information in terms of the number of plots and hours has been provided in table A.3.2.17. Predominance of irrigation as the operation was clearly evident, which had been translated into the amount of material consumed. As indicated earlier, energy values for various items were taken as the average of those found in the literature, mentioned in table A.2.6.1. However, material consumption included use in own cultivation as well as the hired out ones. The ratio of machine hours in the two, had been used to calculate the amount of material consumption in own cultivation.

Again, like many other inputs, there had been no information on the consumption of materials for hired and exchanged machines. For these inputs, derived average

[65] Certainly, this non-inclusion of unused assets imposes a downward bias on the energy value of the inputs, and an consequent upward bias on the surplus in energy terms.

per hour energy values, on the basis of household owned machine data, as listed in table A.2.6.2, had been used.

3.2.3.7.2. Maintenance-labour and material

Usually, material used for the maintenance of machines was included along with the one directly consumed during the operation. The associated labour, as stated earlier, was considered as a sedentary activity, and accordingly the Calorie values were calculated: they were 2,400, 1,900 and 2,300 Calorie/day for men, women and children respectively.[66] Again, for the hired machines, average of the household owned machines for each type was assumed, as was in the case of materials. In the calculation, rather than taking the age-specific Calorie values for the household labour, average values as above were assumed. The average values, for both material and labour, in Calorie terms have been listed in table A.2.6.2, against each type of machines.

3.2.3.7.3. Depreciation

In households with more than one machine of a particular type, say, pump set, the combined depreciation was apportioned to all the relevant PSCs, in proportion to the machine hours in use.[67] For the hired machines, and also for those without the required information, the following procedure was adopted for calculating the depreciation.

First, the average age of a given type of machine, say, tractor, was found out, from all such machines owned by the households. Further, given the energy value of the materials used, fabrication and manufacturing, as stated in 2.6.2 above, average per hour depreciation was computed. To illustrate, for the owned tractors, the average age was 7.75 years, and there were two such machines. They were engaged with 548 and 197 hours of use respectively.[68] Corresponding per hour depreciation were 37 MJ and 95 MJ respectively. As a result, 66 MJ/hour was taken as the rate of depreciation for tractors. Identical procedure was followed for every other type of machines. Table A.3.2.18 shows such average

[66] It follows from table 2.3.2, as the average Calorie of both the adult groups, namely, 18-30 years and 31-60 years, for men and women. For non-adults, it was the average of Calorie values for 11-17 years male.

[67] The method was stated in 2.6 above.

[68] The one with the larger number of hours was hired out.

values. The <machine hour energy calculation.xlsx> file shows the relevant calculation for the machines.[69]

3.2.4. Identifier for Data-points

For the analysis, a data point represents the unique combination of tehsil, farm, parcel, plot, season, and the crop. It is represented by TTFFRRPS-C.

First two digits represents the tehsil number (1–28, 30–60),[70] third and fourth are for farm number within the tehsil (1–10), fifth and sixth correspond to the parcel number (1–11), seventh, the plot number (1–4), while eighth depicts season (1–3), and final one represents the crop code (for instance, 20 for paddy, following CCS). For illustration, 18101012-20 represents 18th tehsil, 10th farm, 10th parcel, 1st plot, 2nd season and paddy cultivation.[71]

A household has been represented with TTFF. The first two digits represent the tehsil and it is the farm number for the latter two, as earlier. Each TTFF managed multiple plot-season-crop combinations, or PSC, a shorthand identifier for TTFFRRPS-C.

[69] The file <machine maintenance labour.xlsx> shows the labour calculation separately, as the background work.

[70] Excluding no. 29, which was not considered due to data problems, as stated earlier.

[71] Ideally, the crop identifier would not have been required, and the first eight digits could have been sufficient for representing a unique combination. However, cultivation in West Bengal warrants division of season 2 (October–November to April–May); a vegetable is usually planted-harvested during October to January, followed by seasum or rice between February–May. Thus, the crop code had to be added.

3.3. Quantification of the Surplus

We may recall that in scale A, while the energy values were required to be calculated only for days of 'work' within the season by the living labour on the plot in question, the full seasonal output (of products and by-products) was considered. Thus, agriculture has been regarded as an activity in scale A.[72] On the other hand, scale B, C and the annual one consider agriculture as a livelihood, with differences in their scope and temporal boundaries. In B, it is the individual labourer within the season, while it is the household members and animals during the season again in C; on the other hand, the entire agricultural year is considered within the annual scale.

We shall first explain the calculation in the scale A, for one household selected for this particular purpose, and then we shall explain the calculation in the other two scales before providing the annual calculation. The selected household was the 9th farm in the 30th tehsil (TTFF: 3009). We shall be mainly referring to TTFFRRPS-C 30090111-20, or the paddy cultivation during the season 1, carried out in the first plot of the first parcel, of the household, for the purposes of illustration. However, as stated earlier, the plot-wise surplus calculations will be aggregated at the household level for the purposes of analysis in the next chapter.[73]

This farm belonged to one of the more prosperous blocks of Memari-I in Burdwan district, the paddy belt of the State. Its choice arose primarily from the 7 plots under its management, the fact that it derived benefits from canal irrigation and that it undertook cultivation in two seasons, besides certain other distinct characteristics.[74] The village belonged to (ICAR/DES) zone IV (old alluvial).

3.3.1. Members of the Selected Household

The members of the selected household included 2 adult 'earner' males, aged 67 and 38. Dependents included an adult female and a girl child, aged 27 and 12 years respectively. While all the four members lived at home throughout the year,

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[72] 'Even the treatment of production conditions as mere production 'activities'—each producing unit characterised as a sort of a black box turning inputs into outputs—is not merely restrictive but it positively hinders a meaningful understanding of a concrete situation' (Bharadwaj 1974: 2).

[73] Both plot-wise as well as household-wise calculations are included in the <annual sustainability.xlsx> file.

[74] None of the parcels were divided and thus for this household, parcels were identical to plots.

only the adult male members were engaged with the crop cultivation. Accordingly, Calorie norms were set.

3.3.2. Human Labour in scale A

Calorie value against the use of human (physical) labour for 30090111-20 in scale A has been stated in table 3.3.1.

Table 3.3.1: Measurement of Energy Expenditure by Human Labour in Cultivation of the selected household's sample plot in one season for paddy.

Type of Labourer	No of hours	No of days	Calorie/day	Total Calorie	Total MJ
	(1)	(2) = (1)/6	(3)	(4) = (2) x (3)	(5) = (4)/1000 x 4.18
Household Head	91	15.17	2347	35,596	148.79
Family Men	59	9.83	2822	27,750	116.00
Casual Men	378	63.00	2822	1,77,786	743.15
Casual Women	231	38.50	2280	87,780	366.92
Total	759	126.5	N.A.	3,28,912	**1374.85**

Source: RT 110, 710 of CCS WB 2004–05.

Note:

(1) We have assumed a working day to consist of six working hours, both for animals and human labour.

(2) Column 3 follows table 2.3.2 (age-sex-activity-wise Calorie per day).

(3) While the energy content of food and feed is usually expressed in Calorie, for materials it is Mega Joule or MJ. 4.18 MJ = 1000 Calorie.

The informational/managerial inputs resulted in an addition of 44.5 hours of labour (or, 89.45 MJ of energy).[75] Thus, the total energy value of human labour against 30090111-20 was 1463.30 MJ.

3.3.3. Animal Labour in scale A

The cultivation under 30090111-20 involved a total 28 hours of family draught cattle labour. Animals included two cattle, in the age-group 3 (mature), with both being managed as under 'herding, own land'. As by construction, under scale A only the activity was to be considered, following the discussion in 2.5 above, per day Calorie requirements was considered as 73.67 MJ. Given the involvement of 4.66 days of bullock-pair labour, total energy cost was 687.59 MJ.

[75] For the convenience of using numbers of lower magnitude, all energy units will be expressed in MJ, subsequently. Exception will be food and the feed.

3.3.4. Material Inputs in all scales

3.3.4.1. *Seed, main product and by product*

40 kg of paddy seed was used in the 6th month, on a land with a cultivated area of 0.51 ha for the purposes of 'food and cash'. The seed was of improved variety, and accordingly, 577.50 MJ at the rate of 3,454 Calorie/kg following table 2.5.5 was found to be the embodied energy. Harvesting took place on the 11th month; however, as long as the production was to be considered as an activity, as in the scale A, rather than as a livelihood, as in the scale B, the time duration did not have any role. Total yield included 22 quintals of paddy and 23 quintals of by-products. Corresponding energy values were 31,762.98 MJ and 28,745.86 MJ respectively.

3.3.4.2. *Organic Manure, Chemical Fertiliser, Macro- and Micro-nutrients*

Relevant information on the use of NPK fertiliser (code: 1200) in columns (1)–(5) of table 3.3.2. Using the unit energy value from table 3.2.3 above, total embodied energy was measured. Calorie value of the labour for the application of these as well as every other type of recorded inputs were taken into consideration together, as covered within the illustration in table 3.3.1 above.

Table 3.3.2: Energy content of the chemical fertilisers in selected PSC

Month	Quantity (in kg)	Composition			Energy Content (in MJ/kg)	
		N%	P%	K%	Unit	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (6) x (2)
6	50	18	46	0	22.08	1104
6	40	46	0	0	33.75	1350
7	60	46	0	0	33.75	2025
8	40	46	0	0	33.75	1350
8	8	0	0	60	6.60	52.8
					Total	5881.8

Source: RT 712, CCS WB 2004–05

While no organic manure was used in the representative PSC combination, the process of accounting was identical to the one mentioned above for the chemical fertilisers. For instance, 30091012-20 managed by the same household used 80 quintal of FYM and 'other organic' of 200 gm. Accordingly, the energy values were measured at the rate of 1.74 MJ/kg and 12 MJ/kg respectively.

3.3.4.3. *Pesticides*

300 cc and 800 gm of pesticides (of 400 gm each) were used with varying prices. Given the assumptions in table 3.2.5 above, and following the energy values in A.3.2.14, the corresponding energy values were computed. Price of 300 cc was corresponding to Sumidon, while the subsequent two, were taken as Diathion M 45 and Durspan/Caroban. Thus, 126.62 MJ was found to be the embodied energy.

Table 3.3.3: Monthly material consumption against owned machines in representative household

Machine being maintained	Physical Input/ payment	Month	Quantity (in litre)
6502	3001	1	153
6502	3001	2	299
6502	3001	3	291
6502	3001	4	232
6502	3001	5	62
6502	3001	6	122
6502	3002	6	2
6502	3001	7	128
6502	3002	7	2
6502	3001	8	125
6502	3002	8	2
6502	3001	9	95
6502	3002	9	2
6502	3001	11	29
6502	3001	12	24
6901	3001	6	45
6901	3001	7	8
6901	3001	7	15

Source: RT 742, CCS WB 2004–05
Note: 6502–Pumping Set, 6901–Power tiller, 3001–Diesel fuel, 3002–Mobil

Table 3.3.4: Hours of pump use, in selected household

TTFFRRPS	Month	Total 'work-hour-machine-of-family'
30090111	all	85
30090112	all	206
30090211	all	50
30090212	all	170
30090311	all	60
30090312	all	169
30090411	all	38
30090412	all	95
30090511	all	85
30090512	all	217
30090512	all	14
30090611	all	67
30090612	all	27
30090711	all	85
30090712	all	200
Total	All	1568

3.3.4.4. *Machines and Implements*

The household was equipped with both canal and tubewell, as far as the irrigation facilities were concerned, with two pumping sets of 5 HP of different vintages and a power tiller. Energy value of the annual consumption of materials was measured against every kind of owned machines. Table 3.3.3 illustrates the annual consumption of all types of physical inputs, against each of the owned machines. For the pumping sets, the annual energy value was 71,075 MJ, while for the power tiller it was 3,082 MJ. Both the sums were apportioned on the basis of the machine hours. A summary of the calculation has been shown in table 3.3.4, for the pumps. First row correspond to the selected PSC combination, totalling 3,853 MJ against use of pumping sets for 85 machine hours. Further, use of 8 hours of power tiller resulted in expenditure of 256.8 MJ. Thus, the total energy value of the material used in the machines was 4,109.8 MJ. In the present case, neither of the owned machines had been hired out. There was no hired machine use, either.

3.3.4.4.1. Maintenance of Machines–material and labour

The materials used, as listed in table 3.3.3 did not include the ones for the maintenance. Total labour energy expenditure for maintenance of power tiller was 21,384 Calorie, and it was 23,760 Calorie for both the pumping sets. Apportionment on the basis of machine hours resulted in 1,782 Calorie (7.46 MJ) for power tiller and 1,288 Calorie (5.39 MJ) against the representative PSC.

3.3.4.4.2 Depreciation of Machines

Total depreciation of 5,073 MJ for power tiller and 1,028 MJ for both the pumping sets were apportioned to yield 422.7 MJ and 55.7 MJ respectively. Together, against the power tiller, the total energy value for its seasonal use in the particular plot was 687 MJ (256.8 MJ for consumption of materials, 7.46 MJ for maintenance by labour, and 422.7 MJ as depreciation). For pumping sets, it was 3,914 MJ (3,853 MJ for the consumption of materials, 5.39 MJ for the maintenance, and 55.7 as the depreciation). All together, all machine uses had resulted in an energy expenditure of 4601.03 MJ.

3.3.5. Results of scale A, for selected PSC

Results of the energy balance analysis in scale A, for the selected PSC has been shown in table 3.3.5. Subsequently, result of all the PSC combinations for the selected household will be shown later in table 3.3.9.

Table 3.3.5: Energy balance analysis for the selected PSC, scale A (all energy values in MJ)

Input groups	Human Labour	1467
	Animal Labour	689
	Pesticides	127
	Fertiliser	5891
	Machines	4609
	Rest of the inputs	578
	Total	13361
Output	Main Product	31816
	By-product	28794
	Total	60610
Surplus (Output-Input, both in MJ)		**47249**
EROI (Output in MJ/Input in MJ)		**4.54**

3.3.6. Human Labour in Scale B

For both the earners in the selected household, there was no hired out labour. While in the selected PSC, the season was of 120 days duration, as noted earlier, there were other plots managed by the same household, within the same season with cultivation duration of 150 days. Thus, by construction, the necessary Calorie for the maintenance of labour was required for the unemployed days during the season of 150 days. The total amount was to result from all the seven plots of land under cultivation within the season. Plot-wise analysis necessitated apportionment of this requirement of Calorie. We had used area under cultivation for this purpose. Identical method of apportionment will follow for Calorie requirements for the dependents in scale C, feed for animal in scale C as well attribution of dung output in scale C.

Table 3.3.6: Distribution of area under cultivation in season 1 for selected household

Parcel	Plot	Season	Area under crop (in ha)	Share
1	**1**	**1**	**0.51**	**16.83**
2	1	1	0.46	15.18
3	1	1	0.38	12.54
4	1	1	0.26	8.58
5	1	1	0.51	16.83
6	1	1	0.4	13.20
7	1	1	0.51	16.83
Total			3.03	100.00

The selected PSC accounted for 16.83% of the cultivated area under the management of the household in season 1, as shown in table 3.3.6. Thus, for the 'non-active' days or the days of 'rest' within the season, this plot was expected to generate 16.83% of the Calorie required, so as to sustain the labour working on it.

For the selected household, one of the earners (household head) had spent 331 hours, or 55 days in 7 plots together, during the season 1. Thus for this labourer, the representative PSC was to 'supply', albeit notionally, 16.83% of the Calorie requirements for the remaining 95 days of sedentary activity. The other earning member of the household was engaged with 396 hours or 66 days or work. Thus in his case, the representative PSC was to provide 16.83% of the Calorie requirements of 84 days of sedentary activity. Given 94.83 days of sedentary activity for the household head, 84 days for the other male member, and respective calorie values from table 2.3.2,[76] the total additional energy for their maintenance was found to be (94.83 x 1976 + 84 x 2376 Calorie=) 3,86,975 Calorie. Table 3.3.7 explains the calculation, for the selected household.

[76] For male adults within an age-group of 31-60 years Calorie requirements for non-active (sedentary) days is 2376 Cal/day. For the elders aged beyond 60 years it is 1976 Cal/day.

Table 3.3.7: Calculation for days of Calorie for maintenance of labourers of selected household			
Row no.	Item	Operand	Days
1	Length of Season		150
2	Hired out days Season 1		0
3	No of days, Head of Household		55.17
4	Additional days for Head	= row1 – row3 – (row2/row12)	94.83
5	No of Family Men cultivator other than head		1
6	Total days Family Men		66
7	Additional days per Men	= row1 –row6/row5–(row2/row12)	84
8	No of Family Women cultivator other than head		0
9	Total days Family Women		0
10	Additional days per Women	= row 1 – row9/row 8 – (row2/row 12)	0
11	No. of days, servant		0
12	Total family members in crop cultivation including servant		2

Table 3.3.8 explains the calculation of Calorie requirements for the maintenance of hired-in labour and labour in exchange. Thus the total additional energy for the maintenance of labour power was 30,23,208 Calories for the entire season 1, consisting of 3,86,975 Cal for household labour and 26,36,233 Cal for the hired labour. Apportioning it to each of the 7 plots on the basis of plot area resulted in 5,08,856.8 Cal (or 2,127.02 MJ) for the selected PSC (first plot) for which illustration calculation are being made.

Table 3.3.8: Calculation of Calorie for maintenance of hired/ exchanged labourers in selected PSC				
Type of labour	No of days	Additional days for maintenance	Per inactive day Calorie requirement	Additional Calories
	(1)	(2) = 2 x (1)	(3)	(4) = (2) x (3)
Work day exchange men	0.00	0.00		0
Work day exchange women	1.17	2.33	1,900 Cal/day	4,433
Work day casual men	363.83	727.67	2,400 Cal/day	17,46,400
Work day casual women	233.00	466.00	1,900 Cal/day	8,85,400
			Total	**26,36,233**

Note:

(1) One working day consisted of six working hours.

(2) The selected household did not have any woman with Crop production as an occupation. As a result, in case of the 'exchange women', for the unemployed days was assumed, average Calorie requirements of 1,900 Calorie per day were assumed as for the casual labourer.

(3) For casual labour, Calorie values follows the assumption stated during the derivation of the surplus at the beginning of this chapter. Following table 2.3.2, Calorie requirements per non-active days for male of 18-30 years and 31-59 years were 2,424 and 2,376 Cal respectively. Calorie requirements per non-active days for female labourers were 1,872 Cal per day and 1,920 Cal per day. The average Calorie value(s) were taken, approximated to the nearest hundred.

3.3.7. Results of scale B for selected Household

Results of the energy balance analysis in scale B have been presented in table 3.3.9. The variations in the EROI may be noted across plots. The last row include the EROI for the household, obtained by dividing the total output by total input in the scale. On the other hand, average of the plot-wise EROIs were 4.53 and 3.89 respectively for scale A and B respectively. Construction of such an average will reflect the weight of each EROI. With vastly different EROIs across PSCs, this 'weighted' average may not reflect the correct average. The difference between the two types of average, in this case of the selected household was minor, because of very small variation in the per PSC EROIs. This was not the case for most other households.

Table 3.3.9: Energy balance analysis for the selected household, scale B, season 1

TTFFRRPS	Input in scale A (in MJ)	Additional MJ in scale B	Input in scale B (in MJ)	Output, in scale A (& B) (in MJ)	Surplus, scale A (in MJ)	Surplus, scale B (in MJ)	EROI, scale A	EROI, scale B
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=(4)-(1)	(6)=(4)-(3)	(4)/(1)	(4)/(3)
30090111	13361	2127	15488	60610	47249	45122	4.54	3.91
30090211	11551	1918	13469	55214	43663	41745	4.78	4.10
30090311	9932	1585	11517	41723	31791	30206	4.20	3.62
30090411	6229	1084	7313	30305	24076	22992	4.87	4.14
30090511	12905	2127	15032	55214	42309	40182	4.28	3.67
30090611	10246	1668	11914	44422	34175	32507	4.34	3.73
30090711	12602	2127	14729	59358	46757	44630	4.71	4.03
Total	**76827**	**12637**	**89464**	**346846**	**270020**	**257383**	**4.51**	**3.88**

It may be emphasised here that while the scatter diagrams (to follow) for all households/plots will reflect the 'complete' picture, for the purposes of analysis we will be using tabular representation. In the latter households and plots will be grouped together on the basis of NCA, GCA, gross output or location, where the intra-group variation will not be visible.

3.3.8. Results in scale C for selected Household

Based on the duration of the season, and the unit Calorie values from table 2.3.2, total Calorie requirement for the dependents in season 1 was found to be 2,448 MJ.[77] On the basis of the share of the plot area under selected PSC (16/83%) of the total area under cultivation in season 1, the corresponding Calorie

[77] 100% of (1,872 Calorie/day + 2,032 Calorie/day) x 150 days

requirements (16.83% of 2,448 MJ= 411.9 MJ) was calculated. The energy values of annual feed and the labour for the upkeep of animals, in accordance with the seasonal duration of 150 days, was added in this scale C. Total labour upkeep [78]

Total annual material consumption was 1,31,375 MJ, and thus for the duration of the season of 150 days it was 54739.58 MJ. Labour upkeep on the other hand for this season was 1247.76 MJ. Apportionment of these two inputs in scale C based on the share of the plot area (16.83%) yielded 9213.59 MJ and 210.02 MJ respectively, against the selected PSC, 30090111-20. On the other hand, Calorie requirements for animals on the basis of the number of working days, that we had accounted for in scale A was deducted to avoid double counting. It was 687.59 MJ against 4.66 working days (see, 3.3.3 above). Thus the net additional input for the first plot owing to animals in scale C was (9213.59 + 210.02 – 687.59=) 8736.02 MJ, as captured in row 4 of table 3.3.10.

Table 3.3.10: Energy balance analysis for the selected household, scale C, season 1

TTFFRRPS	Input, scale A (in MJ)	Input, scale B (in MJ)	MJ for depen-dents, scale C	MJ for animals, scale C	Input, scale C (in MJ)	Output, scale A (and B) (in MJ)	Output, scale C (in MJ)	Net addition due to animals (in MJ)	EROI		
									Scale A	Scale B	Scale C
	(1)	(2)	(3)	(4)	(5) = (2)+(3)+(4)	(6)	(7)	(8) = (7)-(6)-(4)	(6)/(1)	(6)/(2)	(7)/(5)
30090111	13361	15488	412	8736	24636	60610	73486	4140	4.54	3.91	2.98
30090211	11551	13469	372	7886	21727	55214	66828	3728	4.78	4.1	3.08
30090311	9932	11517	307	6481	18305	41723	51318	3113	4.2	3.62	2.8
30090411	6229	7313	210	4657	12180	30305	36869	1908	4.87	4.14	3.03
30090511	12905	15032	412	9227	24672	55214	68090	3649	4.28	3.67	2.76
30090611	10246	11914	323	7391	19629	44422	54521	2708	4.34	3.73	2.78
30090711	12602	14729	412	9178	24319	59358	72234	3698	4.71	4.03	2.97
Total	**76826**	**89462**	**2448**	**53556**	**145468**	**346846**	**423346**	**22944**	**4.51**	**3.88**	**2.91**

Note:
(1) Energy value of dung in season 1 was 76,500 MJ, shown as the difference between column total of (7) and (6).
(2) Duration of the season was taken as 150 days. Accordingly Calorie values for the maintenance of dependents and animals during the unemployed days was calculated only for 150 days.
(3) EROI of each of the scales were arrived at from the total output and total input in the respective scales.

Further, 7 animals in the household's possession had contributed significant amounts of dung, all of which was used in the crop cultivation of the household. Energy value of the dung for the selected household in season 1 and 2 was 76,500 MJ and 45,900 MJ respectively. For the remaining period of the year it was 45,900 MJ.[79] As a result, 'full' output of the household in energy terms was

[78] See, <scale C.xlsx> for the calculation of all the PSCs.
[79] see, 'Dung' sheer in <animals for scale C.xlsx> where monthly dung output was aggregated for each of the periods.

enhanced. Likewise, the output of each individual plot was also increased, following the apportionment based on plot area. Results have been presented in table 3.3.10.

The proportional increase in input (around 58% on average) was much more than the increase in output (around 22% on average), as a result of which EROI had recorded a fall.[80] Admittedly, milk outputs had not been considered, inclusion of which may have retarded the extent of reduction.

3.3.9. Annual Sustainability of selected Household

The selected household had carried out cultivation in all the plots in season 2, like in season 1. However, in season 3, there was no cultivation or any hired out of household labour or animals in its possession. It follows that, the annual surplus will consist of three terms: (a) surplus of scale C, in season 1, (b) surplus of scale C, in season 2, and (c) the Calories necessary for the members of the household and the animals for the agricultural year as a whole over and above what has already been provided for in scale C. We may begin with the last one.

Following table 2.3.2, total per day Calorie for the non-active days for the four household members was 8,200 Calorie or 34.33 MJ/day.[81] Presence of 7 animals resulted in a further addition of 250.11 MJ/day, following table 2.4.2.[82] Thus, the total energy requirement for the maintenance of members and animals in possession of the household was 284.5 MJ/day.

Further, while the hired out labour (both human and animal) days were deducted from the required energy income during this period,[83] the energy value of dung had been added, for the household. It may be noted that the depreciation of the owned machines, unused during these periods of inactivity had been ignored, and similarly the maintenance cost, if any.

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[80] However, there were households for which scale C EROI was higher than the scale B ones. We will discuss this aspect in the next chapter.

[81] We may recollect that every member of the household was living 100% time at home. Thus, there was no scope for any moderation of the requirement. The per day Calorie values for unemployed days are 1,920 Cal, 2,376 Cal, 1,872 and 2.032 Cal respectively. Total is 8,200 Cal.

[82] 35.73 MJ/day x 7.

[83] In the present case hired out days for the earners and the animals was nil.

Quantification of the input, output and surplus in season 2 was done in an identical manner as illustrated above for season 1. Interestingly, the fifth plot was used twice during the season 2 (see, bottom part of the table 3.3.11 (a)).[84] As a consequence, the 0.51 ha of land was used thrice during the agricultural year 2004–05. Table 3.3.11 shows the summary calculation for the annual sustainability calculations for the selected household.

Table 3.3.11: Annual sustainability of the selected household (input, output and surplus are in MJ)

(a) Plot-wise energy balance analysis, for the cultivated period

Season	TTFFRRPS	30090111	30090211	30090311	30090411	30090511		30090611	30090711
Season 1	Crop	20	20	20	20	20		20	20
	Plot area (in ha)	0.51	0.46	0.38	0.26	0.51		0.4	0.51
	No. of days	150	150	150	150	150		150	150
	Input, scale C	24636	21727	18305	12180	24672		19629	24319
	Output, scale C	73486	66828	51318	36869	68090		54521	72234
	Surplus, scale C	48850	45101	33012	24689	43419		34892	47916
Season 2	TTFFRRPS	30090112	30090212	30090312	30090412	30090512	30090512	30090612	30090712
	Crop	20	20	20	20	20	20	210	20
	Plot area (in ha)	0.51	0.46	0.38	0.26	0.51	0.51	0.4	0.51
	No. of days	120	120	90	120	90	90	60	120
	Input, scale C	160133	22467	19008	13358	29409	29409	82304	26547
	Output, scale C	98737	71133	68310	50079	96043	96043	7126	98909
	Surplus, scale C	-61396	48665	49301	36721	66633	66633	-75177	72361

(b) Seasonal and annual sustainability

Description	Season 1 (1)	Season 2 (2)	Non-active period (3)	Annual (4)
Length in days	150	120	90	360
Input	145468	382636	25650	553754
Output	423346	586379	45900	1055625
Surplus	277879	203743	20250	501872
Area under Cultivation (in ha)	3.03	3.54	Nil^	6.57
EROI = Output in MJ/input in MJ	2.91	1.53	1.79*	1.91

Note:
(1) Input, output and surplus, in energy terms and area under cultivation for both the seasons, in columns 1 and 2 have been taken from the sum of corresponding row total(s) in part (a) of the table.
(2) In column 3, input is obtained by multiplying per day Calorie requirement of members and animals in possession of the household by the number of days, i.e. 285 MJ/day x 90 days = 25650 MJ.
(3) Output in column 3, was consisted of only dung, with an energy value of 45,900 MJ.
(4) An EROI of more than 1, during the non-active period marked with a * shows that the presence of animals had resulted in a positive surplus even during the non-cultivating period.
(5) ^ Area under cultivation in scale C for the household is identical to the one under the annual scale.

[84] This particular possibility could be found for only one other household. Length of the season was taken as the highest one for the PSC combinations other than the plots with multiple cultivations during one season. Thus, for the selected household, 120 days was taken as the length of season 2.

It may be mentioned here that while all of the scales corresponding to only the cultivation period, it is only in the annual calculation, non-cultivation period was accounted for (see, part (b) of the table). Seasonal surplus and EROI was presented in part (b), along with the annual calculations.

Table 3.3.12 shows the derivation of rate of surplus value, during the cultivating period or scale C, obtained as the ratio of surplus of scale C, in energy terms and the value of labour power or total labour input in scale C, in energy terms.

Table 3.3.12: Rate of Surplus Value, scale C, for the selected household

TTFFRRPS	Scale-wise human labour during season 1 (in MJ)			TTFFRRPS	Scale-wise human labour during season 2 (in MJ)			TTFFRRPS	Scale-wise human labour during season 2 (in MJ)		
	A	B	C		A	B	C		A	B	C
	(1)	(2)	(3)		(4)	(5)	(6)		(7)	(8)	(9)
30090111	1467	2127	412	30090112	952	284	281				
30090211	1270	1918	372	30090212	1657	257	254				
30090311	1066	1585	307	30090312	1122	212	157				
30090411	599	1084	210	30090412	1340	145	143				
30090511	1441	2127	412	30090512	2086	284	211	30090512	2086	284	211
30090611	1131	1668	323	30090612	1414	223	110				
30090711	1353	2127	412	30090712	2030	290	287				

Plot/parcel	Scale-wise human Labour during cultivating period (in MJ)			Total Surplus during cultivated period
TTFFRRP	A	B	C	
	(10) = (1) + (4) + (7)	(11) = (2) + (5) + (8)	(12) = (3) + (6) + (9)	(13)
3009011	2418	4830	5523	-12545.9
3009021	2928	5103	5728	93766.5
3009031	2188	3985	4449	82313.34
3009041	1939	3168	3522	61410.28
3009051	5612	8308	9142	176685.6
3009061	2545	4436	4870	-40285.5
3009071	3383	5800	6499	120277.2
Total	**21014**	**35630**	**39733**	**481621.5**
Rate of Surplus Value, scale C = row 13 total / row 12 total				**12.12**

Table 3.3.13 shows the rate of surplus value in the annual scale that takes into account both cultivating and the non-cultivating period, or the entire agricultural year. It also shows the number of inactive/unemployed days that the annual surplus could sustain the living labour and animals of the household. Alternatively, given that the surplus was 1763 days, the selected household could provide the annual Calorie requirements of nearly five identical households engaged in activities other than crop cultivation.

Table 3.3.13: Rate of Surplus Value, in annual scale and no of inactive days that the surplus can sustain members and animals of the selected household			
Row	Description	Operant	Number
1	Per day Calorie requirements of household members, for unemployed days (in MJ)		34.51
2	Per day MJ of dependents		16.32
3	Number of members of household		4
4	No of earners		2
5	No o days of land in use		270
6	No of days for dependents beyond the cultivating period	=360 – row 5	90
7	Additional Calorie (in MJ) for dependents	row 2 x row 6	1469
8	Hired out days for household labour		0
9	Hired out days per earner	=row 8/row 4	0
10	No of days per earner beyond the cultivating period, net of hired out days	=360 – row 5– row9	90
11	Total Calorie requirements (in MJ) for earners beyond the cultivating period net of hired out days	=(row 1– row2) x row 10	1637
12	Total Calorie requirements for the household members beyond the cultivating period (in MJ)	=row 7 + row 11	3106
13	Total Calorie requirements for the household members during the cultivating period (in MJ)	Table 3.3.12	39733
14	Value of labour power, annual (in MJ)	=row 12 + row 13	42839
15	Surplus, annual (in MJ)	Table 3.3.11	501872
16	Rate of Surplus Value, annual		11.7
17	Daily Calorie requirements for animals in possession of the household, during inactive days (in MJ)		250.11
18	Daily Calorie requirement of members and animals in possession of the household for inactive days(in MJ)	=row 1 + row 17	285
19	Number of inactive/unemployed days the annual surplus can sustain living labour and animals	=row 15/row 18	1763

In the end, we may emphasise once again that in the surplus calculations no account was taken of the property relations. Notwithstanding the fact that bulk of the land under the purview of our analysis belongs to the farmer-cultivator, apportionment of surplus, say, for rent, will certainly reduce the surplus. The surplus derived in the thesis, it may be noted, is in pure energy terms.

In the next chapter, we shall present the results of energy balance analysis of all the 3384 plot-season-crop combinations towards exploring the sustainability of West Bengal agriculture in 2004–05. Before we end this chapter, some of the key indicators for the selected household may be noted in table 3.3.14; we have listed these at the end of section 3.1.3 above, for carrying out the analysis in the remaining 3 chapters.

Table 3.3.14: Summary of indicators for analysis of sustainability of cultivation by the selected household

Description	Scale A		Scale B		Scale C		Annual Scale	
	In MJ	as % of total	In MJ	as % of total	In MJ	as % of total	In MJ	as % of total
Total Input	421393	100.0	436010	100.0	528104	100.0	554208	100.0
Human Labour	21014	5.0	35630	8.2	39733	7.5	42839	7.7
Animal Labour	5701	1.4	5701	1.3	93693	17.7	116691	21.1
Organic Manure	208800	49.5	208800	47.9	208800	39.5	208800	37.7
Inorganic Manure	85657	20.3	85657	19.6	85657	16.2	85657	15.5
All Manure	294457	69.9	-294457	67.5	294457	55.8	294457	53.1
Machine*	89923	21.3	89923	20.6	89923	17.0	89923	16.2
Rest^	10298	2.4	10298	2.4	10298	1.9	10298	1.9
Gross Output	872026	100.0	872026	100.0	1009726	100.0	1055626	100.0
Main product	452436	51.9	452436	51.9	452436	44.8	452436	42.9
By product	419590	48.1	419590	48.1	419590	41.6	419590	39.7
Dung	-	-	-	-	137700	13.6	183600	17.4
Surplus	450632	-	436016	-	481621	-	501418	-
EROI	2.07	-	2.00	-	1.91	-	1.90	-
Labour/ha	3198	-	5423	-	6048	-	6520	-
Output/GCA	132728	-	132728	-	153687	-	160674	-
Surplus/GCA	68589	-	66365	-	73306	-	76319	-
Surplus/NAS	148724	-	143900	-	158951	-	165484	-
Rate of Surplus Value	-	-	-	-	12.122	-	11.7	-

No of members of household	4
No of earners	2
Daily Calorie for members during inactive days	34.5
No of animals	7
Daily Calorie for animals during inactive days	250.1
NAS	3.03
GCA	6.57
NAS/number of household members	0.76
GCA/number of household members	1.64
Cropping intensity	2.17

Note

* includes material used directly and for maintenance, depreciation and labour for maintenance

^ includes seeds, pesticides, micro- and macro-nutrients

> 'The discovery of the *net product*', wrote Mirabeau, 'which we owe to the venerable Confucius of Europe, will one day change the face of the world [...]. The whole moral and physical advantage of societies is [...] summed up in one point, *an increase in the net product*; all damage done to society is determined by this fact, *a reduction in the net product*. It is on the two scales of this balance that you can place and weigh laws, manners, customs, vices, and virtues'. (1932, *Correspondance Générale de J.-J. Rousseau*, T Dufour, ed., Vol. XVII, pp. 171–2, quoted in Meek 1962: 19–20; emphasis as in original)]

In this chapter, the results of the energy balance analysis of West Bengal agriculture will be presented for the agricultural year 2004–05. As noted in the previous chapter, the indicators selected for the present purpose will mainly be surplus, under the four alternative scales of sustainability of this thesis. Other indicators will be used towards explaining its variability, as its augmentation is a necessary condition for the sustainability of agriculture.

We may start with noting the definitive and positive relationship between the annual output (in MJ) and the GCA (in ha) in figure 4.1.1. Figure 4.1.2 plots the annual output (in MJ) and output in scale C (in MJ) against GCA (in ha), aggregated over size-groups.

Figure 4.1.1: Annual output (in MJ) in relation to GCA (in ha)

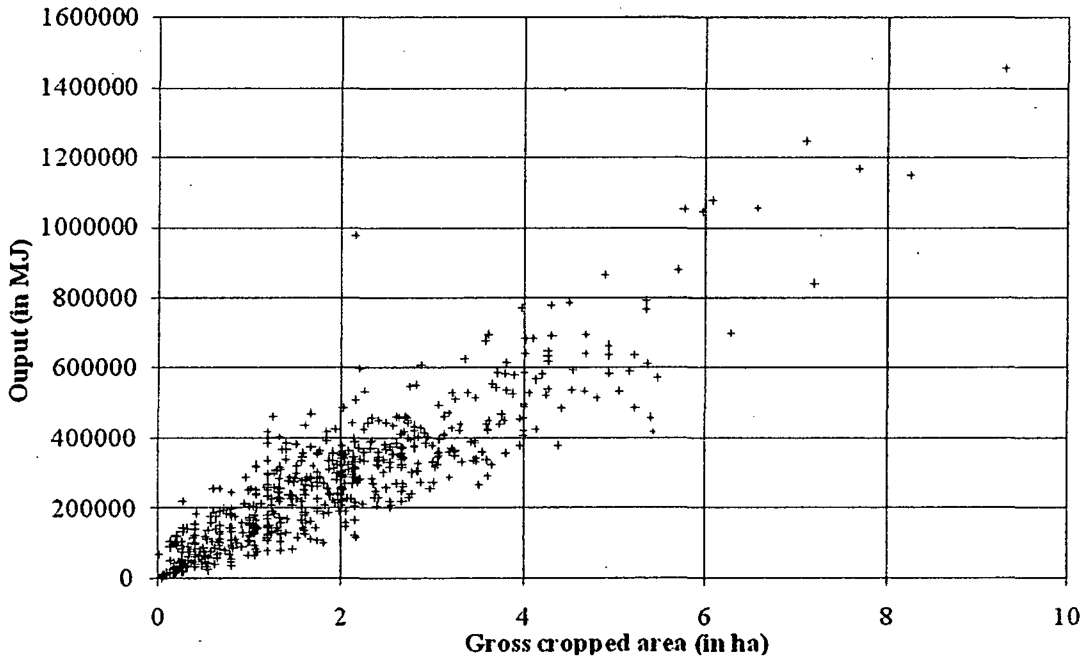
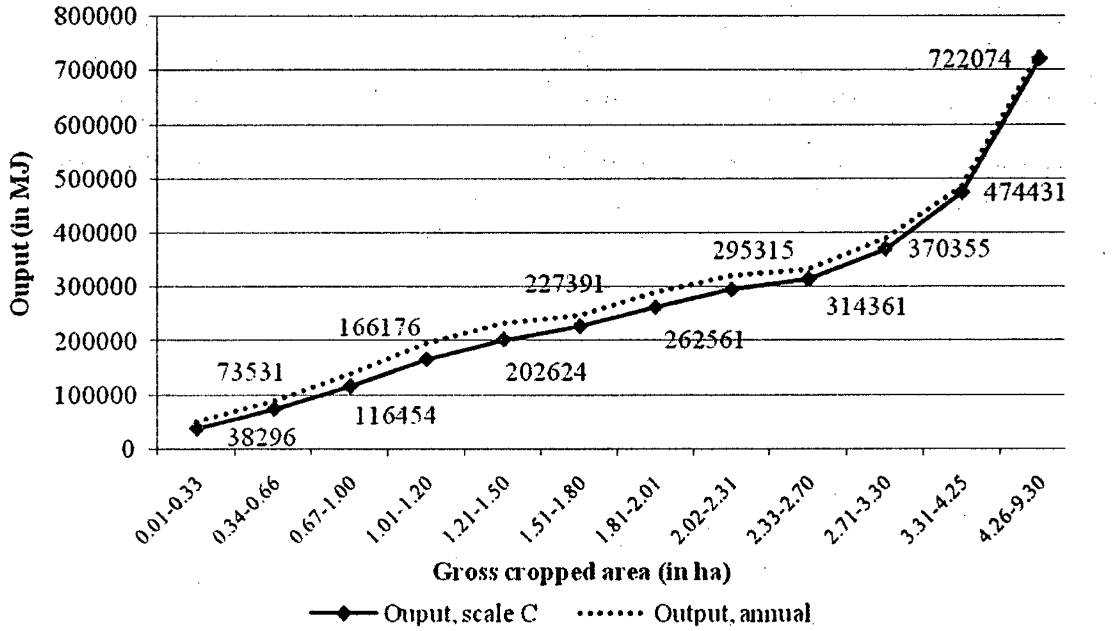


Figure 4.1.2: Annual output (in MJ) and Output, scale C in relation to GCA, aggregated over size group



In figure 4.1.2, corresponding to every size-group,[1] we may observe the difference between the annual output and the output in scale C;[2] as the former takes account of the non-cultivating period apart from the cultivating one, while the latter considers only the cultivating period. The difference arises, due to the inclusion of dung from the animals in possession of the household.

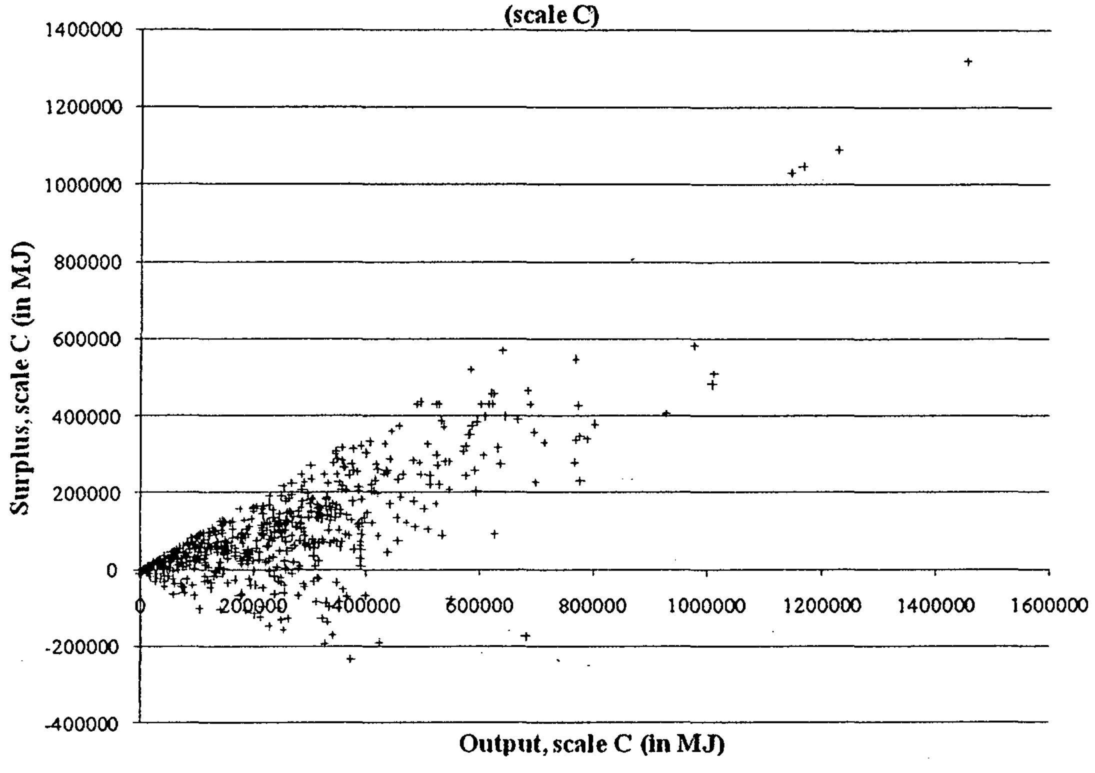
With emphasis on this basic monotonic relationship, which had implications on the question of scale of production, we may proceed further with the rest of the results. We shall begin with the surplus of scale C, in absolute as well as in per hectare terms (4.1), followed by an analysis of the annual sustainability through an analysis of the annual surplus (4.2). Subsequently, the EROI in the four scales of sustainability will be looked into (4.3). Finally, we will analyse the rate of surplus value and per hectare labour under scales of A, B and C (4.4).

[1] The size-group ranges have been delineated with the intention of having a near uniform density. See, table 4.2.1 below for the number of households in each size-group.
[2] See, <annual sustainability.xlsx> in the attached CD.

4.1. Surplus

While we had calculated surplus in all the four scales, for analytical purposes mainly two will be used: of scale C, corresponding to the cultivated period, and the annual one, for the entire agricultural year. We may first note the relationship between the surplus of scale C and the gross output of scale C in figure 4.1.3. One may note the negative surplus in some of the farms corresponding to as high output as 700,000 MJ in the figure.

Figure 4.1.3: Surplus (in MJ) against output (in MJ), in cultivated period (scale C)



Figure(s) 4.1.4 and 4.1.5, represent figure 4.1.3 along with the two additional markers, as stated earlier: CCS size-group and agro-climatic zones. Former represents the area under the command of the household (see, 3.1.3 above), while the latter serves as a proxy for the bio-physical framework, within which crop cultivation took place.

From figure 4.1.4, we may note the obvious concentration of the two lowest CCS size-groups corresponding to a negative surplus.[3] Further, some of the households with a cultivable area within a range of 2–4 ha, also had reported with

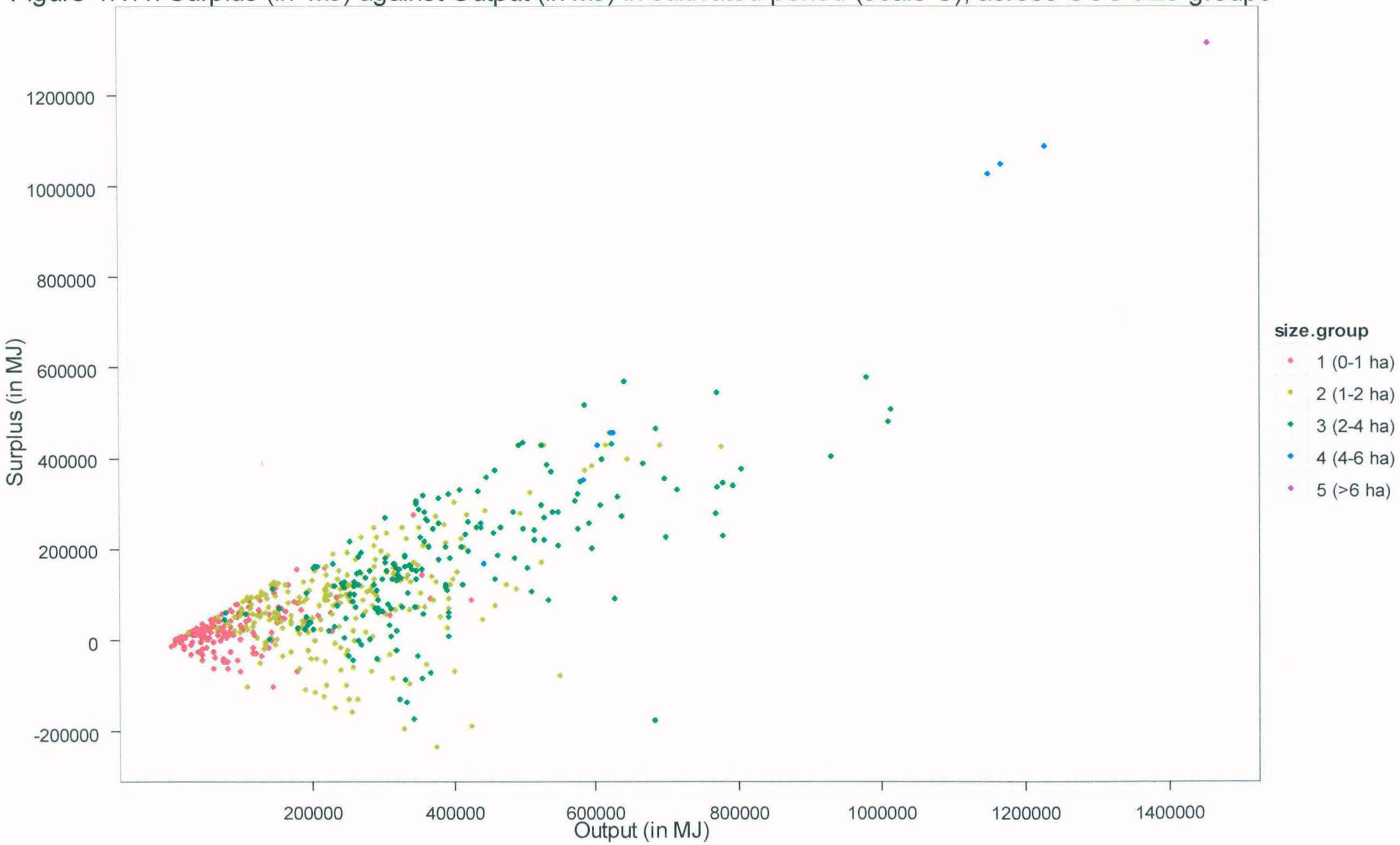
[3] Number of households belonging to each of the CCS size-groups is as follows: 160 (0–1 ha), 237 (1–2 ha), 185 (2–4 ha), 7 (4–6 ha) and 1 (above 6 ha). We may add here that as this categorisation had resulted in a very few number of households in the upper two size-groups, we shall be using our own size-classes, in addition to the CCS one.

a negative surplus. Given the fact that two uppermost size-groups consisted only 8 households, we have found the phenomenon of negative surplus rather universal, so far as CCS size-groups are concerned. In sum, we may state that the minimum output for ensuring a positive surplus during the cultivated period, differs across size-groups. There is, however, a certain size of output at the household level, above which there is no negative surplus.

In terms of agro-climatic zone, as in figure 4.1.5, such negative surpluses could be located in all the five zones. However, the minimum output, beyond which there was no negative surplus differed across zones. For instance, the households belonging to the new alluvial zone, in general, had a positive surplus, barring a few with a very low level of output. On the other hand, those in the old alluvial zone had shown a rather extreme variation: some of the farms have yielded very high output associated with a very high surplus, while some others have reported a negative surplus with as high output as 370,000 MJ. Output from the farms located in the red laterite zone (zone V) was concentrated within a range of 60,000 and 400,000 MJ; nearly half of which had reported a negative surplus. Further, in general, the surplus in zone V was less in comparison to the farms in the coastal saline zone (VI), in spite of producing a similar range of output. Again, like zone V, many farms in zone VI also had reported a negative surplus. Farms in zone II terai, did not reveal any definite relationship. However, of note is the negative surplus associated with relatively higher levels of output, for many farms in this zone. In sum, we may reiterate that the critical minimum output for yielding a positive surplus differed across the bio-physical framework.

Association of a negative surplus with a range of output—differentiated with respect to economic, social, technical, and biophysical characteristics—was also evident from the relationship between surplus and GCA (see, figure 4.1.6). This was obvious though, given the relationship between output and GCA in figure 4.1.1.

Figure 4.1.4: Surplus (in MJ) against Output (in MJ) in cultivated period (scale C), across CCS size-groups



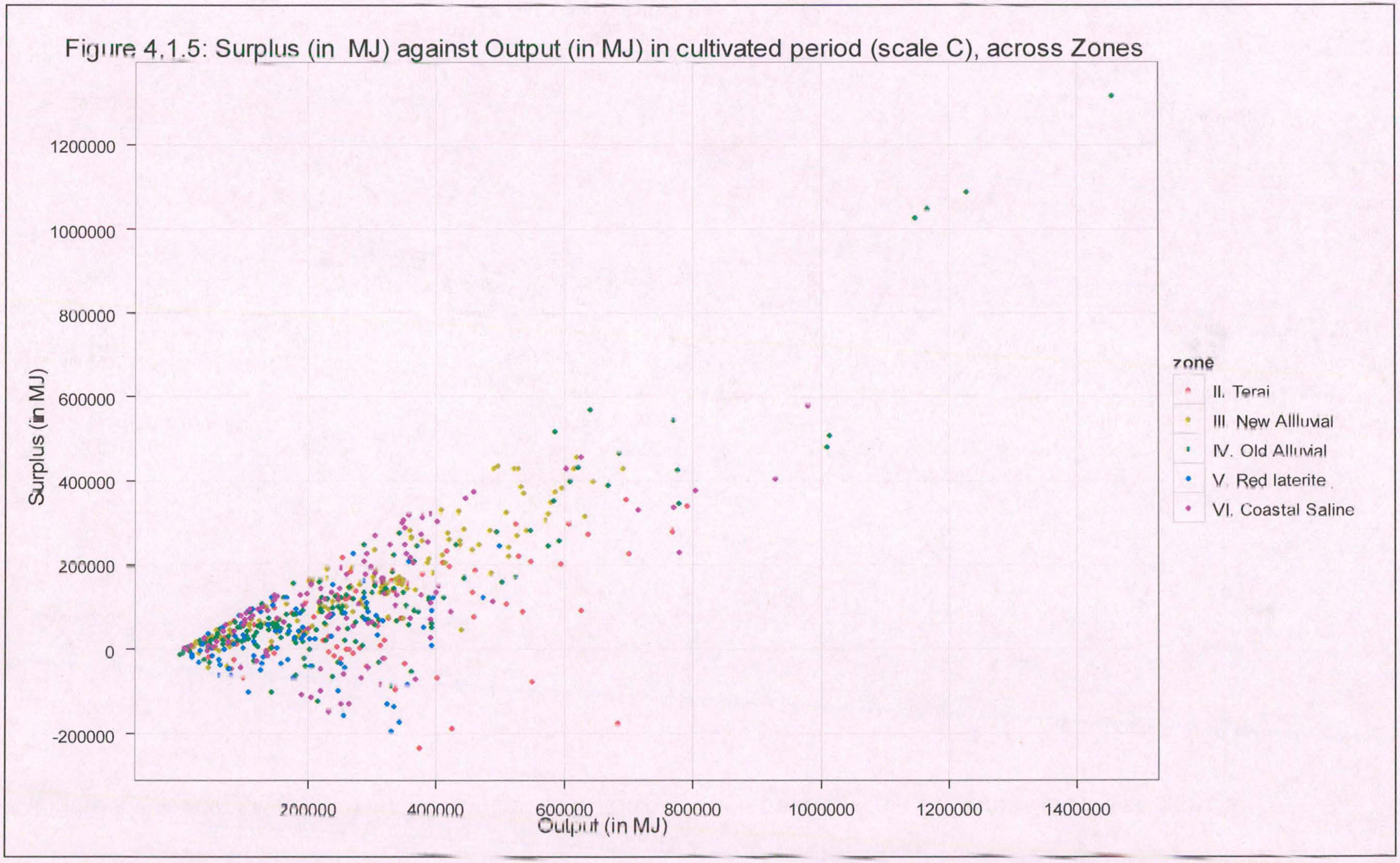


Figure 4.1.5: Surplus (in MJ) against Output (in MJ) in cultivated period (scale C), across Zones
Surplus (in MJ)
1200000
1000000
800000
600000
400000
200000
0
-200000
200000
400000
600000
800000
1000000
1200000
1400000
Output (in MJ)
zone
II. Terai
III. New Allluvial
IV. Old Alluvial
V. Red laterite
VI. Coastal Saline

Figure 4.1.7 plots input, output and surplus against GCA with farms grouped into size-classes: one may notice that the increase in the total input was relatively uniform unlike that of the output.[4] Consequently, surplus recorded a steep rise for the two of our highest size-groups. We may note the slight fall in the surplus against the size-group, namely 1.21 –1.5 ha, due to a steep rise in the total input (figure 4.1.7).

Figure 4.1.6: Surplus (in MJ) in cultivated period (scale C) against GCA (in ha)

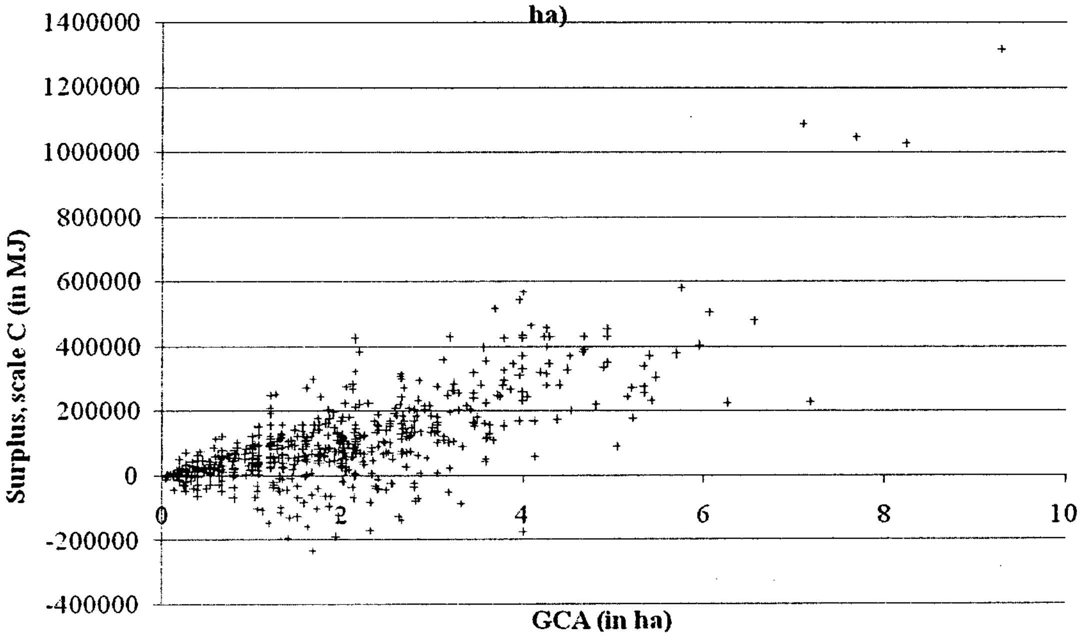
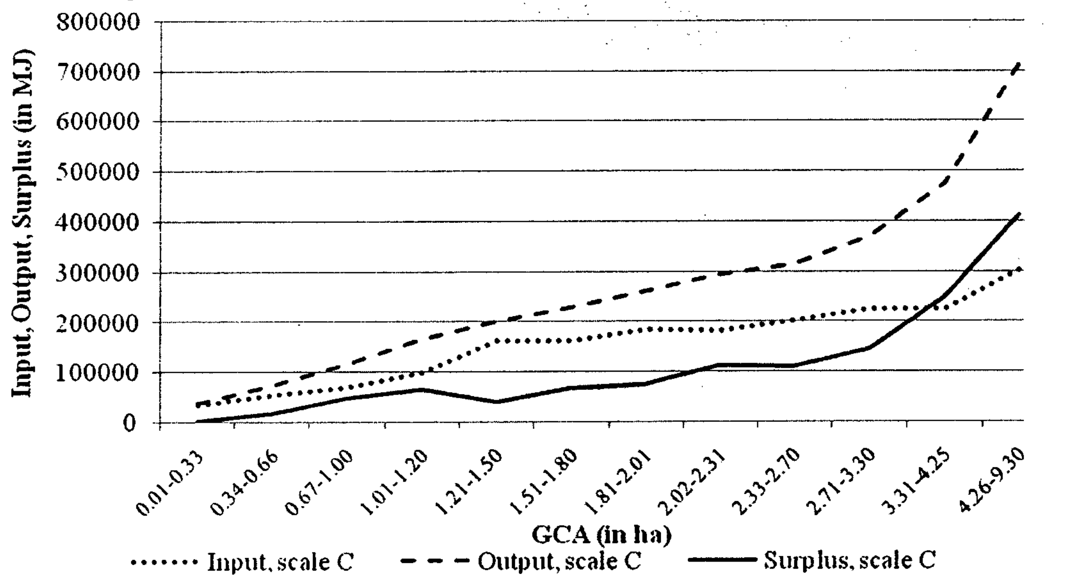


Figure 4.1.7: Input, output and surplus (all in MJ) during cultivated period, (scale C) in relation to GCA (in ha), aggregated over size group



[4] In chapter 4 we shall discuss composition of inputs in a greater detail.

Figure 4.1.8 shows the same relationship as in figure 4.1.6 with CCS size-groups, as the marker; figure 4.1.9 does the same with agro-climatic zones. We may note the minimum gross cropped area for generation of a positive surplus during the cultivated period was around 3 ha (see, figure 4.1.6). Figure 4.1.8 shows it more clearly: most of the households, belonging to the lowest two CCS size-groups, could cultivate a GCA of less than 3 ha, and consequently, several of them produced a negative surplus. For the other three size-groups the relationship between GCA and surplus is identical to figure 4.1.4; among the farms belonging to the third CCS size-group (2–4 ha) there were only a few with a negative surplus while all the 8 households in the other two, as expected, produced a positive surplus.

In figure 4.1.9, like in figure 4.1.5, one may notice the differences in the critical minimum GCA across the agro-climatic zones for ensuring a positive surplus. For the new alluvial zone, as complemented by figure 4.1.5 on the relationship between surplus (scale C) and output (scale C) , the minimum GCA (around 0.5 ha) for ensuring positive surplus was lower than that for the old alluvial, that includes districts of Hooghly and Burdwan (see, figure 3.1.1). For the households in the latter zone, indeed, such a minimum GCA is much higher (more than 3 ha). Together these results imply that while the bio-physical framework, could be an important factor towards the generation of a positive surplus, there are other equally important factors as well. For example, the rate at which surplus could increase with a rise in the GCA in the old alluvial zone was higher than that of the new alluvial zone, which cannot be explained by the natural factors alone. The relationship between GCA and the surplus, for the agriculturally less developed red laterite and coastal saline zones, was identical to the one plotted in 4.1.5; so was for the terai zone as well.

In sum, we may emphasise on two types of thresholds for the sustainability of the labour: one is related to the gross output during the cultivated period (scale C), and the other is to the GCA. Given the relationship between Output, Surplus and GCA (figure 4.1.1 and 4.1.7), these thresholds are connected no doubt. Further, the agro-climatic environment of the crop production system was found to be influencing both these thresholds, along with the other factors.

Figure 4.1.8: Surplus (in MJ) in cultivated period (scale C), against GCA (in ha), across CCS size-groups

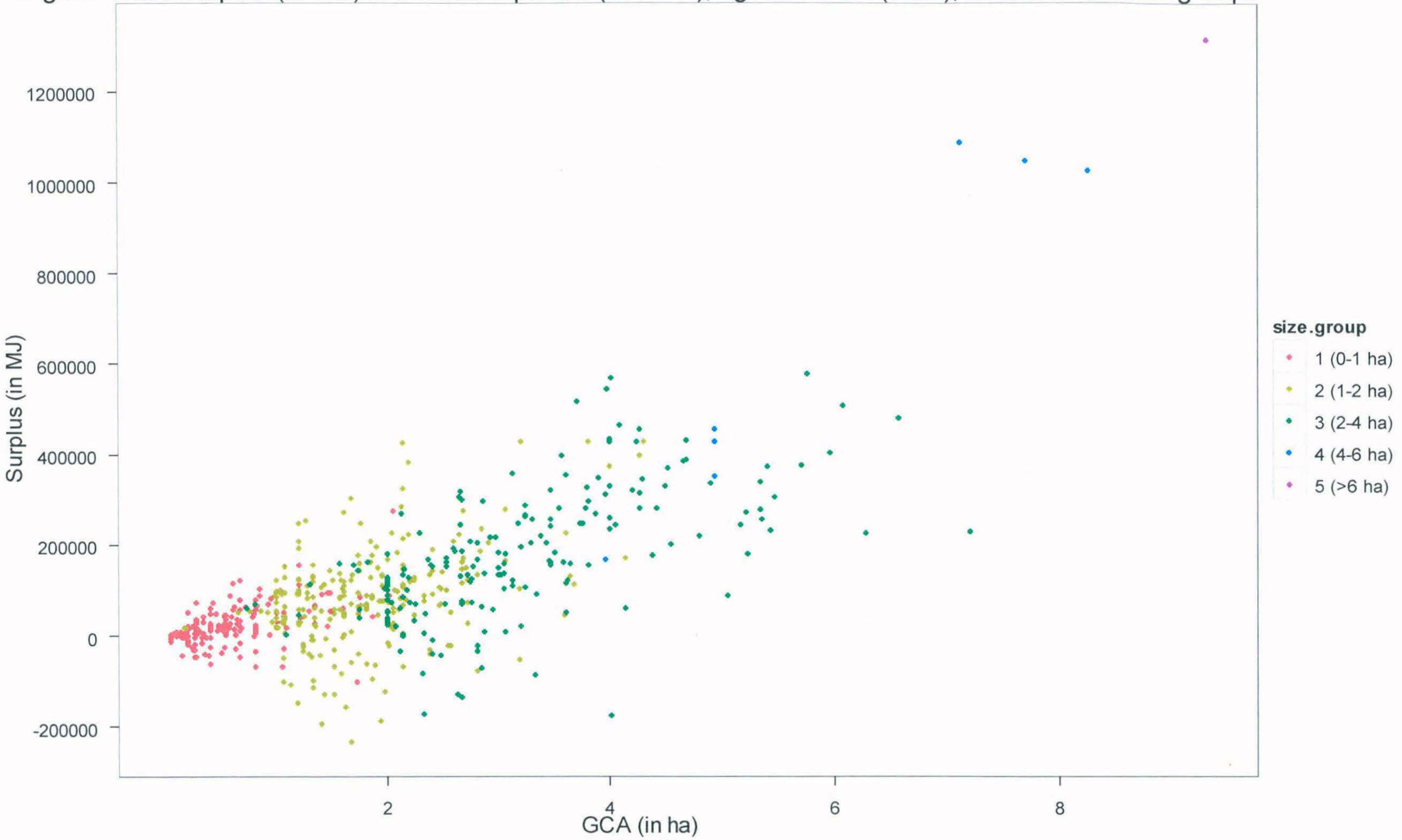
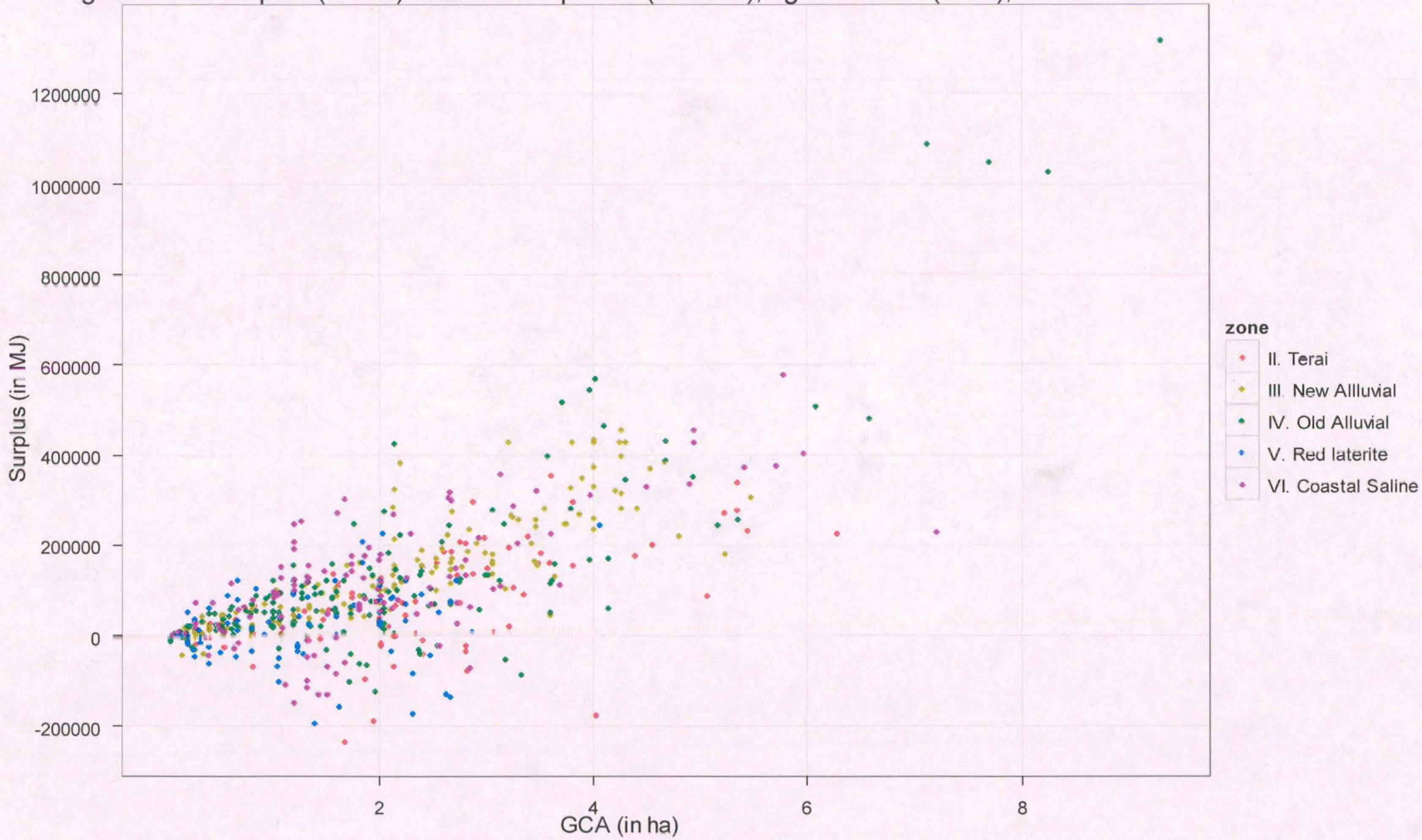
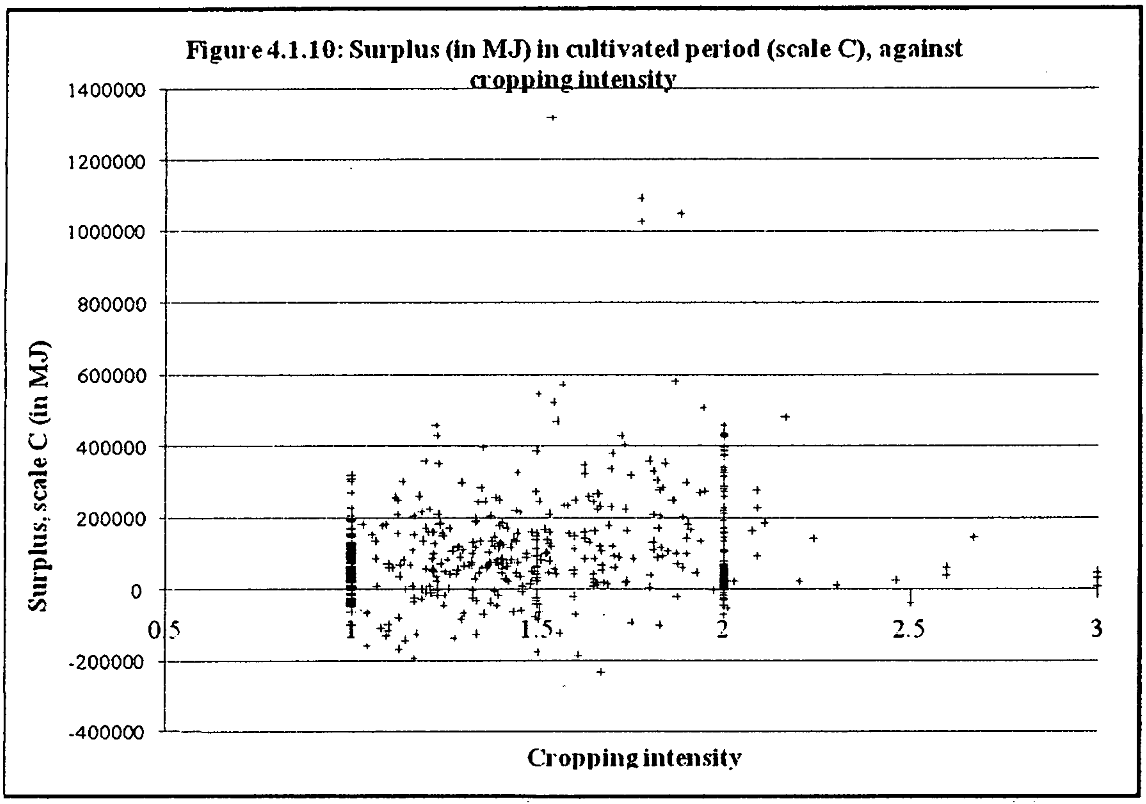


Figure 4.1.9: Surplus (in MJ) in cultivated period (scale C), against GCA (in ha), across zones



4.1.1. Impact of Cropping Intensity on Surplus, Scale C

We may look at the surplus in the cultivated period in relation to the nature of agricultural production, through cropping intensity (GCA/NAS) (figure 4.1.10).



As expected, the highest surplus of scale C was associated with a cropping intensity of around 1.5. With households grouped together on the basis of a range of cropping intensities, the one between 1.5 and 1.8 will correspond to highest average surplus. On the other hand, a cropping intensity of 2.2 and above was associated with a rather low surplus.

Indeed, figure 4.1.11 reveals an interesting picture. Irrespective of the cropping intensity, lower surpluses were associated with the lowest CCS size groups. With a rise in the area of land in possession (as revealed by different CCS size-groups), the surplus increased, notwithstanding the changes in cropping intensity. For example, for the third size-group (2–4 ha), one may notice the initial rise in surplus with cropping intensity, followed by a fall. Similarly, for the second lowest CCS size-group (1–2 ha) the level of surplus across cropping intensities also showed an inverse-U pattern. Interestingly, for a range (1–1.7), against a given cropping intensity, one can notice farms belonging to the second lowest CCS size-group (1–2 ha) with a lower surplus than those from the lowest size-group (0–1 ha). On the other hand, cultivation by the two highest CCS size-groups could yield a distinctly high surplus with cropping intensity range of 1.2–1.8, with the highest corresponding to 1.5. The association of high surpluses with the two highest CCS size-groups irrespective of the cropping intensity shows the benefits of economies of scale. In sum, we may add that, a very small area, irrespective of the cropping intensity (including very high ones) was associated with a very low or even a negative surplus. This is particularly true for lowest two CCS size-groups (0–1 ha and 1–2 ha).

Importance of the agro-climatic environment in the crop cultivation, once again, was shown by figure 4.1.12. Farms in the red laterite and coastal saline zones mostly recorded a cropping intensity of 1, but with a range of surplus ranging from −100,000 MJ to around 300,000 MJ. Figure 4.1.11 (along with 4.1.18),[5] on the other hand, revealed that these were the farms mostly belonging to the three lowest CCS size-groups; those with the negative surplus belonged to the two lowest CCS size-groups (0–1 ha and 1–2 ha). On the other hand, other farms in the same size-group but located in the two alluvial zones (as revealed by figure(s) 4.1.11 and 4.1.12 together), could not only increase cropping intensity, but also yield more surpluses.

In general, one may find that the farms located in red laterite and coastal saline zones could achieve the same amount of surplus with a lower cropping intensity than both the alluvial zones (figure 4.1.12). Further, while the cropping intensities against the farms in the new alluvial zone were greatly varied, the surplus was within a rather narrow band, barring a few exceptions with a very high cropping intensity. On the other hand, for the old alluvial zone, no such range exists: both cropping intensity as well as surplus varied greatly. Once again, for terai, no conclusion could be drawn.

It seems that higher surpluses in the locations with a poor agro-climatic environment and also with a lower cropping intensity, may have resulted from relatively higher contributions from the other inputs, in contrast to the other zones. On the other hand, farms belonging to the lowest CCS size group but located in the new alluvial zone recorded a very low surplus, associated with a very high cropping intensity.

[5] Figure 4.1.8 plots per hectare surplus with cropping intensity, across CCS size-groups.

Figure 4.1.11: Surplus (in MJ) in cultivated period (scale C), against Cropping Intensity, across CCS size-groups

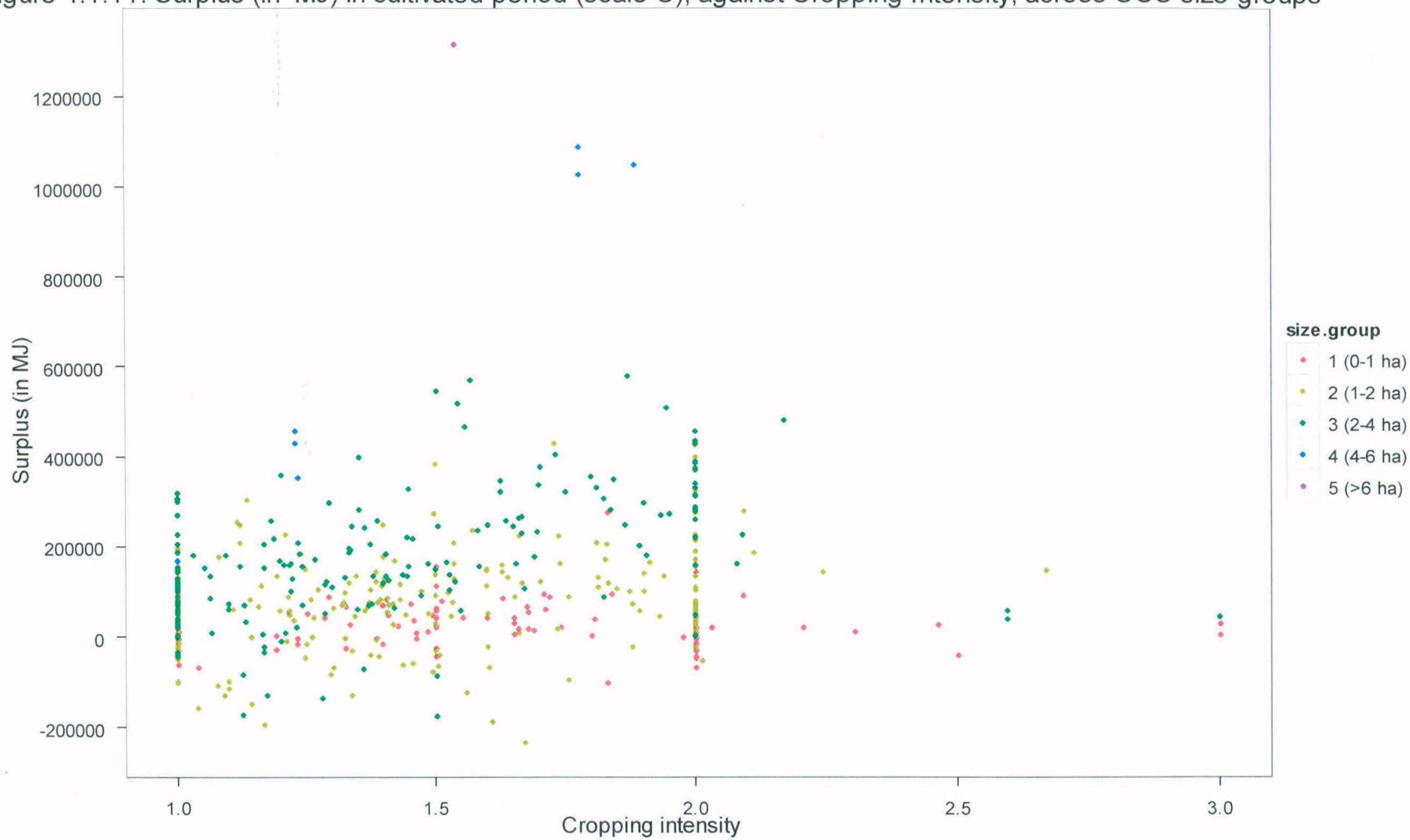
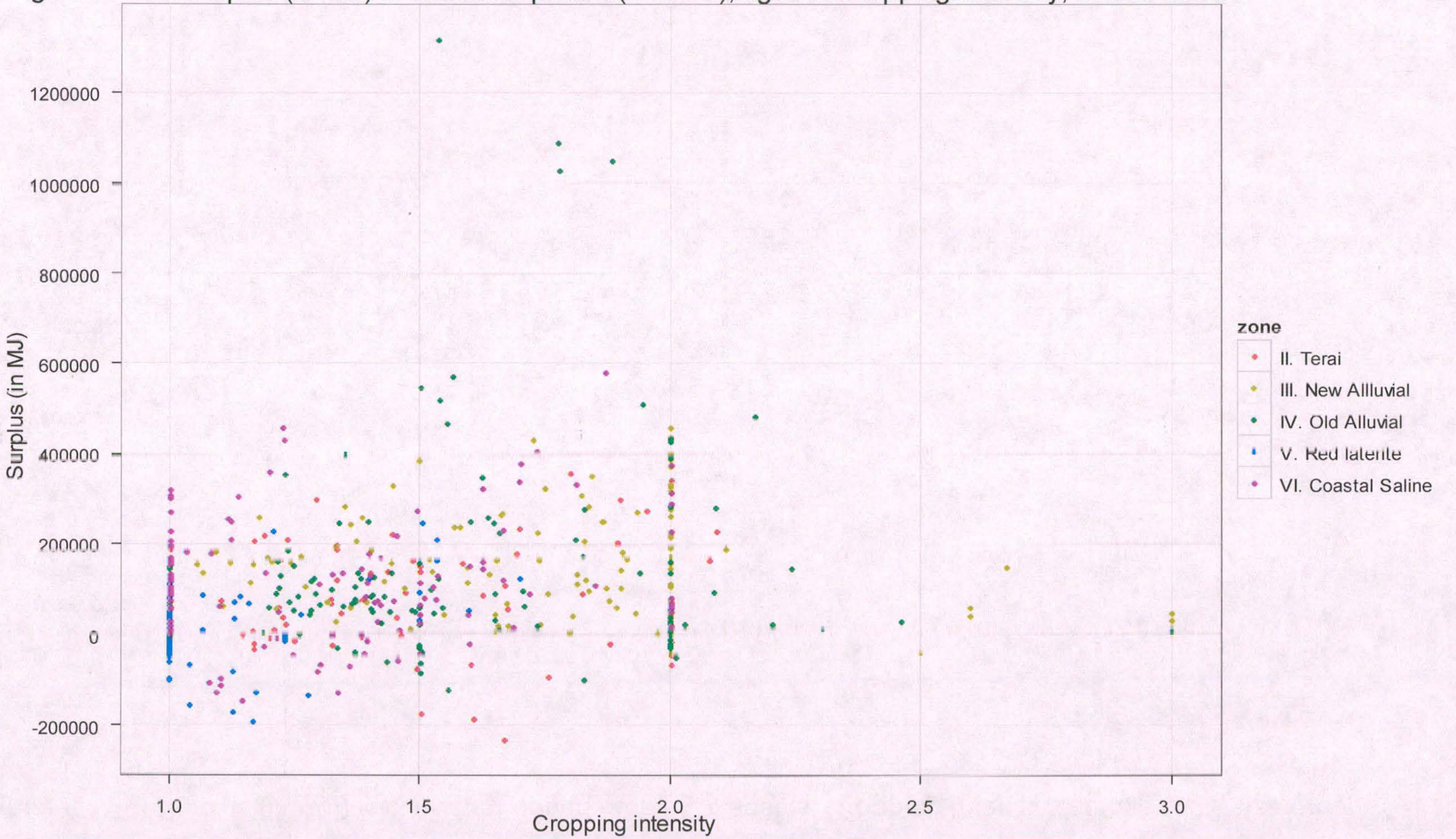


Figure 4.1.12: Surplus (in MJ) in cultivated period (scale C), against Cropping Intensity, across Zones

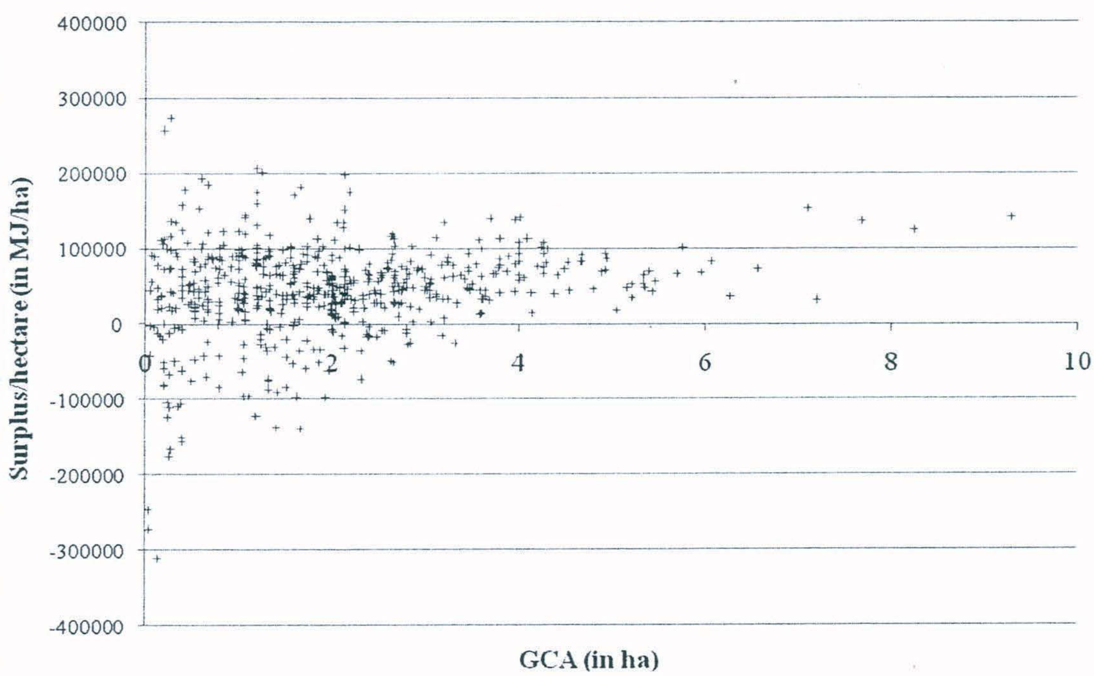


In sum, we may state the following: an association between higher cropping intensities and higher surpluses existed only for a land size beyond a threshold (certainly higher than 2 ha, the upper bound of the second lowest CCS size-group). This association was strengthened by the relative superior bio-physical framework of both alluvial zones. Thus, for a household located in other zones and having a small land, even with a high cropping intensity, could yield only a low or a negative surplus. Only an elimination of either of the conditions can increase the surplus. While the alterations in bio-physical framework, other than land quality is beyond the human control, the only option for augmenting the surplus is to increase the area under cultivation, in operational terms.

4.1.2. Per hectare Surplus

Figure 4.1.13 portrays the per hectare surplus, against the gross cropped area. Certainly, there had been rather wide variations against the lower area of land under cultivation.[6] The extent of such variation can be seen from table 4.1.1. On the other hand, figure 4.1.14 portrays per hectare surplus against GCA, aggregated over size-groups. We may note once again—like in figure 4.1.7 for surplus—of a fall in the surplus/hectare, against size-group 1.21–1.5 ha.

Figure 4.1.13: Per hectare surplus(in MJ/ha) in cultivating period (scale C) against gross cropped area (in ha)



[6] Analysis of per hectare surplus excludes TTFF 0201 (GCA=0.01 hectares, per hectare surplus = −869,873 MJ/ha).

Table 4.1.1: Per hectare surplus (in MJ/ha), its variance in relation to GCA (in ha), aggregated over size-groups			
Gross Cropped Area (in ha)	No of households	Per hectare Surplus (in MJ/ha)	Variance
0.01–0.33	54	8596	112240
0.34–0.66	51	35052	74179
0.67–1.00	48	56593	6790
1.01–1.20	46	57453	10561
1.21–1.50	48	30544	8961
1.51–1.80	52	40495	8414
1.81–2.01	50	39524	5942
2.02–2.31	48	52868	7302
2.33–2.70	51	43449	5549
2.71–3.30	52	48372	4741
3.31–4.25	50	65527	5327
4.26–9.30	40	73901	4747

Figure 4.1.14: Per hectare Surplus (in MJ/ha) in relation to GCA (in ha), aggregated over size-group

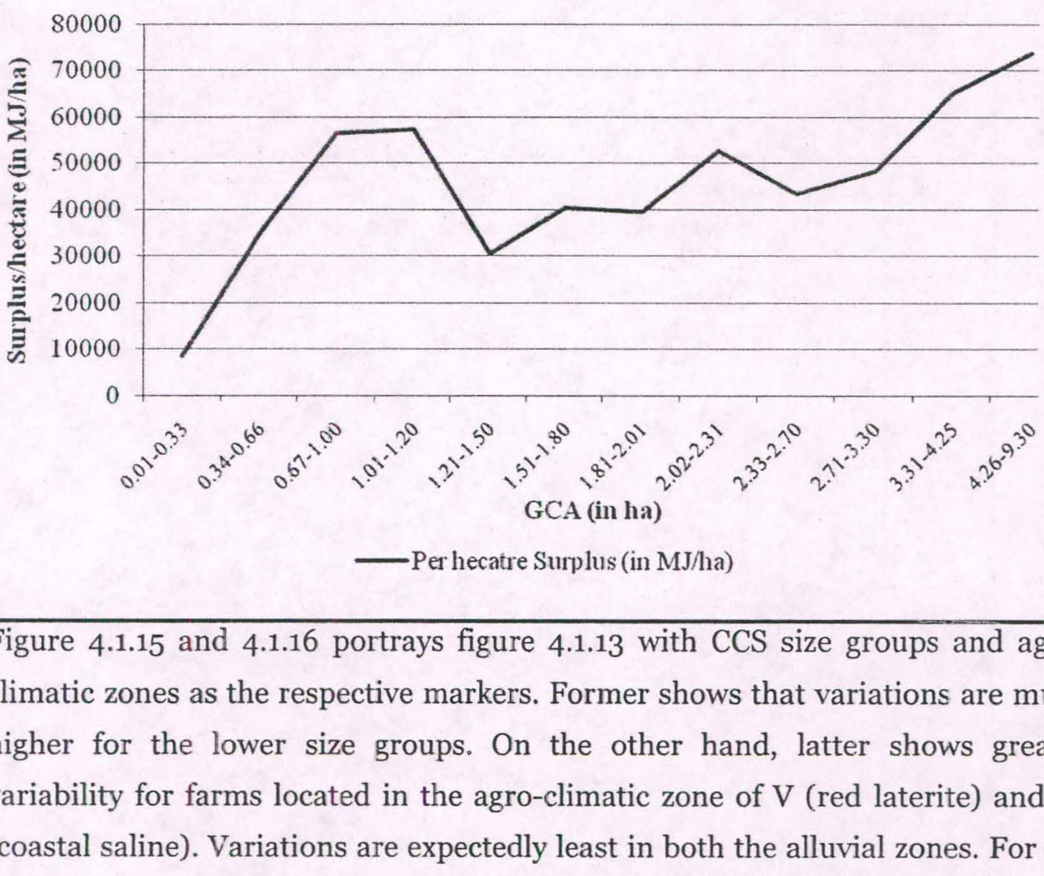


Figure 4.1.15 and 4.1.16 portrays figure 4.1.13 with CCS size groups and agro-climatic zones as the respective markers. Former shows that variations are much higher for the lower size groups. On the other hand, latter shows greater variability for farms located in the agro-climatic zone of V (red laterite) and VI (coastal saline). Variations are expectedly least in both the alluvial zones. For the farms in the terai zone, while variability could be observed against the lower levels of GCA, it reduced with an increase in GCA, as captured by table 4.1.1 for all farms.

Figure 4.1.15: Surplus per ha (in MJ/ha) in cultivated period (scale C), against GCA (in ha), across size-groups

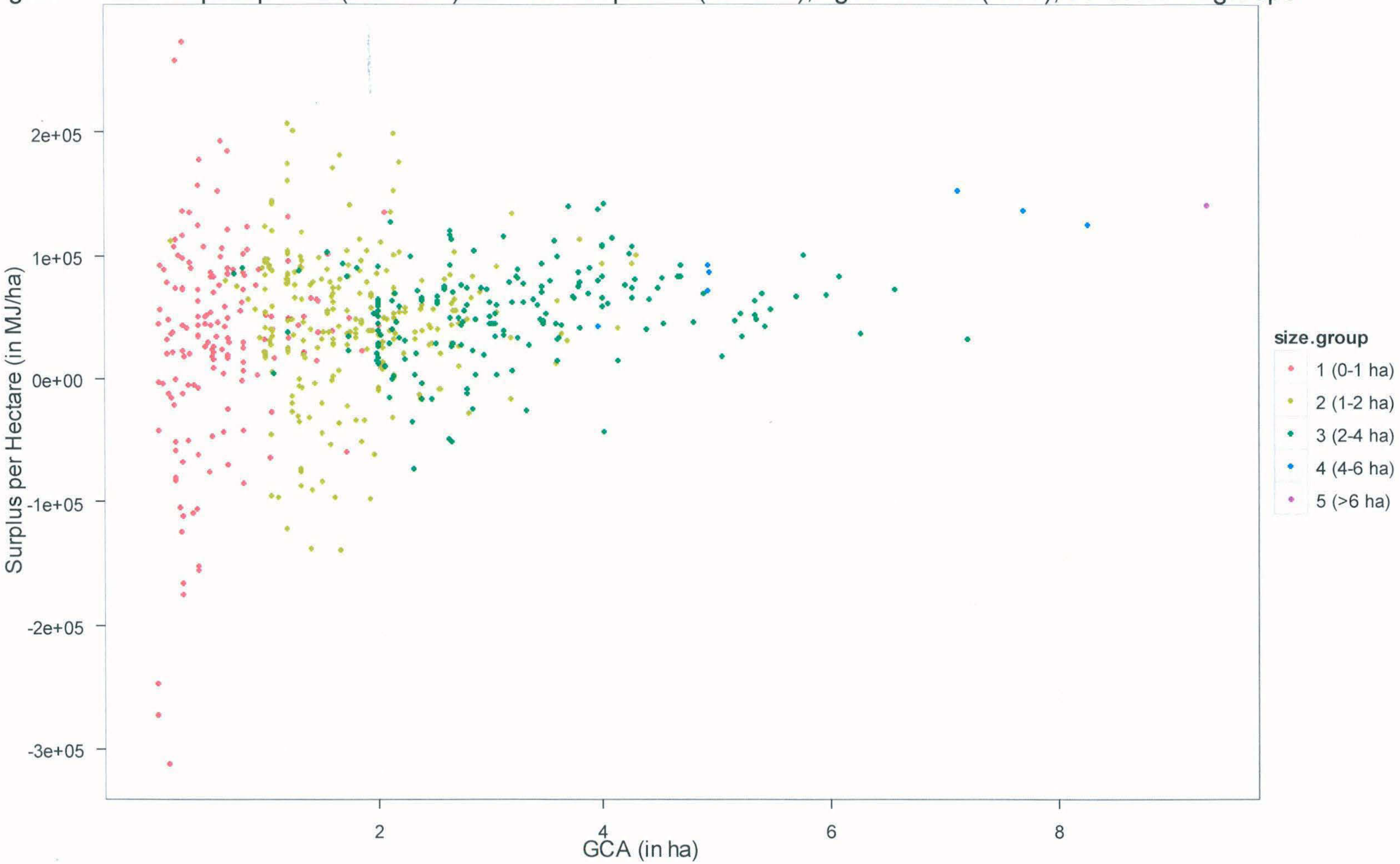
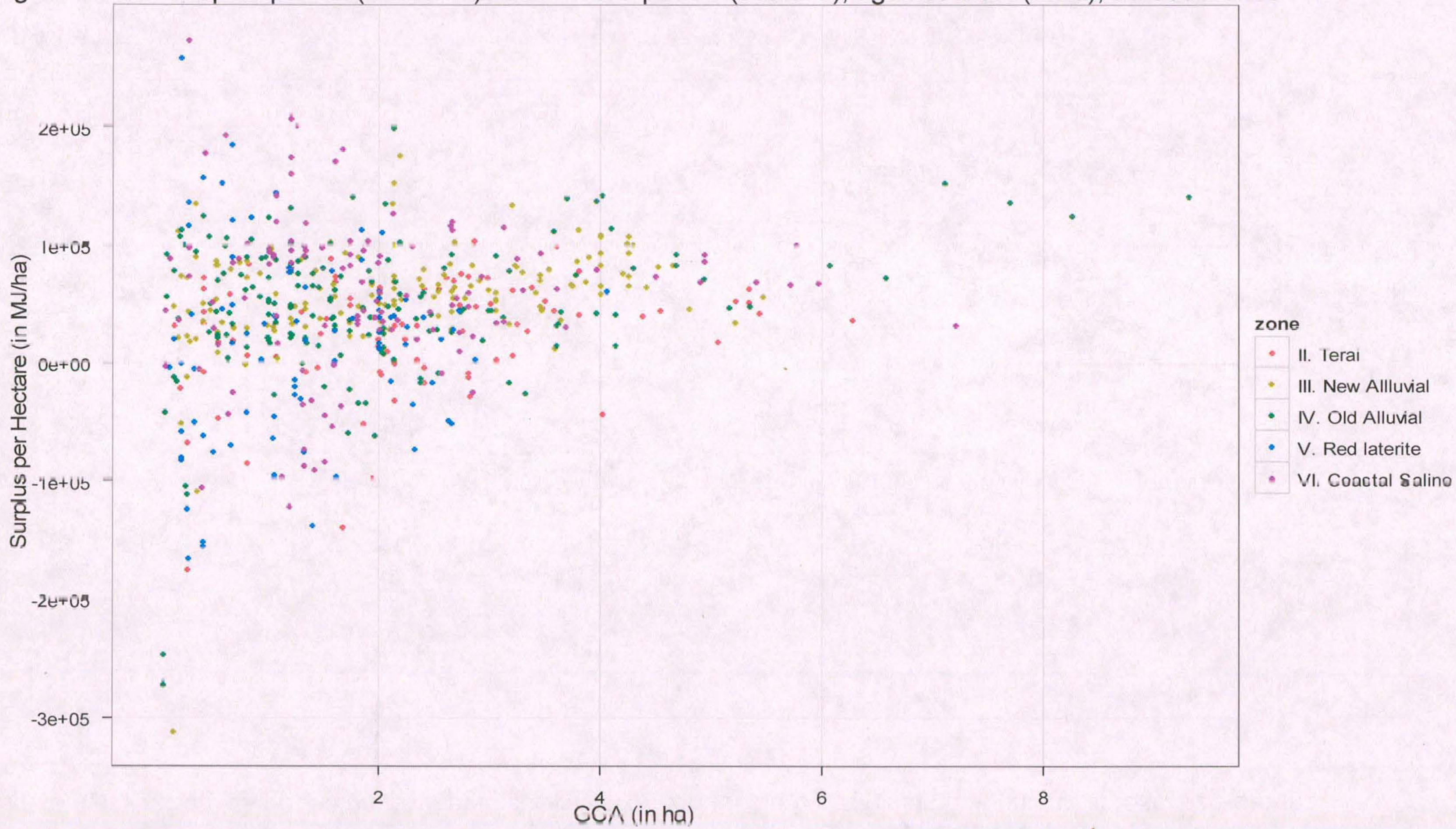


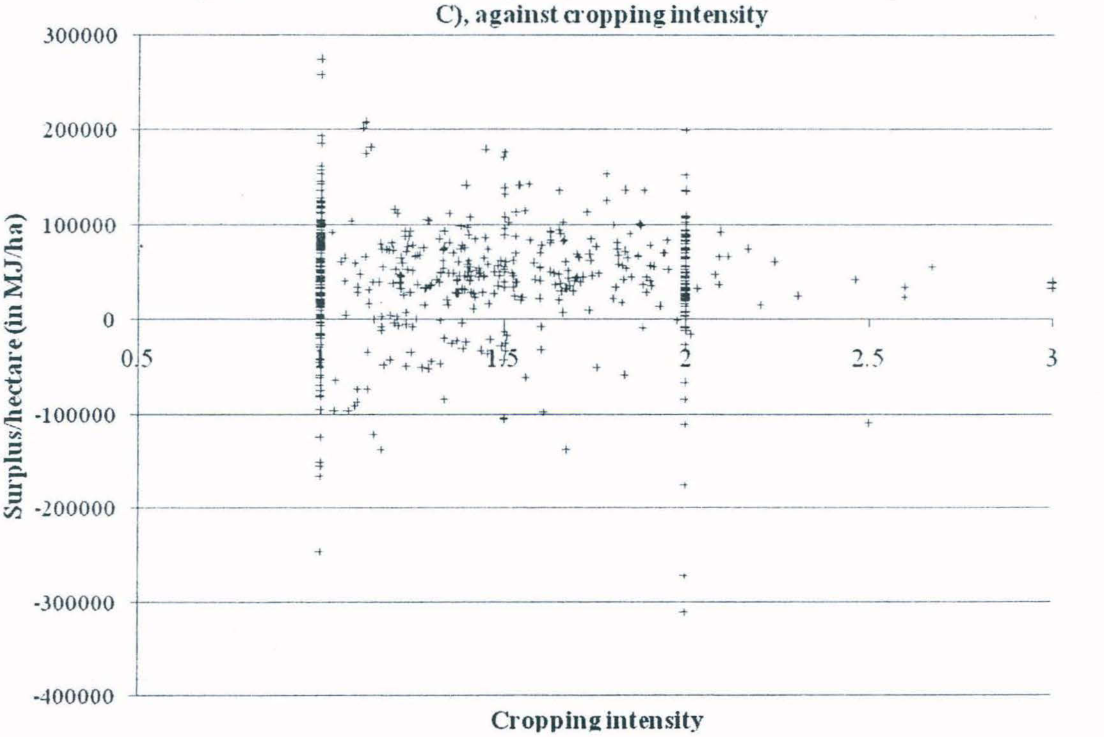
Figure 4.1.16: Surplus per ha (in MJ/ha) in cultivated period (scale C), against GCA (in ha), across Zones



In sum, we may state two things on the per hectare surplus.[7] First, variations in it are higher for lower size-groups as well in agro-climatic zones with a relatively inferior bio-physical framework. Second, despite the variations, there seems to be an upper bound on the per hectare surplus; notably, it is associated with the farms cultivating a very small area, which is even higher than the largest farms. Even otherwise, such an upper bound is visible for farms with GCA higher than 2 ha as well. This certainly demands an intense scrutiny.

Figure 4.1.17 presents the relationship between per hectare surplus during the cultivating period with the cropping intensity. If we take only the positive numbers, per hectare surplus, shows a negative relationship with the cropping intensity, bringing the importance of leaving the land fallow for regenerating its 'power'.

Figure 4.1.17: Per hectare surplus (in MJ/ha) during cultivated period (scale C), against cropping intensity



[7] Figure A.4.1.1 shows the relationship as in 4.1.13 with 'Irrigation types' as an additional marker. It may be recalled that the presence of an irrigation facility may not necessarily its use. Even without the aid of any structure, through human labour with or without the animals, farms are irrigated. As expected, figure A.4.1.1 did not reveal any particular pattern, except the predominance of farms without any irrigation facility, as noted earlier in table A.3.2.15. However, those farms with canal based irrigation facility, with higher GCA yielded higher per hectare surplus. Such a facility on the other hand for very small farms could result only in a negative surplus and hence a negative surplus per hectare.

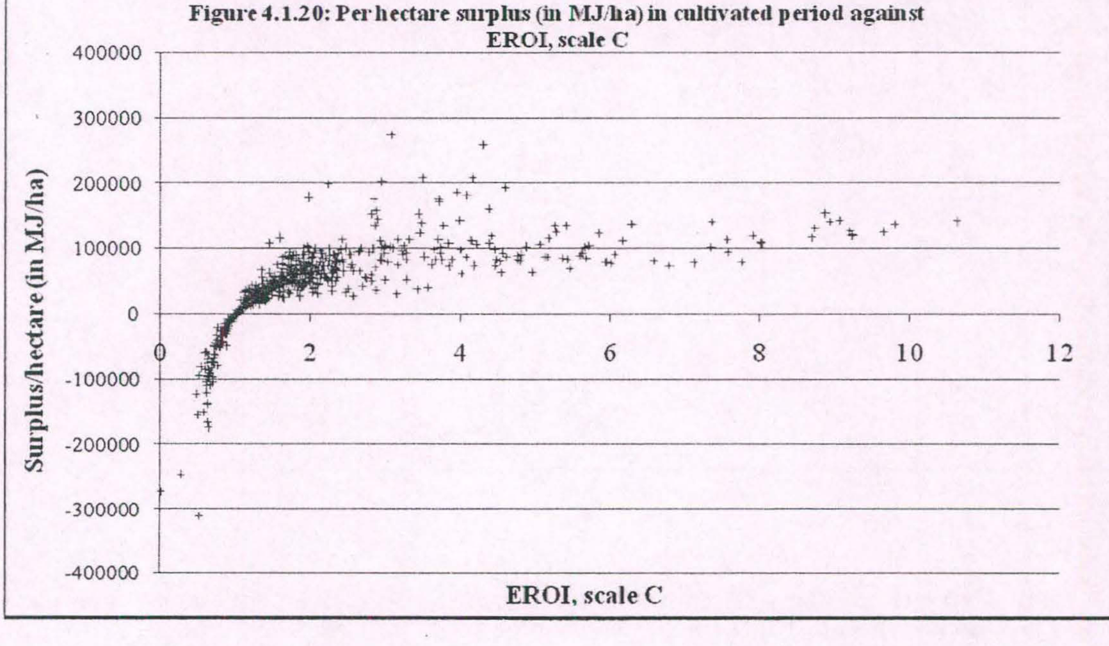
Figure 4.1.18 and 4.1.19 portray figure 4.1.17 with the usual markers. The former shows that the highest surplus/hectare was obtained with a cropping intensity in the range of 1–1.2. The latter confirms the result that it is the households with very small land, and located in zone V and VI.

Further, figure 4.1.18, offers an 'scaled up' version of the figure 4.1.11 (with surplus) for farms with a very small area under cultivation. It reveals once again the association of a negative surplus with many households belonging to the lowest size-groups. Indeed, it is these households that yielded the most variable per hectare surpluses. Certainly, located within a not so conducive natural environment (see, figure 4.1.19), such a high per hectare surplus calls for further investigation.

4.1.2.1. *Per hectare Surplus and EROI*

Figure 4.1.20 plots per hectare surplus in the cultivated period with EROI (scale C). It shows that, while with the increase in the EROI, initially the per hectare surplus increases monotonically, beyond an EROI of around 3, the curve appears flatter, indicating an upper bound. In fact, an increase in EROI and a constant surplus per hectare required input per hectare to fall.[8]

Figure 4.1.20: Per hectare surplus (in MJ/ha) in cultivated period against EROI, scale C



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[8] Surplus/ha = O/ha – I/ha
or, Surplus/ha X ha/I = O/ha X ha/I – 1
or, Surplus/ha X ha/I = EROI – 1
or, K x ha/I = EROI – 1 (K= constant)

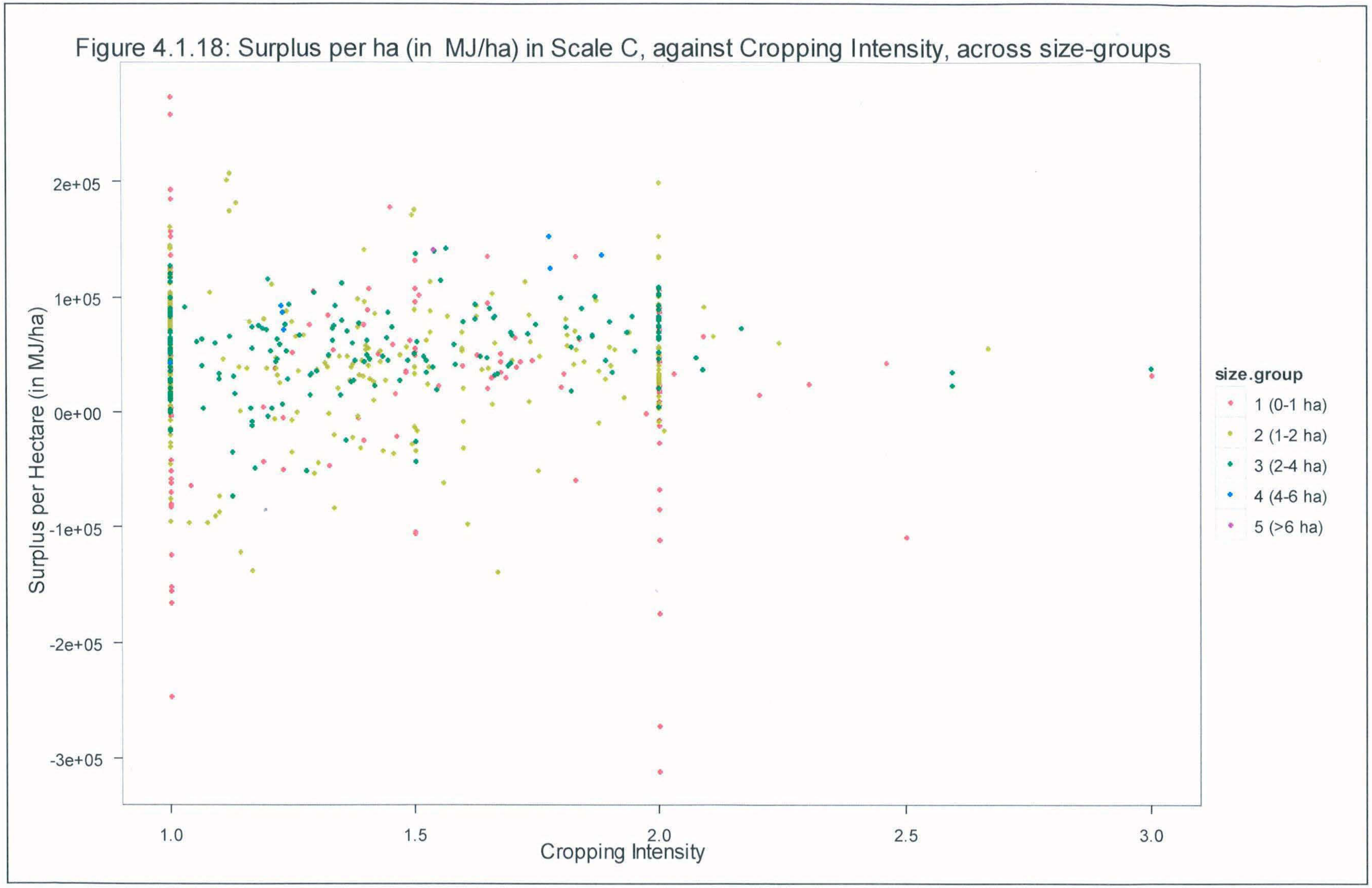


Figure 4.1.18: Surplus per ha (in MJ/ha) in Scale C, against Cropping Intensity, across size-groups
Surplus per Hectare (in MJ/ha)
2e+05
1e+05
0e+00
-1e+05
-2e+05
-3e+05
1.0
1.5
2.0
2.5
3.0
Cropping Intensity
size.group
1 (0-1 ha)
2 (1-2 ha)
3 (2-4 ha)
4 (4-6 ha)
5 (>6 ha)

Figure 4.1.19: Surplus per ha (in MJ/ha) in Scale C, against Cropping Intensity, across Zones

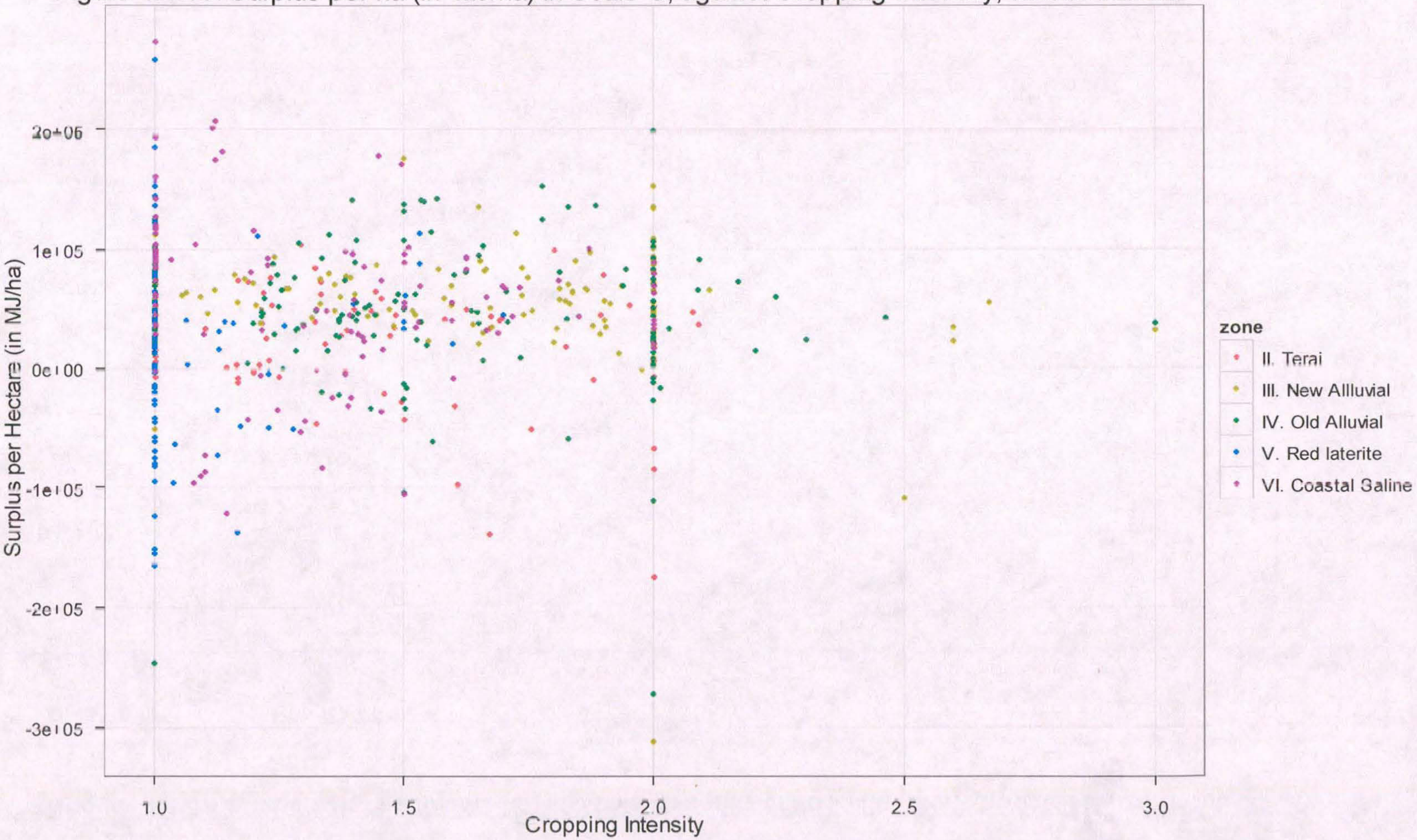


Figure 4.1.21: Surplus per ha (in MJ/ha) against EROI, in Scale C, across size-groups

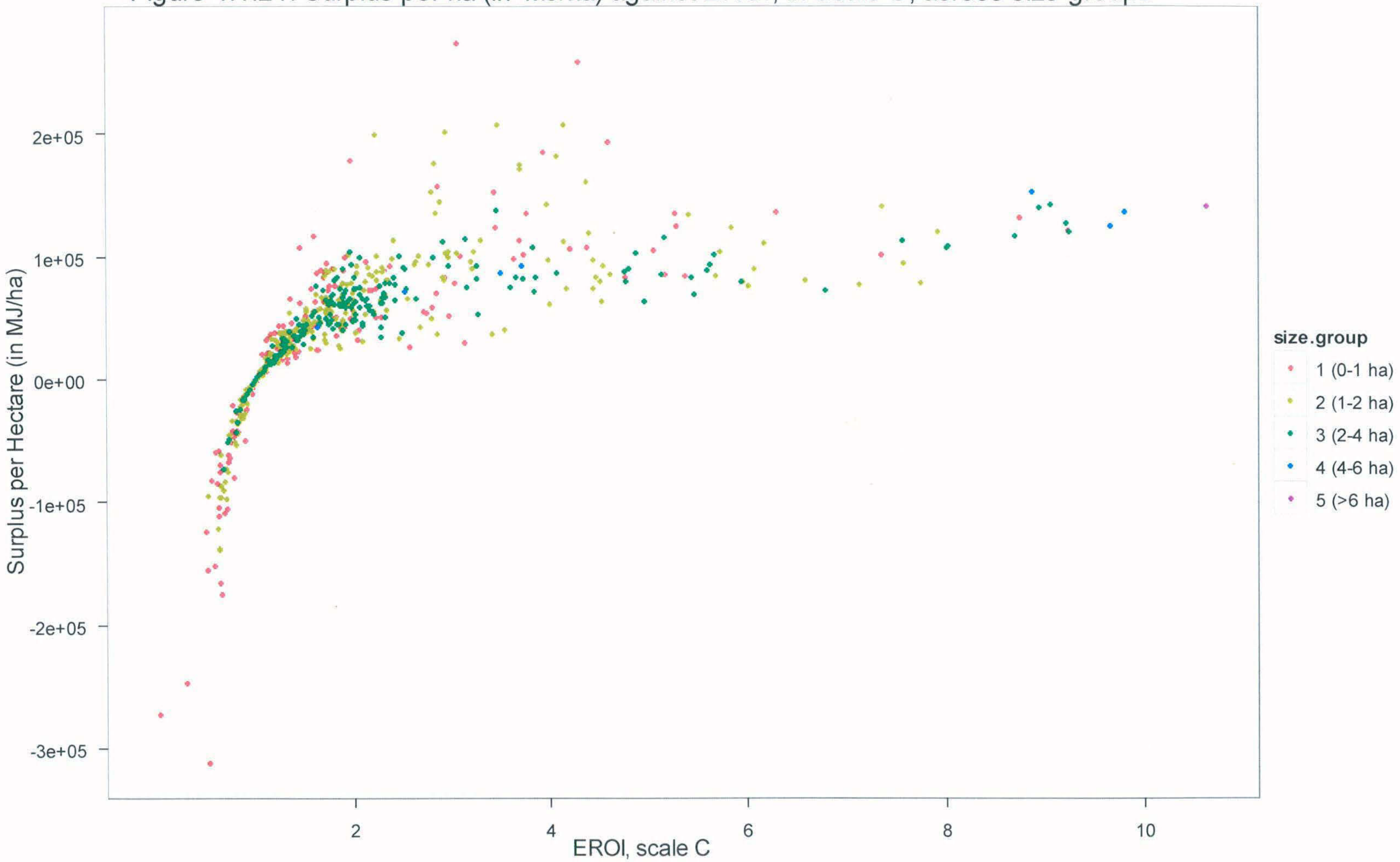


Figure 4.1.22: Surplus per ha (in MJ/ha) against EROI, in Scale C, across Zones

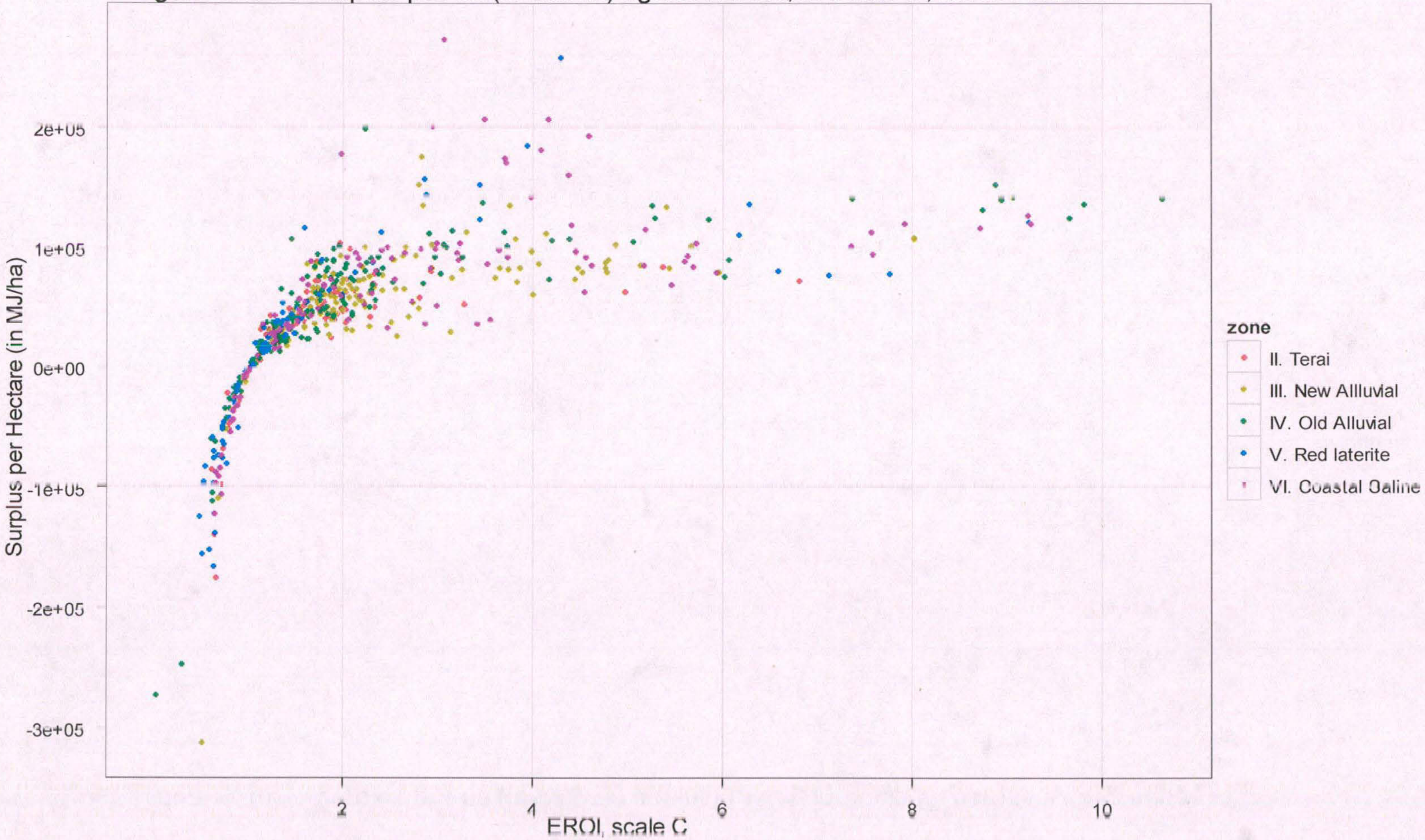


Figure 4.1.21 and 4.1.22, that plots figure 4.1.20 with markers may provide a few additional insights. To begin with, in figure 4.1.21, one may notice the monotonic relationship between per hectare surplus and EROI of scale C, for three lowest size groups, separately.[9] We may focus only on the farms with a positive surplus or surplus/hectare in energy terms. It appears that for a given rise in the surplus per hectare farms of the lowest CCS size-group required the least increase in EROI, scale C among all the three. For the second lowest size-group (1–2 ha), it required higher rise in EROI and for the third size-group, it was even more. However, given the fact that, for the lowest CCS size-group (0–1 ha), surplus per hectare is higher than the surplus in absolute terms, we may focus on the other two size-groups. While EROI, scale C and surplus per hectare shows a positive relationship, it is important to emphasise here that a very high EROI with a low or a negative surplus means hardly anything substantial. Given the predominance of farms belonging to second lowest CCS size-group (1–2 ha) among the high per hectare surplus ones,[10] it seems reasonable to conclude that there are factors other than the land size or GCA which is having a significant influence on the per hectare surplus yield of higher magnitudes.

In fact, as figure 4.1.22 shows, these high surplus per hectare yielding farms are located in all five agro-climatic zones. While for red laterite and coastal saline, single cropping (see, table 1.7.1) could have played its role, through regeneration of soil capacity, such a possibility does not exist for the both the alluvial zones or terai. We may, but conclude, on the existence of some other important factors beyond land size, economies of scale and the agro-ecological framework.

4.1.3. Summary

We may summarise the results of the discussion on surplus. First, the lower size-groups (CCS as well as those taken in this thesis) had shown a negative surplus, as well as wide variations in the per hectare surplus. A number of farms within this size group had been associated with the highest per hectare surplus among all the farms, as well as lowest ones, implying greater variability. Second, while the surplus had shown a monotonic relationship with GCA, like input and output, between 1 and 1.5 ha, there was a sudden rise in input and a consequent fall in the

[9] Due to very small number of farms in the two highest size-groups , no definite relationship could be observed, however.

[10] 237 and 185 are the number of households, for CCS size-group 2 (1–2 ha) and 3 (2–4 ha).

surplus. This was reflected in an amplified form in the relationship between per hectare surplus with GCA, giving an inverse-U pattern, if we leave out very small farms. Third, there are factors other than the land size or GCA, scale of production and the bio-physical framework, that can explain the differences in the surplus or per hectare surplus, which may also serve as the key towards augmenting it. It can range from family size per holding or land size (NAS or GCA), to earner-dependent ratio. We will return to it.

4.2. Annual Sustainability

We may recall the primary aim of the thesis: of evaluating the ability of the land under cultivation to sustain the labour working on it. Certainly, it is to be carried out on an annual basis, and the surplus for such a purpose would be the 'full and final' annual surplus, that considers both cultivating and the non-cultivation period. We may begin with figure 4.2.1 that shows a minimum of 4 ha as the gross cropped area for a non-negative annual surplus. Figure 4.2.2 shows this minimum, while using CCS size-groups as an additional marker. Following our previous observation over surplus in scale C, we may note that for the lowest two size-groups, roughly half of the households reported a negative surplus; and for the third size-group (2–4 ha), a few.

Figure 4.2.1: Annual surplus (in MJ), against gross cropped area (in ha)

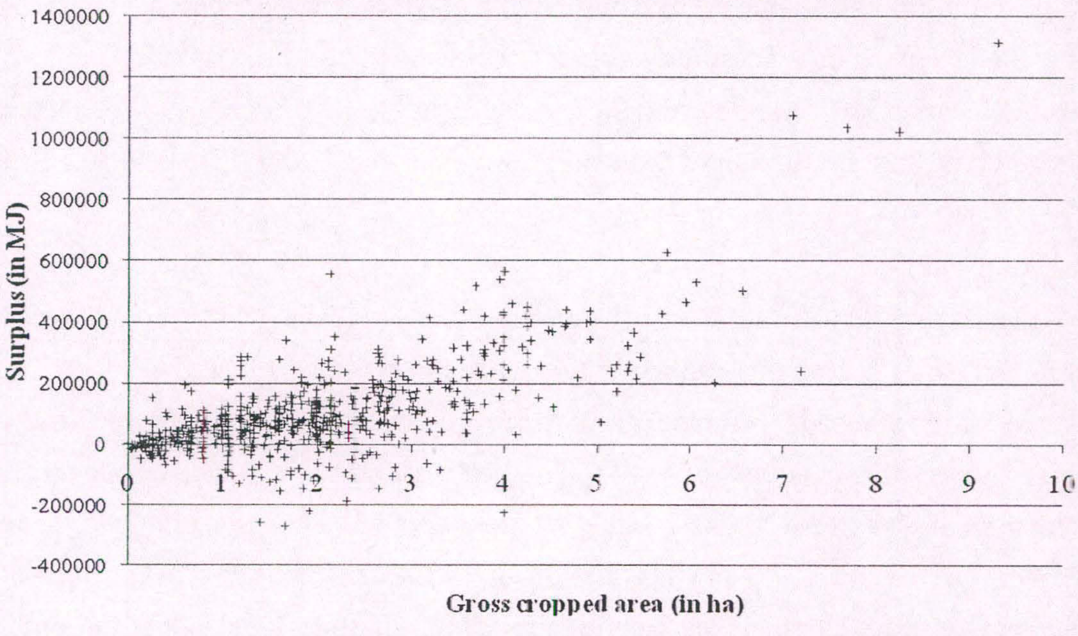
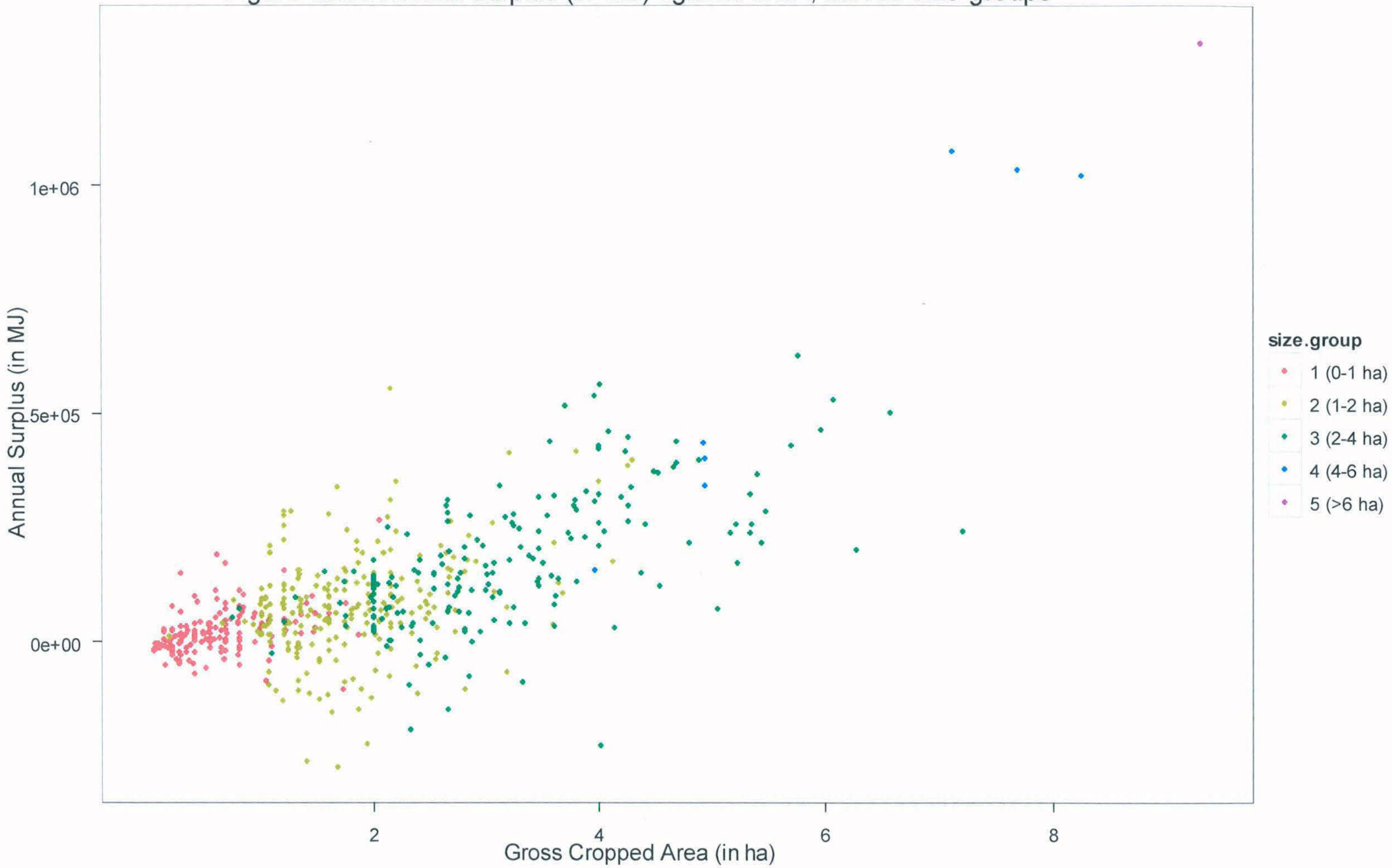
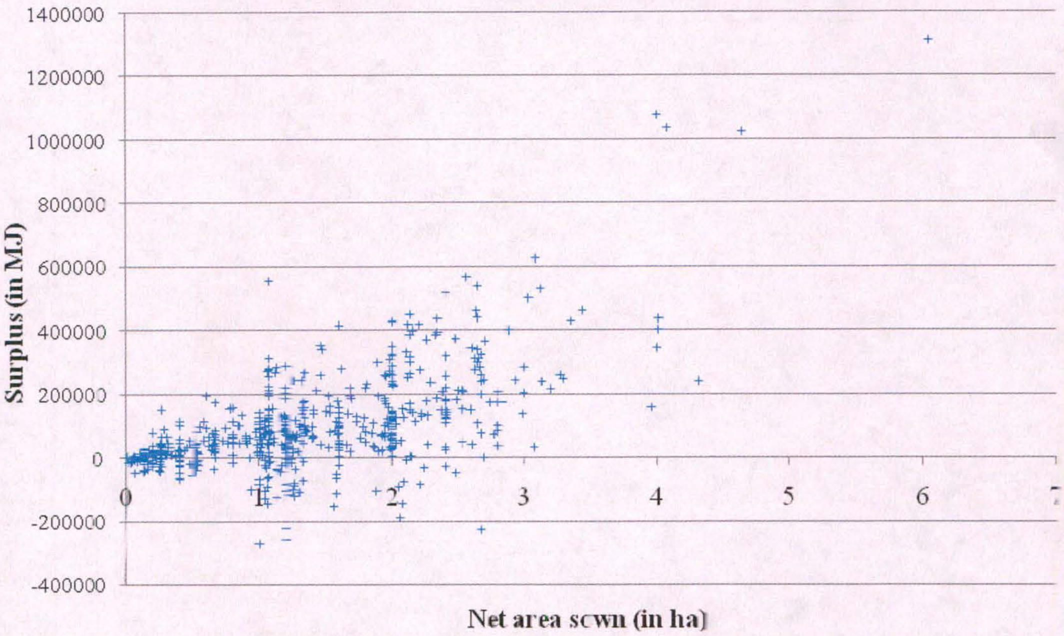


Figure 4.2.2: Annual Surplus (in MJ) against GCA, across size-groups



In terms of net area sown, the more relevant variable in this regard, this minimum is around 2.5 ha, as shown in figure 4.2.3. It implies that it was not just the households in the lowest two size-groups, but for some of the households in the size-group 3 (2–4 ha) as well, cropping intensity was low (less than 1.5). Figure 4.2.4 plot this figure with CCS size-group as the additional marker, and shows more clearly this threshold of 2.5 ha for annual sustainability.

Figure 4.2.3: Annual surplus (in MJ), against net area sown (in ha)



Certainly, of similar interest is the figure 4.2.5, that shows the same relationship as in figure 4.2.3 with agro-climatic zones as the marker. It shows that while the minimum land area that could ensure annual sustainability in the least developed red laterite zones was 2.5 ha, in a relatively better (and certainly not in absolute terms) coastal saline, it was around 1.2 ha. A more intriguing fact is the presence of many households in the terai zone, with a reported negative annual sustainability. Finally, while a handful of households in the old alluvial zone also reflected such a negative surplus, there was none from the new alluvial zone.

Figure 4.2.6 and 4.2.7 show the number of non-active days, that the surplus, if any, could sustain the household members and the animals in their possession, as was done for the illustrative household, against net area sown and annual output. In figure 4.2.7, we may notice the threshold output of around 700,000 MJ for ensuring annual sustainability. Further, while for the higher land sizes, a larger number of days beyond the annual sustenance were expected, what was

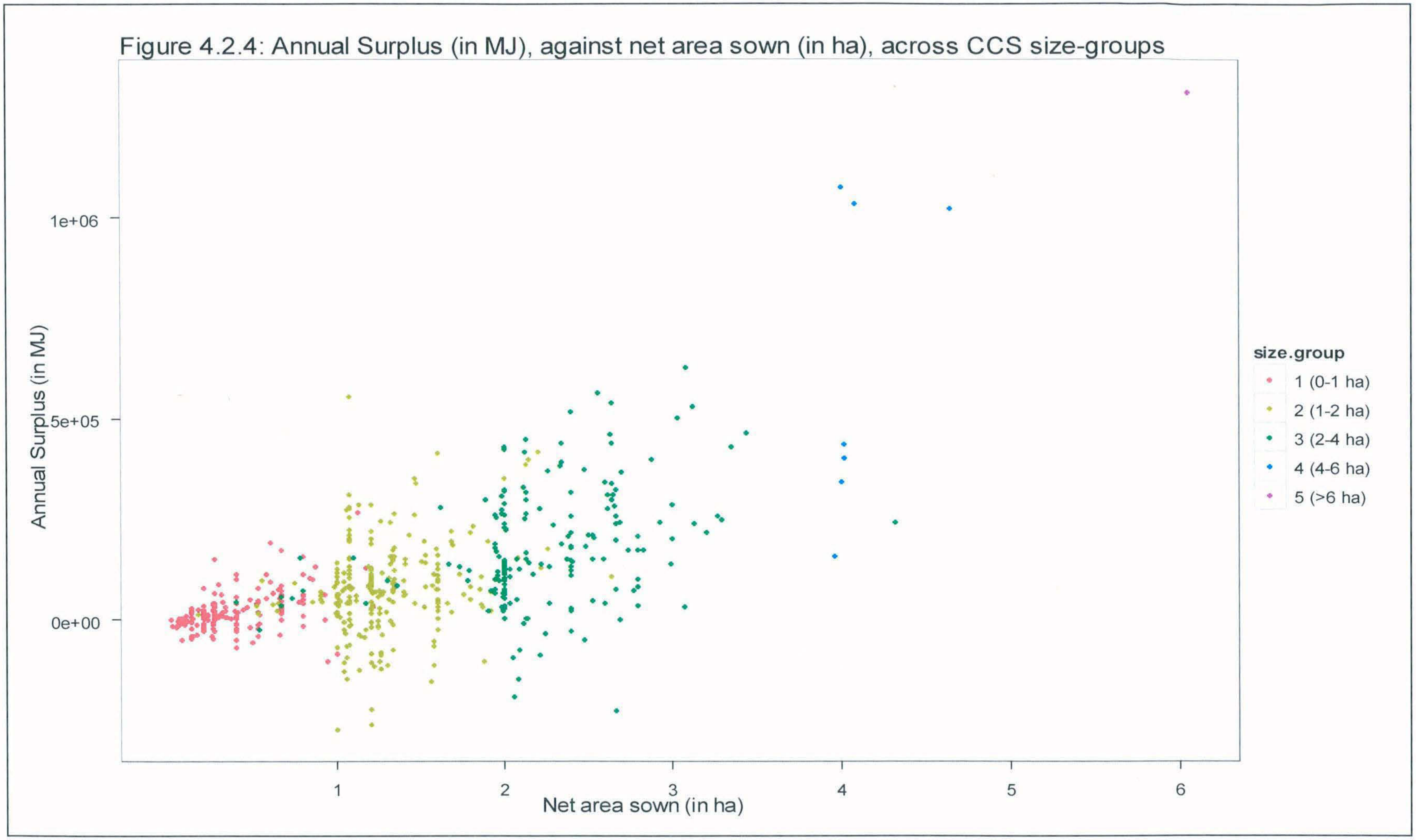


Figure 4.2.4: Annual Surplus (in MJ), against net area sown (in ha), across CCS size-groups
Annual Surplus (in MJ)
1e+06
5e+05
0e+00
1
2
3
4
5
6
Net area sown (in ha)
size.group
1 (0-1 ha)
2 (1-2 ha)
3 (2-4 ha)
4 (4-6 ha)
5 (>6 ha)

Figure 4.2.5: Annual Surplus (in MJ), against net area sown (in ha), across Zones

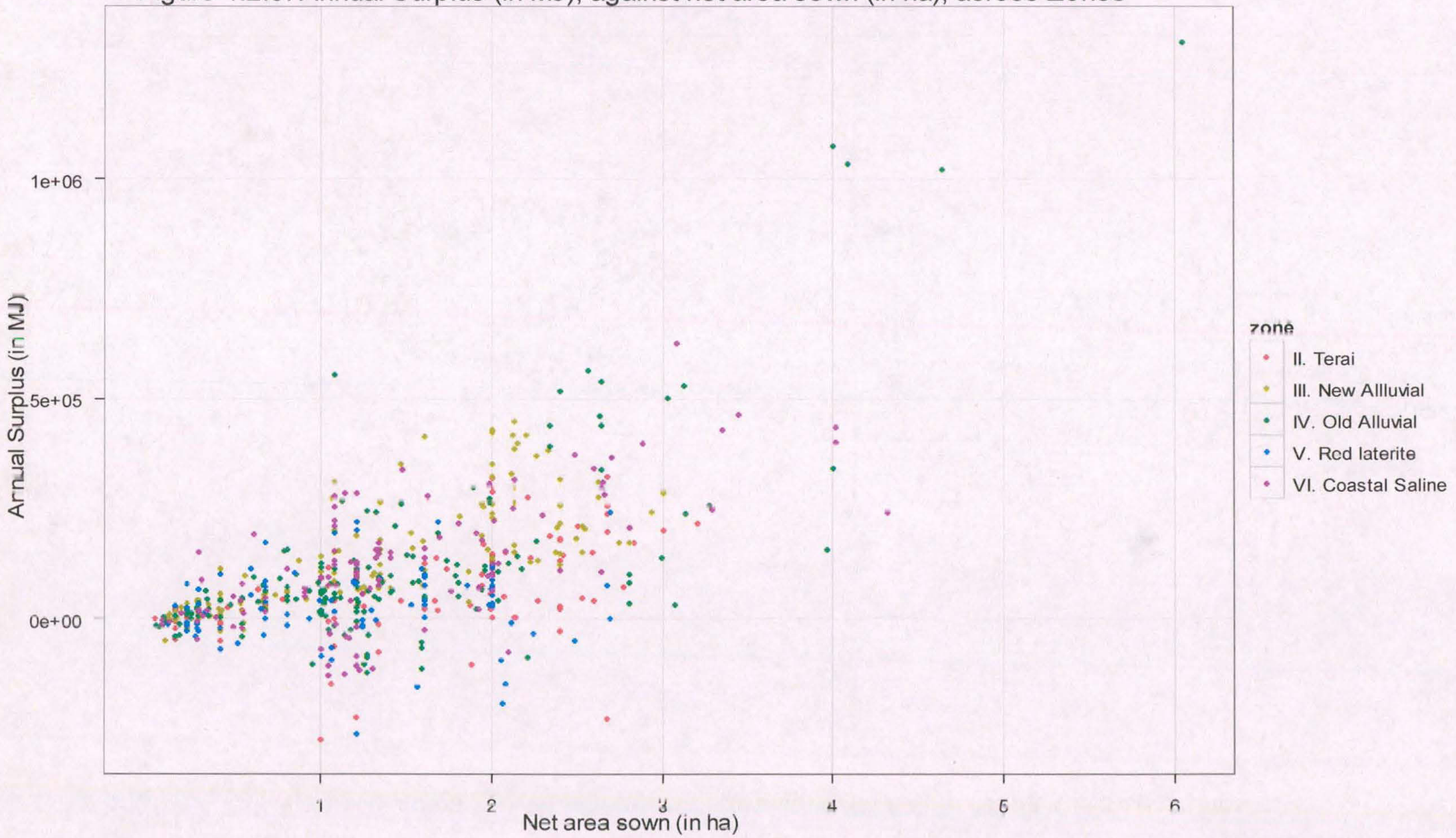
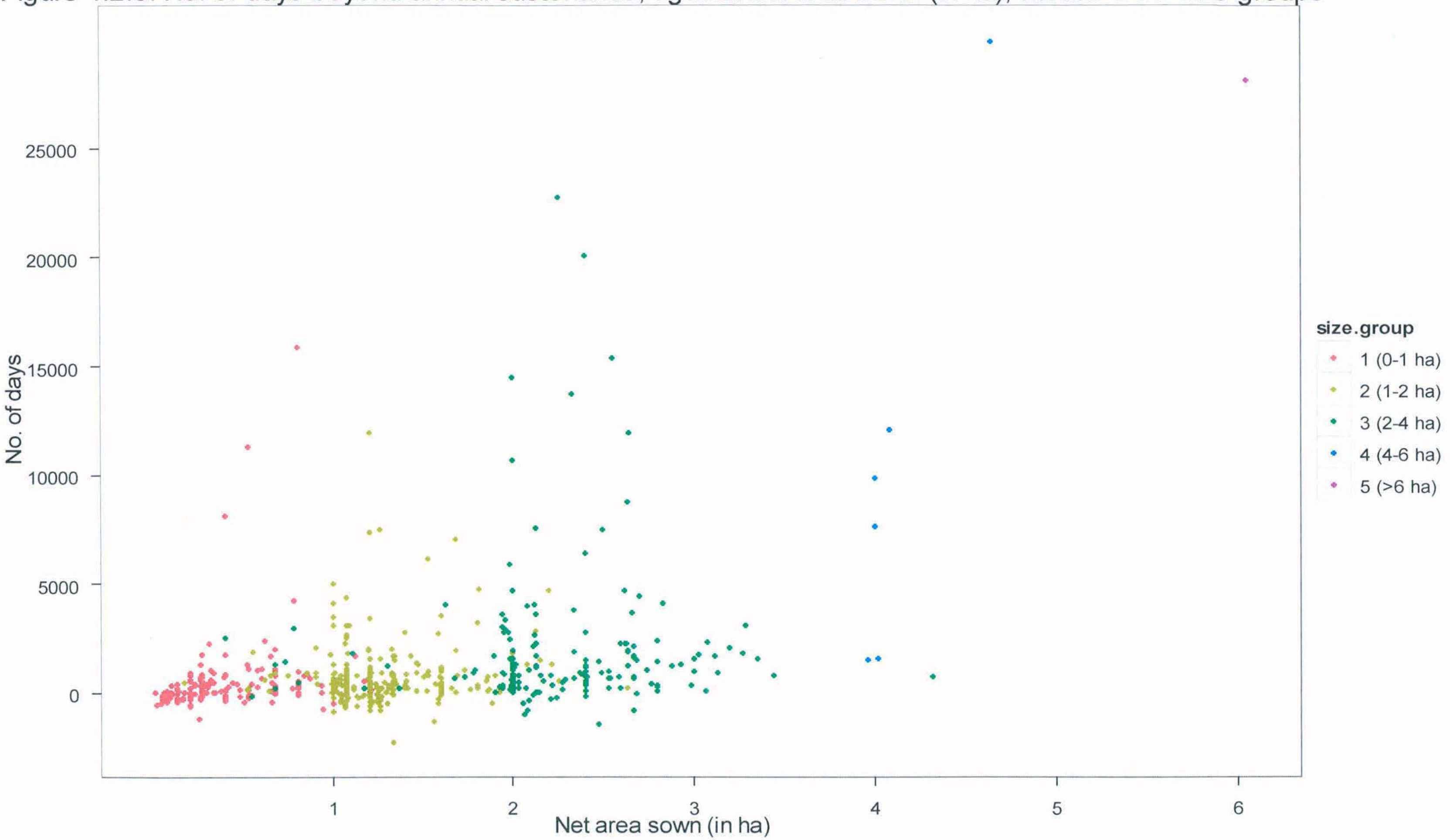


Figure 4.2.8: No. of days beyond annual sustenance, against net area sown (in ha), across CCS size-groups



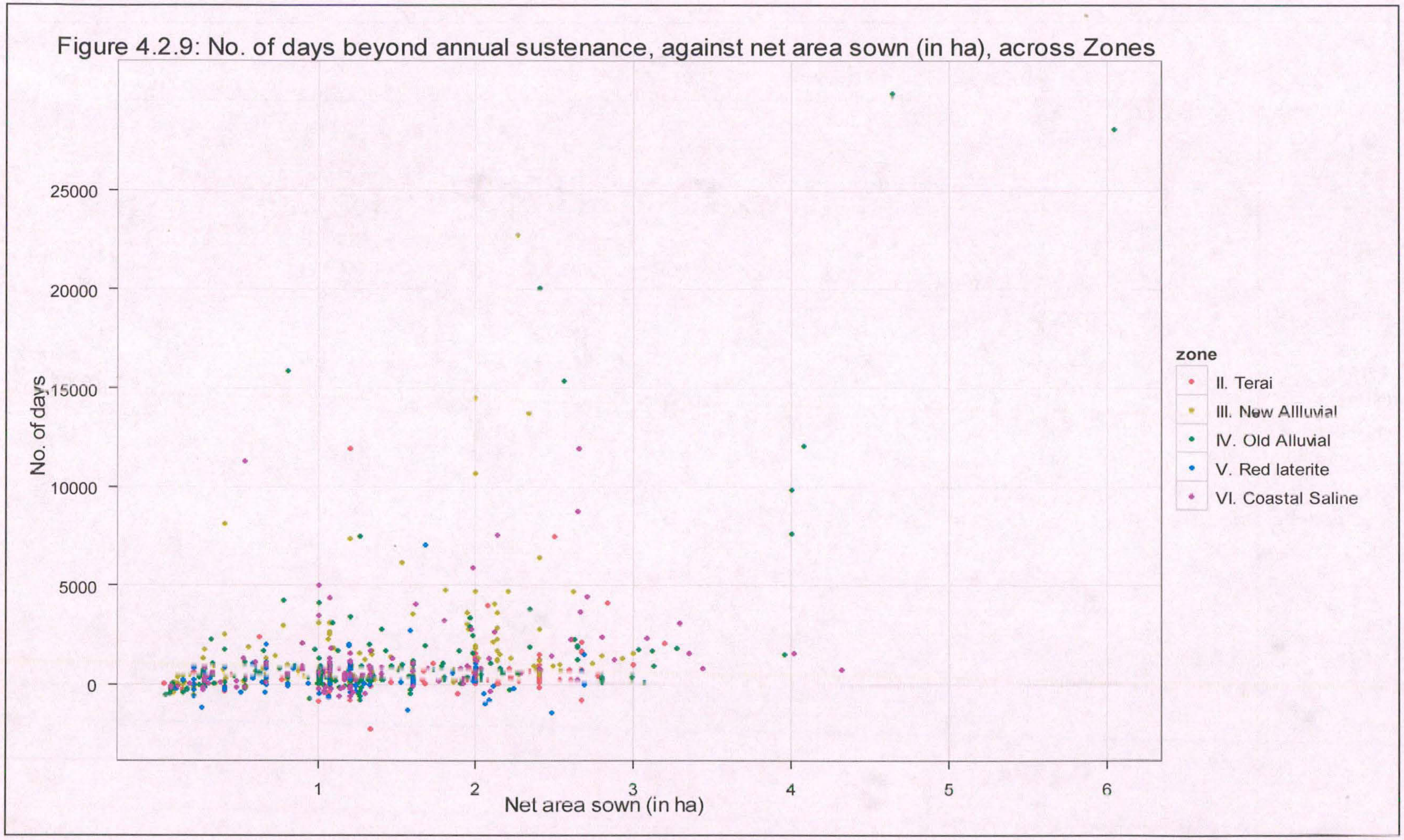


Figure 4.2.9: No. of days beyond annual sustenance, against net area sown (in ha), across Zones
25000
20000
15000
10000
5000
0
No. of days
1
2
3
4
5
6
Net area sown (in ha)
zone
II. Terai
III. New Allluvial
IV. Old Alluvial
V. Red laterite
VI. Coastal Saline

interesting is the presence of such high numbers against all CCS size-groups (see, figure 4.2.8). Finally, no clear trend could be found as far as agro-climatic zones were concerned (see, figure 4.2.9).

Figure 4.2.6: No. of days beyond the annual sustenance, against net area sown (in ha)

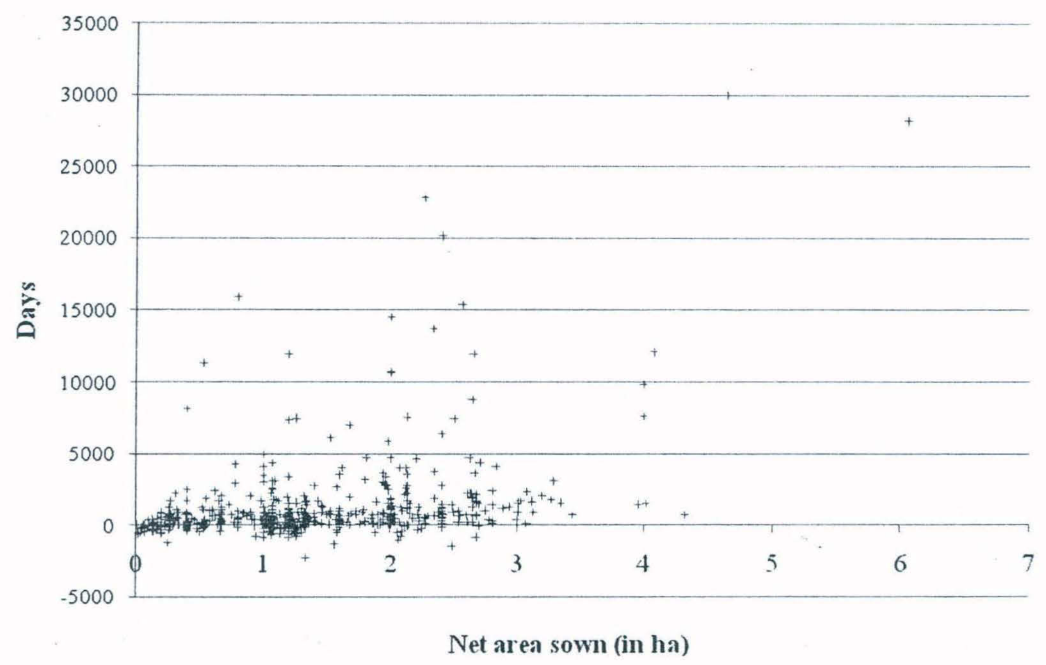
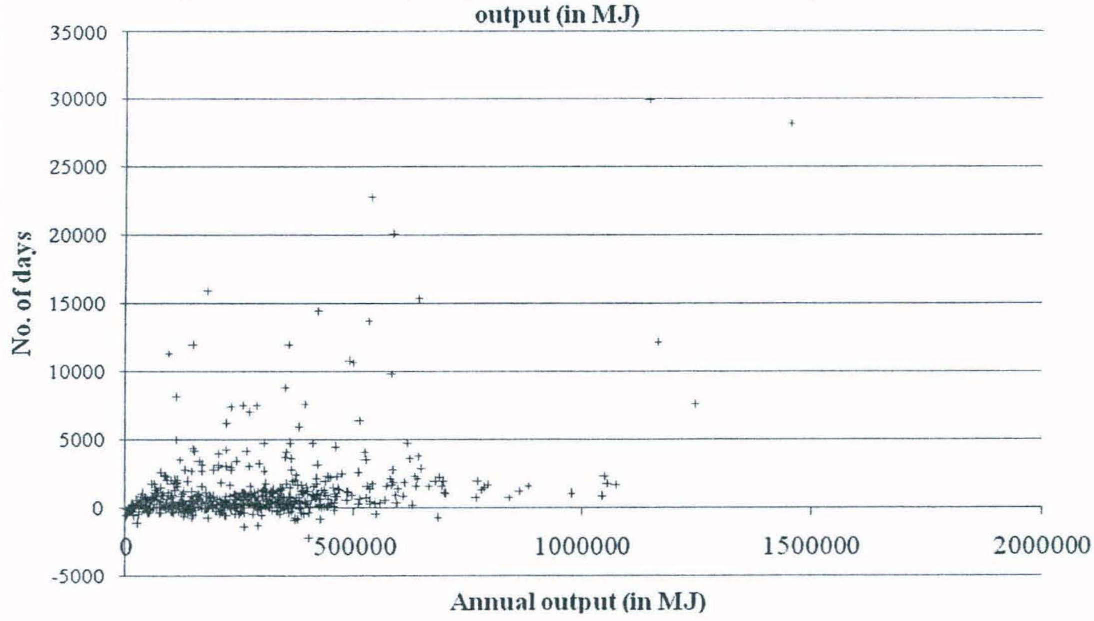


Figure 4.2.7: No. of days beyond the annual sustenance, against annual output (in MJ)



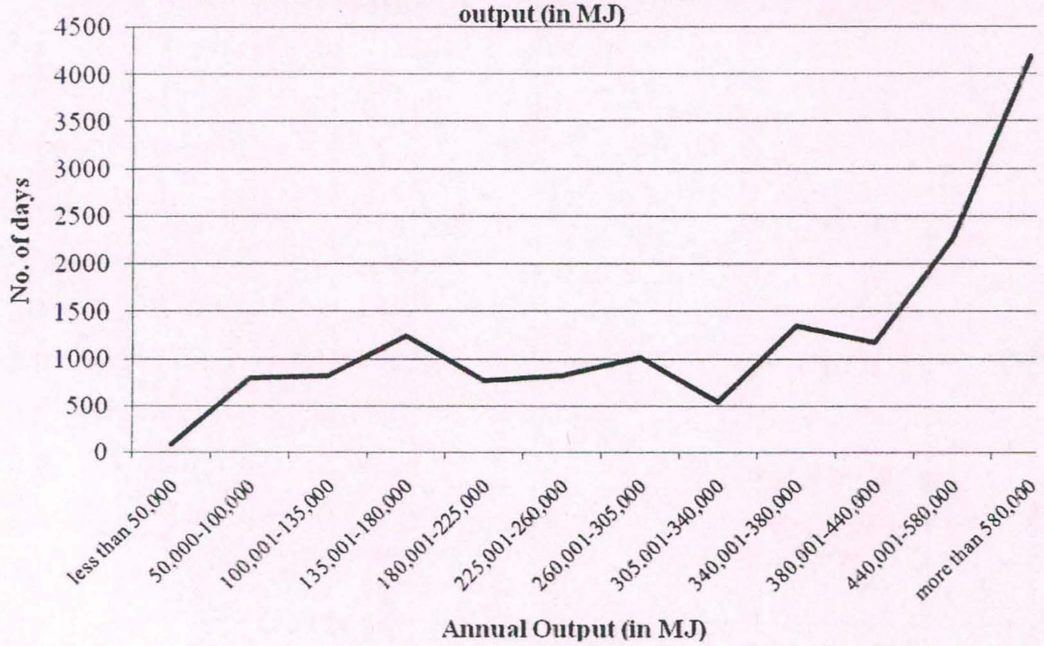
In figure 4.2.7, one may notice the agglomeration of farms closer to the horizontal axis with a few of them with a rather high number of days beyond annual sustenance. Table 4.2.1 aggregates the households on the basis of 12 output ranges, and presents some of the characteristics of the farms within each. Some of it has been portrayed in figure 4.2.10 (no of days beyond annual sustainability against output groups) and figure 4.2.11 (no of members of household along with no of animals in possession of the household against output groups).

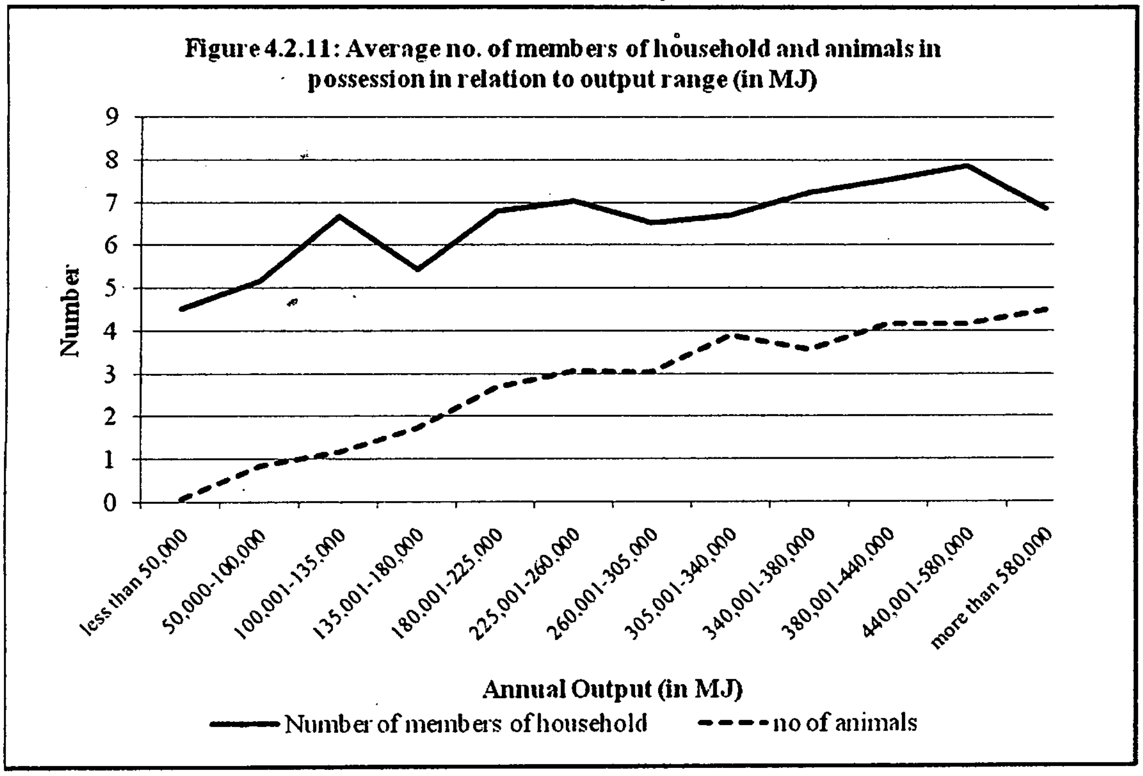
Table 4.2.1: No of days beyond annual sustenance, in relation to output-groups (in MJ)

Output range (in MJ)	No of house -holds	Annual surplus (in MJ)	GCA (in ha)	NAS (in ha)	No. of members of household	No of animals	Daily Energy requirement* (in MJ)	No of days ^
Less than 50,000	47	1914	0.28	0.19	4.51	0.08	43	93
50,000–100,000	52	21021	0.61	0.38	5.17	0.84	75	811
100,001–135,000	48	25460	0.97	0.75	6.7	1.18	101	838
135,001–180,000	50	45677	1.11	0.9	5.44	1.74	110	1246
180,001–225,000	48	46602	1.56	1.15	6.81	2.69	156	776
225,001–260,000	47	66018	1.65	1.3	7.04	3.08	172	830
260,001–305,000	54	90432	2	1.54	6.55	3.05	166	1019
305,001–340,000	52	89473	2.21	1.67	6.71	3.92	200	548
340,001–380,000	50	115045	2.51	1.9	7.26	3.58	192	1351
380,001–440,000	48	130339	2.71	1.91	7.54	4.16	214	1187
440,001–580,000	50	208565	3.42	2.12	7.88	4.16	217	2234
More than 580,000	44	427278	4.48	2.84	6.86	4.5	221	4138

Note:
* for both members and animals under sedentary activity
^ Days beyond annual sustenance

Figure 4.2.10: No of days beyond annual sustainability in relation to annual output (in MJ)





Along the no of days curve, the first rise corresponding to the fourth output range in figure 4.2.10 is due to the sharp drop in the number of members of the household, as shown in figure 4.2.11. On the other hand, the fall at the eighth output group is due to the increase in the number of animals. In fact, figure 4.2.11 clearly shows the monotonic relationship between output and number of animals, with the latter reflecting a purposive planning, where number of animals bear a relationship with the output and land size, stated earlier in chapter 2.

Further, figure 4.2.11 also shows that there was not much variation from the average number of household members (6.58, see, 3.2.3.1), across the output ranges (and hence GCA). As a result, the increase in the daily energy requirements (as in the last column in table 4.2.1) primarily results from the increase in the number of animals. Given that below 180,000 MJ, average number of animals was less than two, this certainly implies that the power requirements were mostly met by the human labour; given the monotonic relationship between GCA and output, and also the NAS is less than 1 ha, this must have been the case.

Figure(s) 4.2.12–4.2.13 shows surplus of scale C against GCA per household size and NAS per household size respectively. Figure(s) 4.2.14–4.2.15 do the same for the annual surplus.

Figure 4.2.12: Surplus (in MJ), scale C, in relation to GCA per household size (no of members) (in ha)

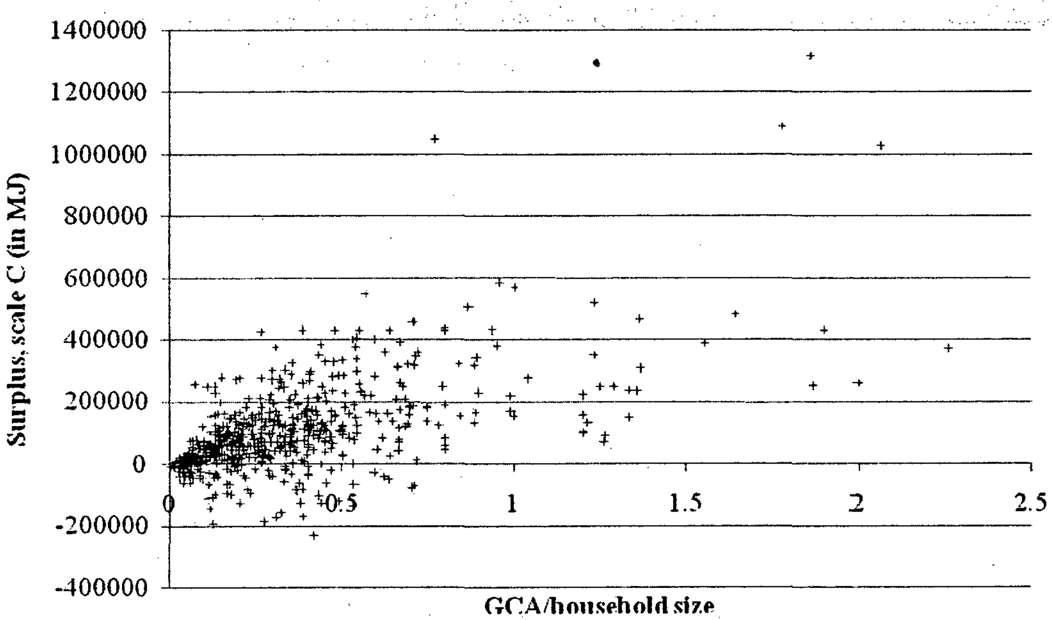
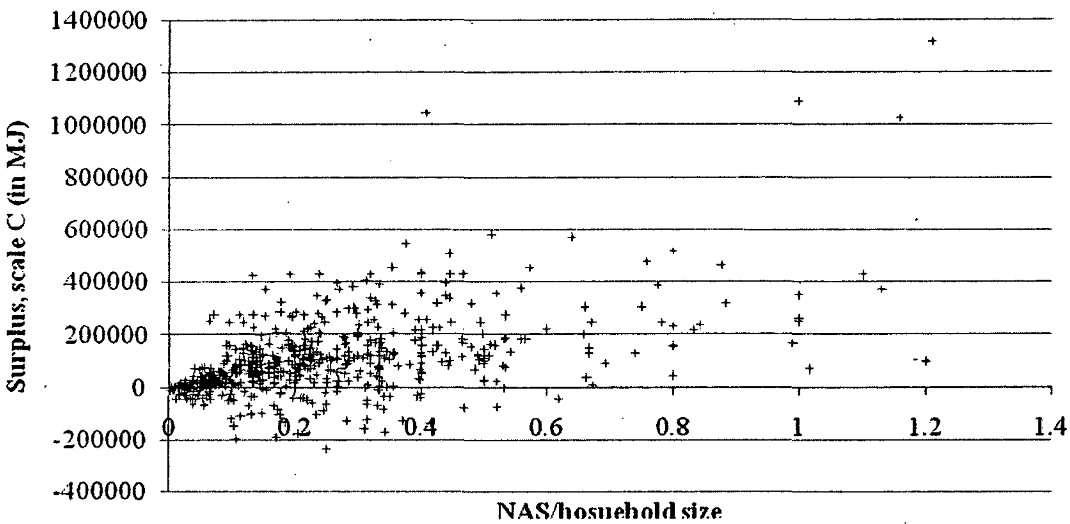


Figure 4.2.13: Surplus (in MJ), scale C, in relation to NAS per household size (no of members) (in ha)



For a positive surplus during the cultivating period or scale C, it seems that a GCA of 0.7 ha per member of household or a little above 0.6 ha of NAS per household member is the threshold. On the other hand, for ensuring a positive annual surplus, the threshold are 0.7 ha per household member as in the case of surplus of scale C. However, in terms of NAS per household member, the threshold is close to 0.7 ha. This is one of the significant conclusions of this thesis.

Figure 4.2.14: Annual Surplus (in MJ) in relation to GCA per household size (no of members) (in ha)

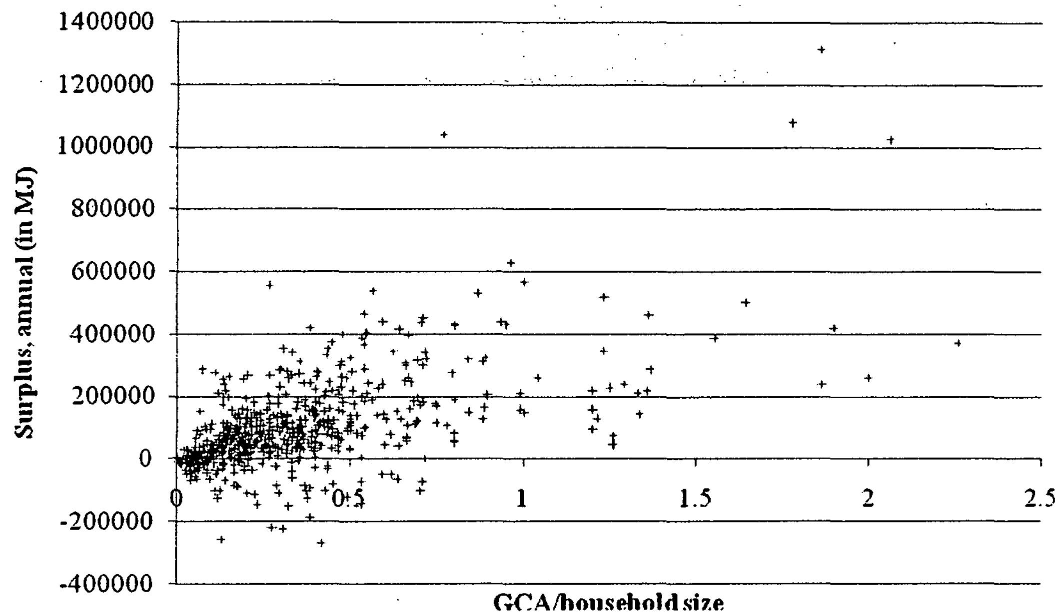
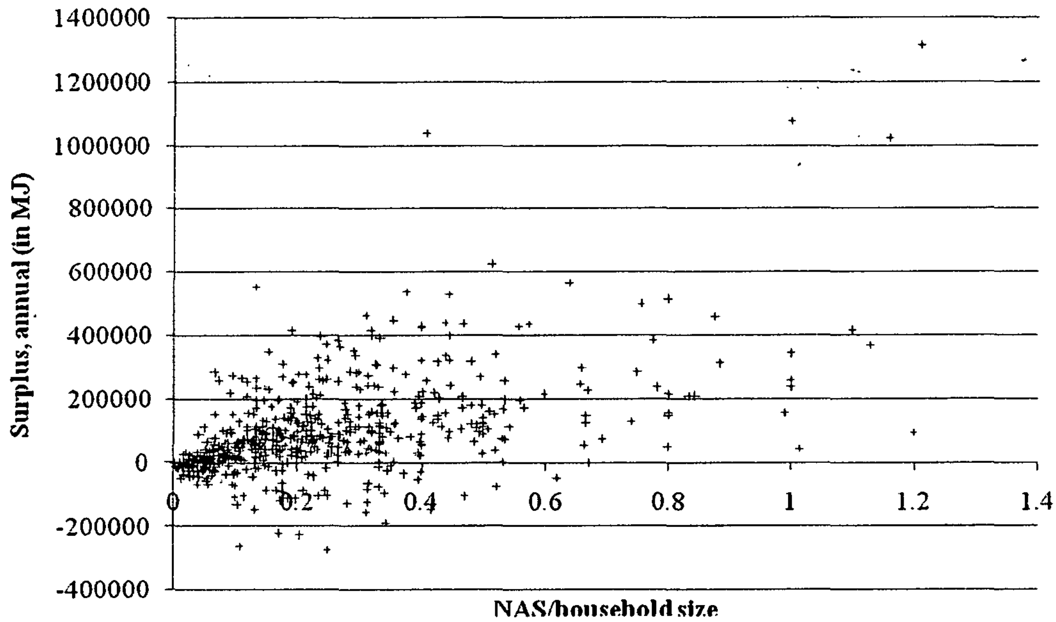


Figure 4.2.15: Annual Surplus (in MJ) in relation to NAS per household size (no of members) (in ha)



Finally, in terms of number of earners per GCA and NAS, such threshold corresponds to 3 ha and 2 ha per earner respectively, for ensuring a positive surplus in the cultivating period, as shown by figure (s) 4.2.16 and 4.2.17. These thresholds are not different for ensuring a positive annual surplus as well, as shown by figure(s) 4.2.18 and 4.2.19 respectively.

Figure 4.2.16: Surplus (in MJ) scale C in relation to GCA per earner in the household (in ha)

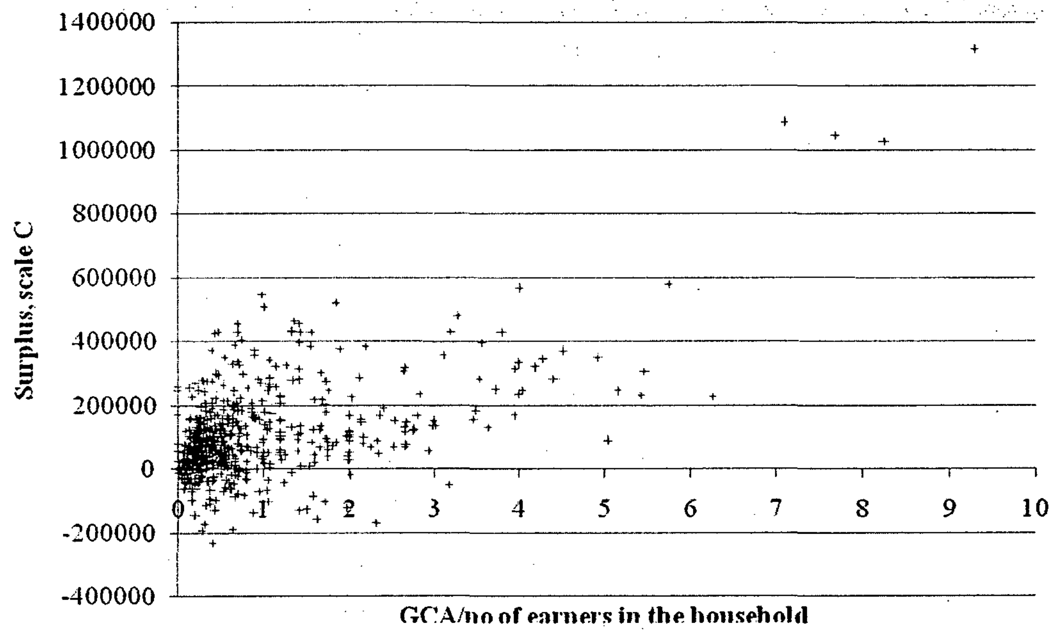


Figure 4.2.17: Surplus (in MJ) scale C in relation to NAS per earner in the household (in ha)

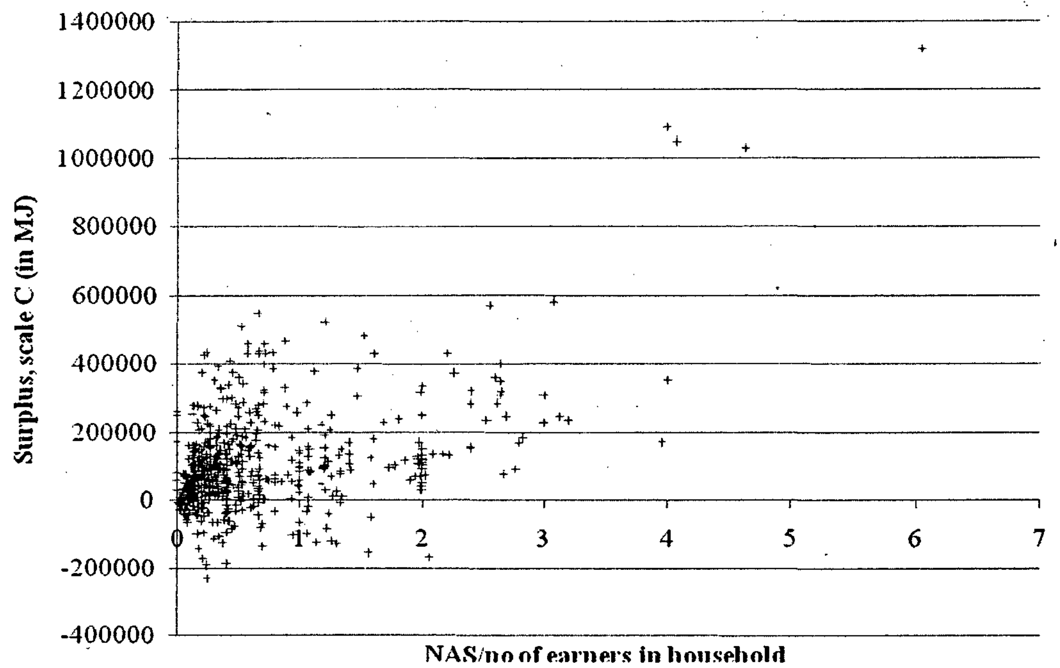


Figure 4.2.18: Annual Surplus (in MJ) in relation to GCA per earner in the household (in ha)

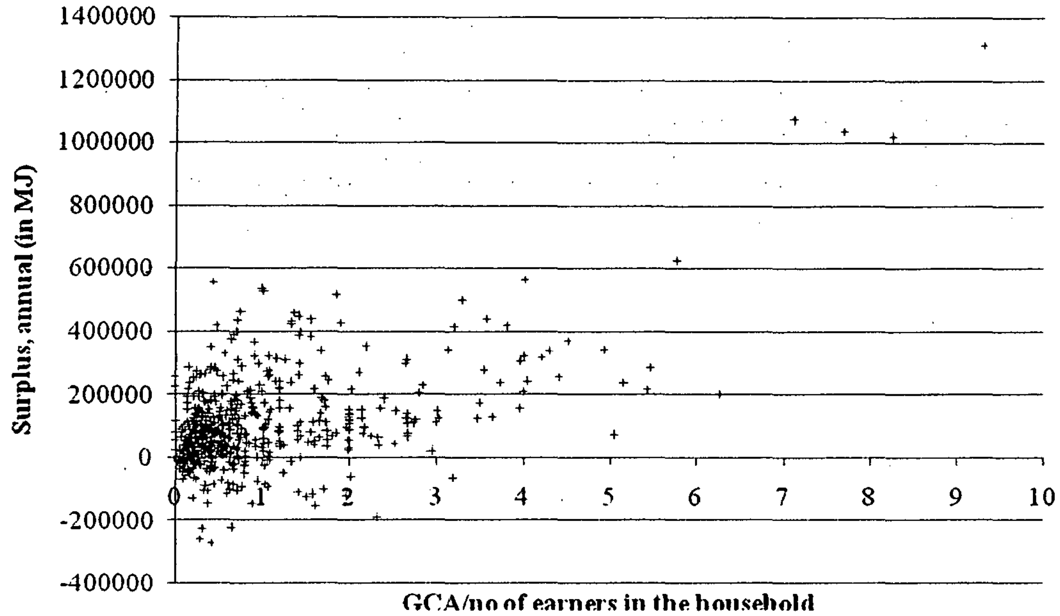
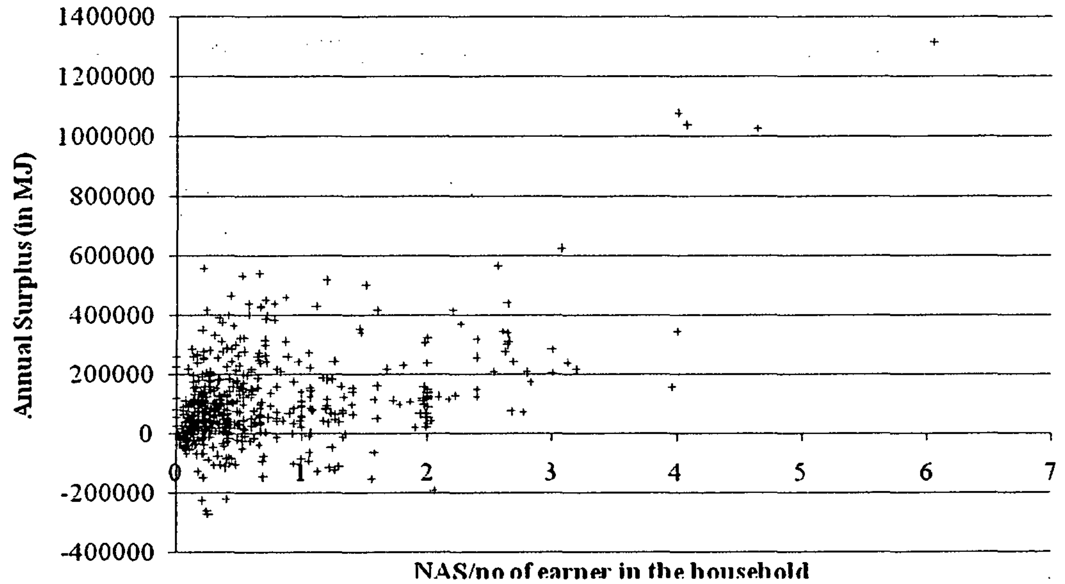


Figure 4.2.19: Annual Surplus (in MJ) in relation to NAS per earner in the household (in ha)



We may conclude this section with showing the relationship between the surpluses in four alternative scales of sustainability with the number of household members through figure(s) 4.2.20–4.2.23.[11] Interestingly, except the very edges (namely with few single member household and the one with 25 members), for every other size, there had been households with a negative surplus. In other

[11] Figure A.4.2.1-A.4.2.4 shows the same relationship with CCS size-groups as the marker.

words, household size per se cannot be an explanation to the negative surplus, but it is area under household or cultivation (GCA or NAS) per member of the household or the number of earners in the household.

Figure 4.2.20: Surplus (in MJ) scale A in relation to number of household members

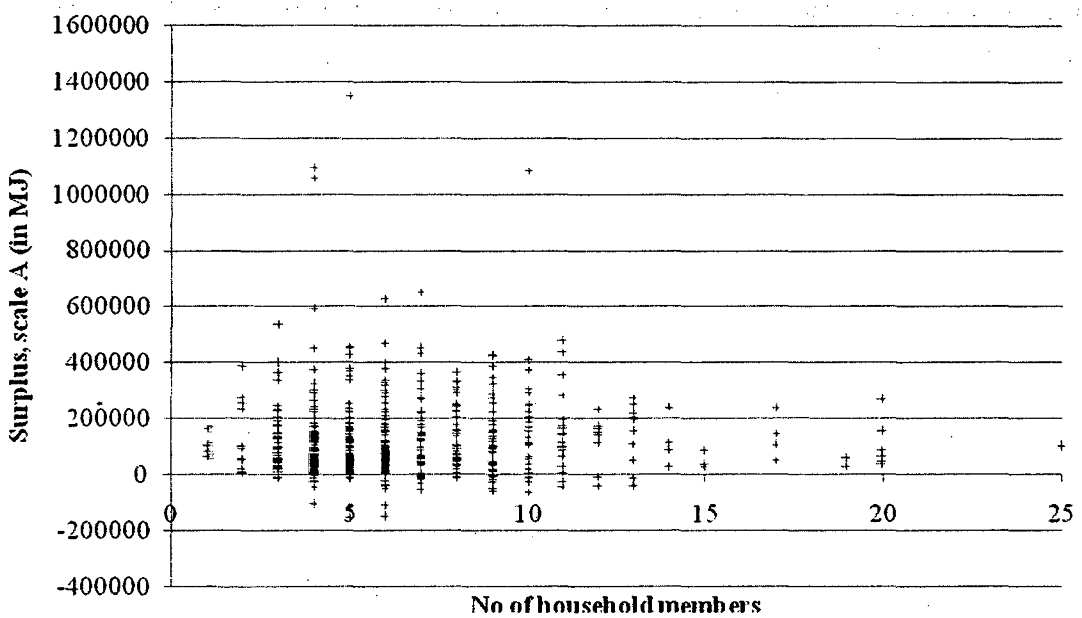


Figure 4.2.21: Surplus (in MJ) scale B in relation to number of household members

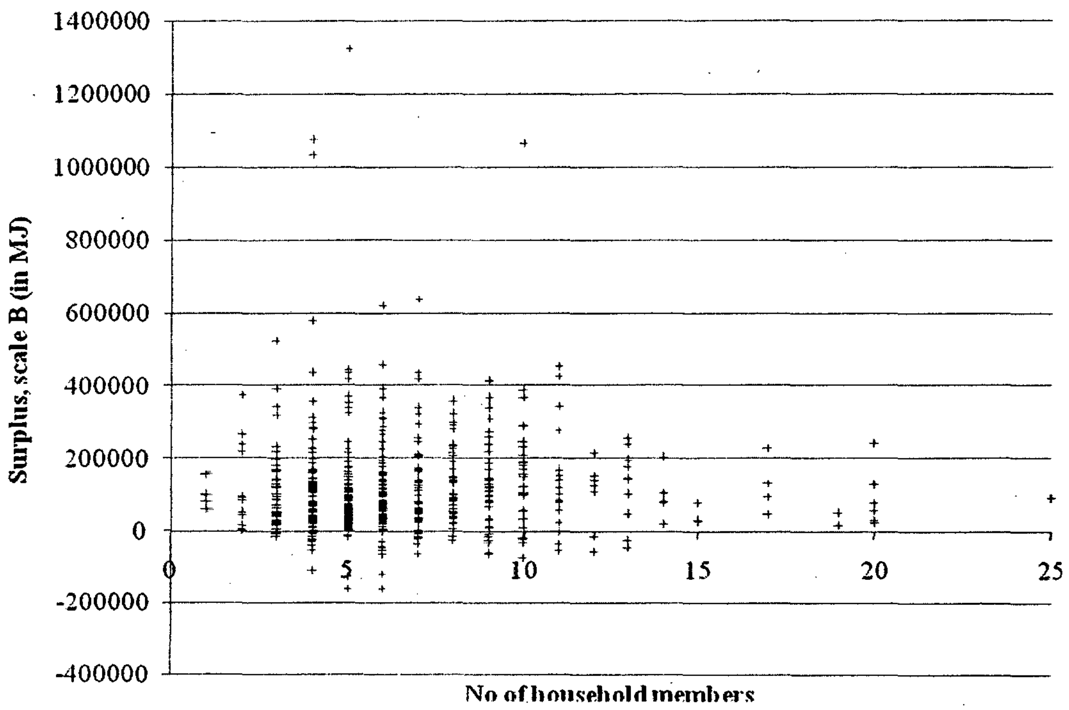


Figure 4.2.22: Surplus (in MJ) scale C in relation to number of household members

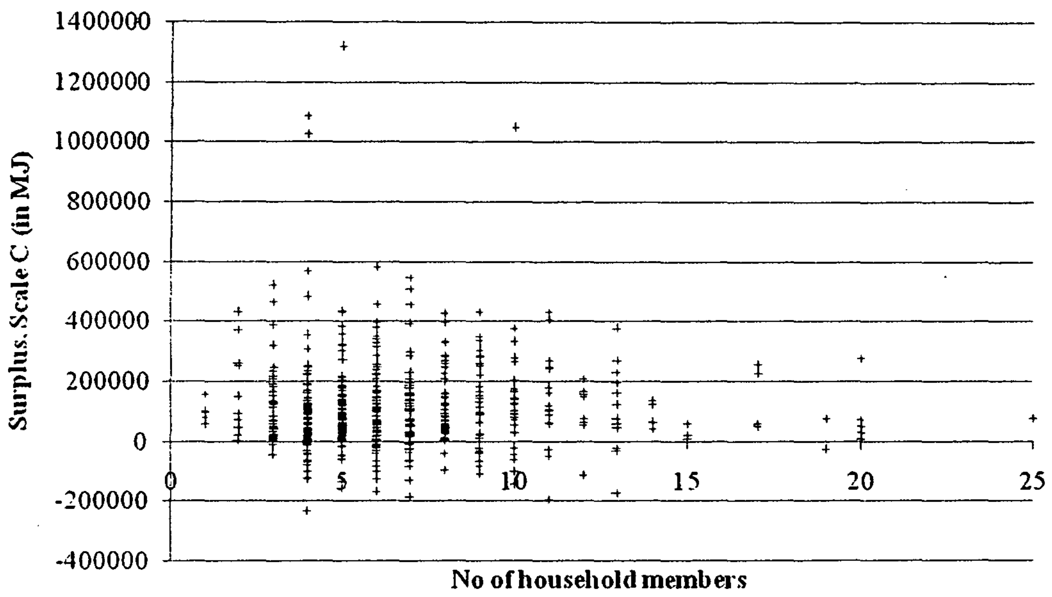
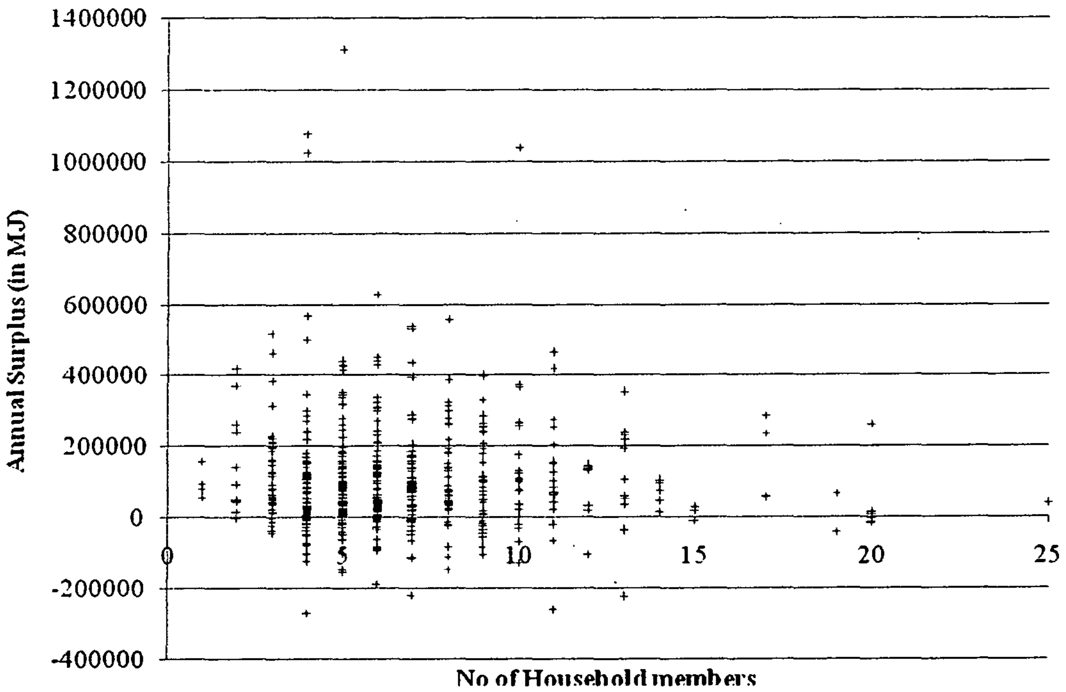


Figure 4.2.23: Annual Surplus (in MJ) in relation to number of household members



4.3. EROI

EROI was calculated under all the four scales. For all plots together, they were 2.46, 2.25, 1.68 and 1.57 respectively. It may be noted that these numbers were arrived at by taking the ratio of total output and total input in each of the scales. Certainly, these averages did not reflect the variations and the underlying causes for it. Before we explore the patterns of EROI, we may note the total input, output, surplus and EROI under all the four scales, aggregated over our ranges of GCA as presented in Table 4.3.1.

Table 4.3.1: Input (in MJ), Output (in MJ), Surplus (in MJ)and EROI in four scales of sustainability in relation to GCA (in ha), aggregated over size-group

Gross Cropped Area (in ha)	Input, scale A	Output, scale A	Input, scale B	Output, scale B	Input, scale C	Output, scale C	Input, annual	Output, annual
0.01–0.33	12948	22643	15447	22643	34816	38296	48228	51450
0.34–0.66	24605	52021	28137	52021	54769	73531	67865	88389
0.67–1.00	39390	88029	43144	88029	68884	116454	89877	138036
1.01–1.20	52393	122992	57627	122992	99880	166176	130080	196445
1.21–1.50	82063	145018	88998	145018	161570	202624	190638	233948
1.51–1.80	78802	164531	85729	164531	155529	227391	190134	248656
1.81–2.01	95338	197195	102469	197195	185772	262561	218001	291107
2.02–2.31	98044	204338	106486	204388	182317	295315	217913	322263
2.33–2.70	114395	242870	123641	242870	203134	314361	231032	334139
2.71–3.30	122937	284602	133863	284602	224841	370355	252331	389434
3.31–4.25	104963	375599	117863	375599	225844	474431	249652	483860
4.26–9.30	145612	604777	159996	604777	278746	722074	325097	733376

Gross Cropped Area (in ha)	Surplus, scale A	Surplus, scale B	Surplus, scale C	Surplus, annual	EROI, scale A	EROI, scale B	EROI, scale C	EROI, annual
0.01–0.33	9695	7196	3480	3222	1.75	1.47	1.10	1.07
0.34–0.66	27416	23884	18762	20524	2.11	1.85	1.34	1.30
0.67–1.00	48639	44885	47570	48159	2.23	2.04	1.69	1.54
1.01–1.20	70599	65365	66296	66365	2.35	2.13	1.66	1.51
1.21–1.50	62955	56020	41054	43310	1.77	1.63	1.25	1.23
1.51–1.80	85729	78802	71862	58522	2.09	1.92	1.46	1.31
1.81–2.01	101857	94726	76789	73106	2.07	1.92	1.41	1.34
2.02–2.31	106294	97902	112998	104350	2.08	1.92	1.62	1.48
2.33–2.70	128475	119229	111227	103107	2.12	1.96	1.55	1.45
2.71–3.30	161665	150739	145514	137103	2.32	2.13	1.65	1.54
3.31–4.25	270636	257736	248587	234208	3.58	3.19	2.10	1.94
4.26–9.30	459165	444781	443328	408279	4.15	3.78	2.59	2.26

While we had noted the pattern of surplus of scale C against GCA, figure 4.3.1 does the same for all the four scales. As we move from a lower (say, A) to a higher (say, B) scale, surplus reduces almost uniformly, across the GCA. Figure 4.3.1 shows the same pattern against output ranges. A closer look reveals a fall in each of the surplus lines against the GCA range of 1.01–1.2 ha, and a sharp change in the slope against the GCA range of 2.33–2.70 ha. However, no such distinct changes can be observed in the surpluses against output ranges in figure 4.3.2. These two GCA ranges may be taken note of, as a similar pattern will be revealed by EROI of all the four scales.

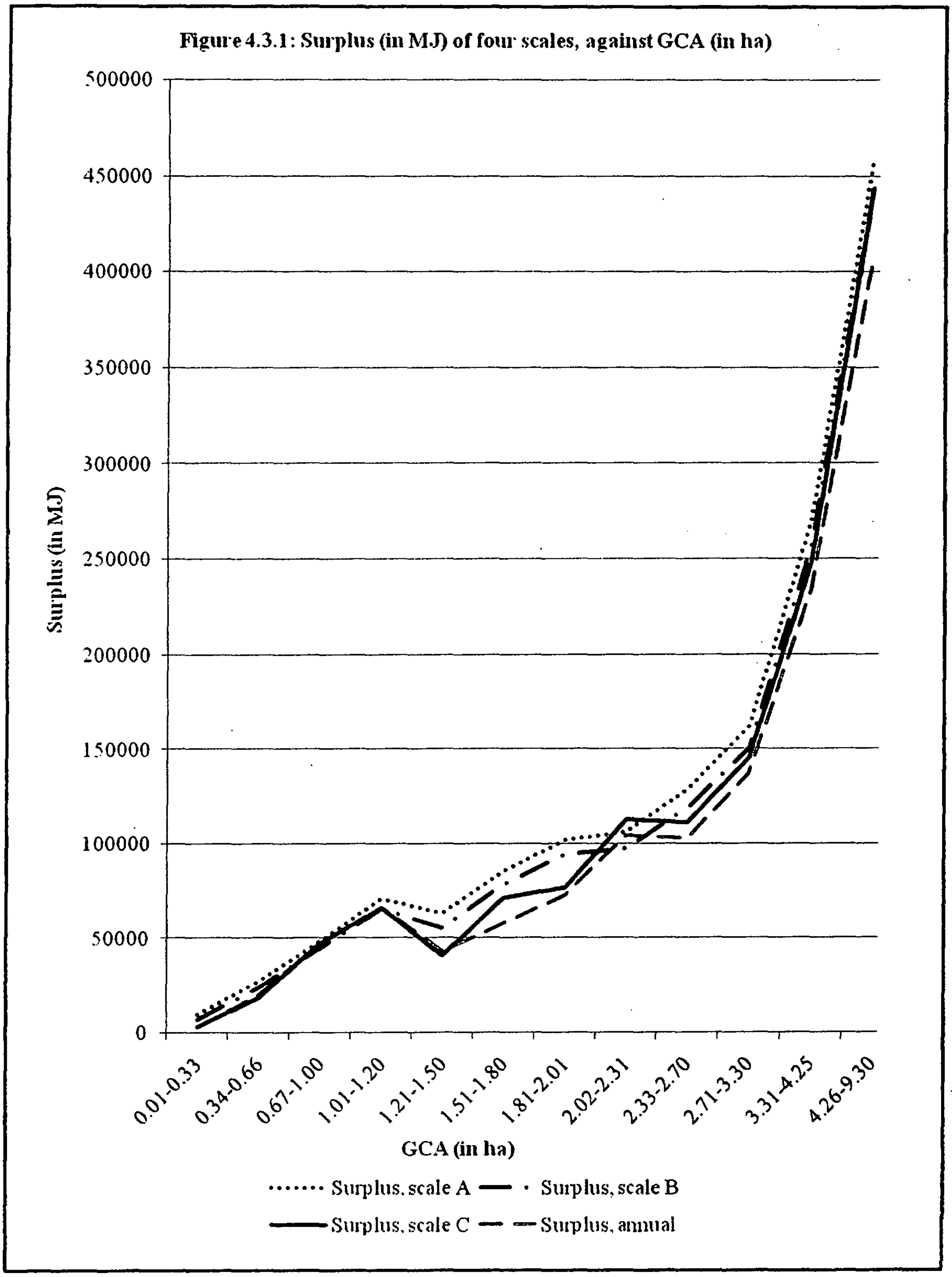


Figure 4.3.2: Surplus (in MJ) in four scales, in relation to Output (in MJ)

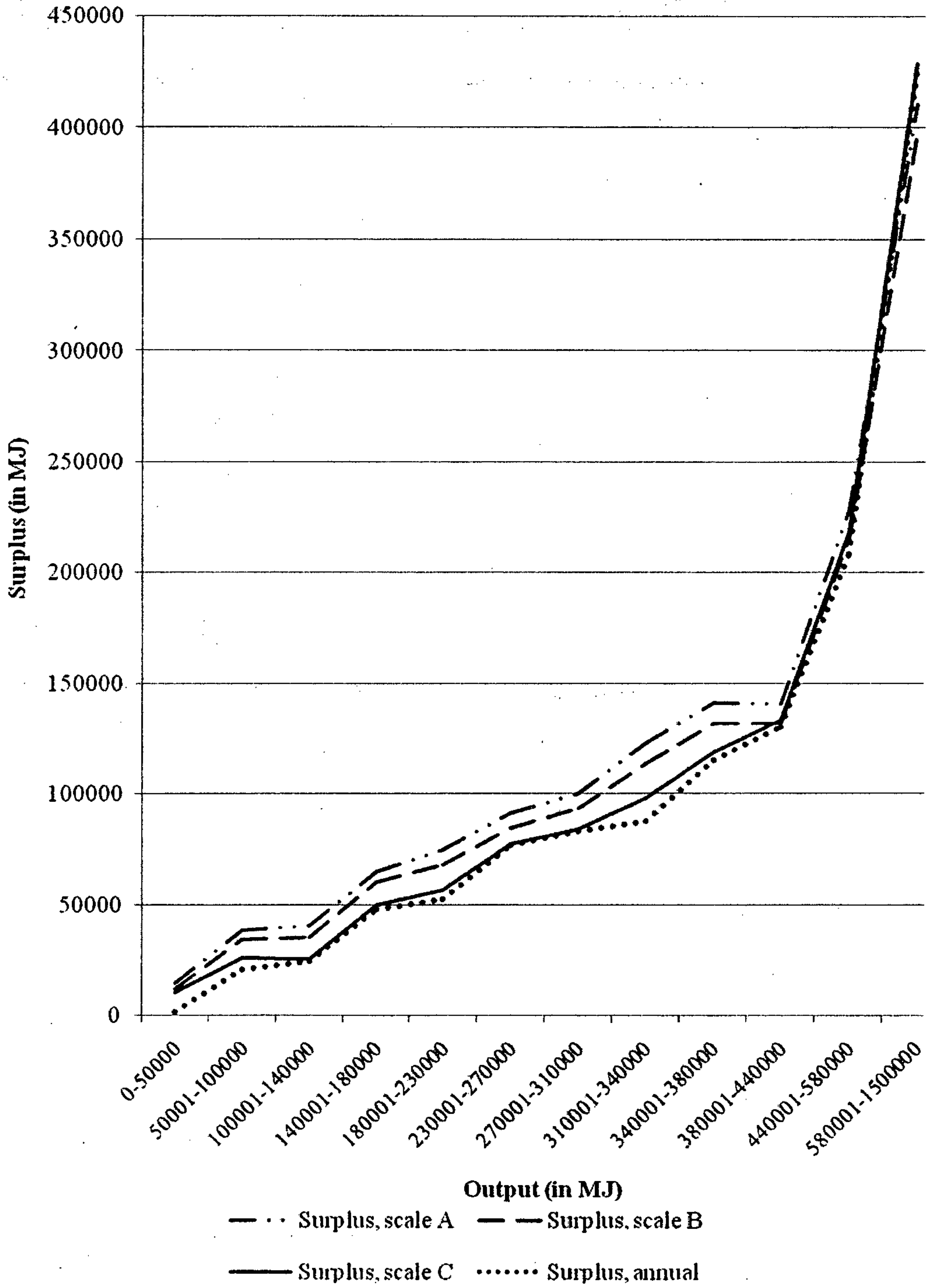


Figure 4.3.3 portrays the relationship between EROI and the GCA in all the four scales. While all four show a similar overall relationship, there are important differences. Overall, the trend shows increase in EROI, with GCA, with a drop in the middle. Indeed, the latter points to the absence of any definite benefits from the opportunities in the increase in the scale of operations due to larger gross area under cultivation. Further, leaving the households of the lowest three size-classes (0–1 ha), the remaining portion of the curve(s) in each of the scales are U–shaped with a long flat portion in the middle; while the extent of fall in EROI with rise in GCA is less, the rise is quite sharp for the last three size-groups. However, as we have noted in the previous section, it is not the absolute land size that is in question but the land with respect to the size of the household that has a significant causal effect on the surplus or the sustainability of the labour engaged in crop cultivation.

Figure 4.3.3: EROI in four scales, aggregated at households, against GCA (in ha)

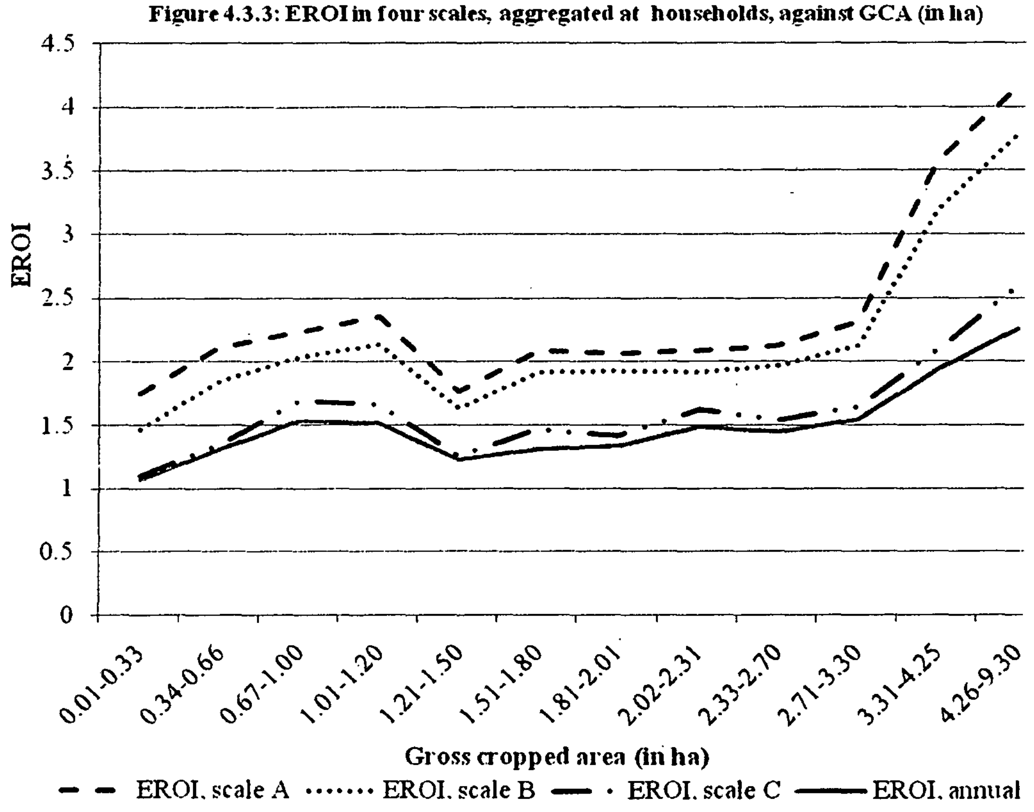
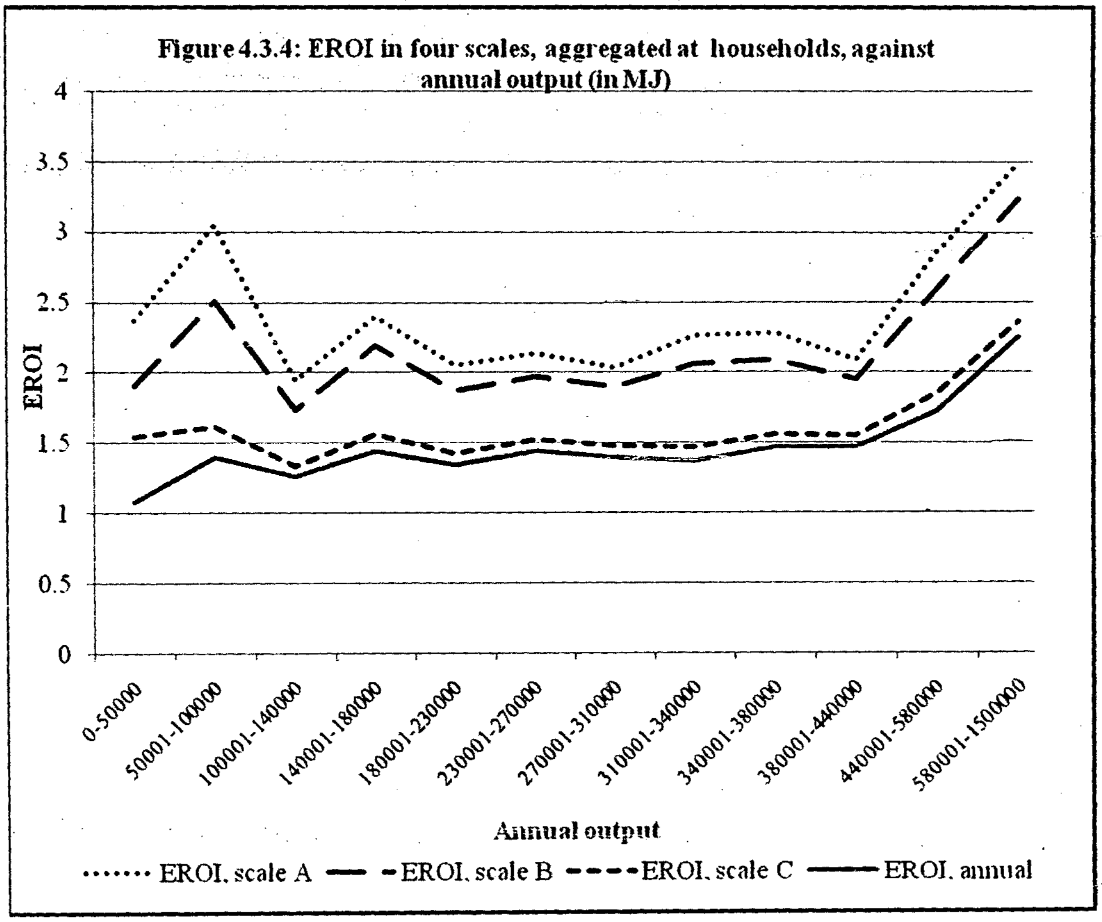


Figure 4.3.4 shows the relationship between the EROI in the four scales against annual output (in MJ). We may note the positive relationship beyond the output of 20,000 MJ, in scales C and the annual one. In contrast to figure 4.3.3, the flat portions of all the four scales are longer, implying a more uniform input-output

relationship against scales of production. As a consequence, the 'fluctuation' towards the lower end of the horizontal axis is more concentrated.



Together, we may note the following, besides the average EROIs in the four scales of sustainability, namely, 2.46, 2.25, 1.68 and 1.57: while for the GCA beyond 3.30 ha, EROI of even the annual scale is a decent one, such a threshold corresponds to an annual output of 440,000 MJ.

4.4. Rate of Surplus value

We may reiterate that we had taken the rate of surplus value for scale C, or only the cultivating (active) period. It is the ratio of the surplus in scale C and the value of the labour power in scale C.

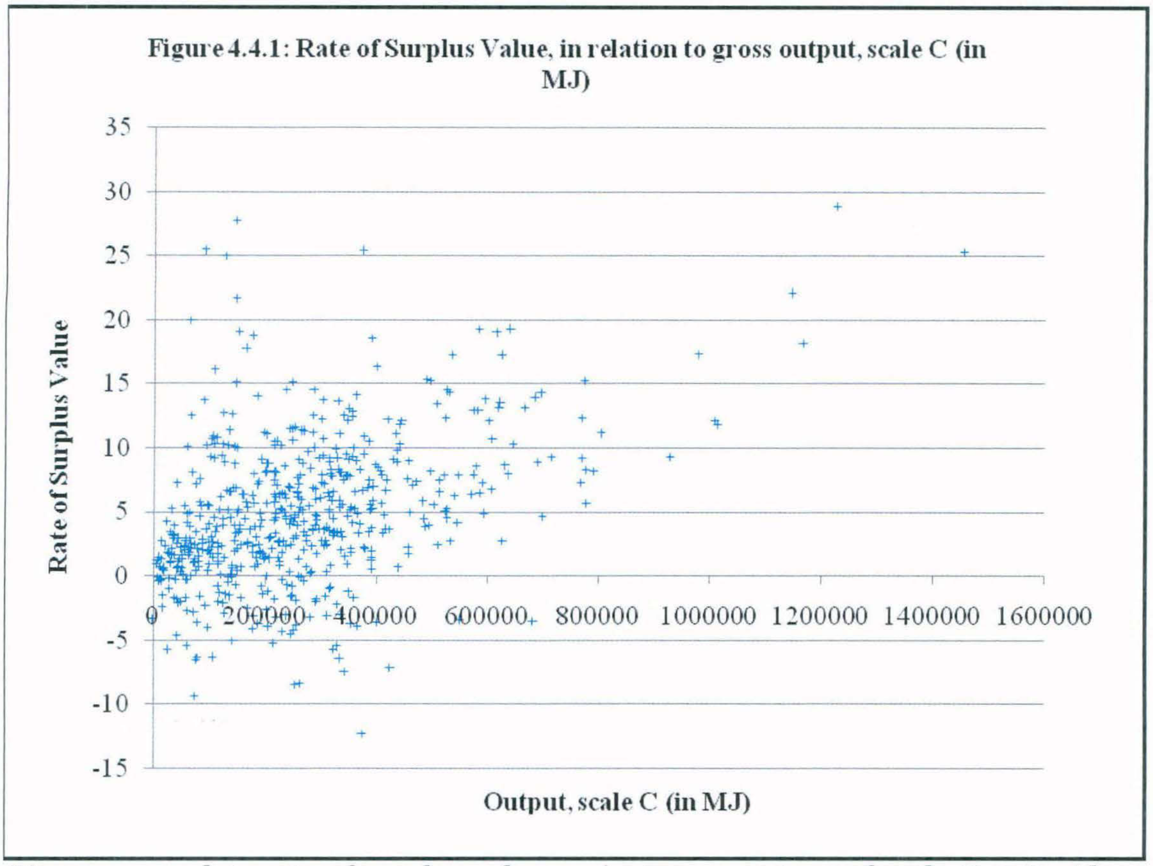


Figure 4.4.2 plots rate of surplus value against gross output of scale C. [12] Besides the rising trend, two other important facts may be noticed. The first is the presence of a considerable number of households with a negative rate of surplus value and the other is the rather high rates of for low levels of output: these points to the greater variance among the smaller land sizes which are associated with lower size of output (table 4.1.1). None of the two is an exception but reflect important characteristics of the agricultural production system. The former results from the negative surplus that we had notice earlier also.

[12] For the convenience of visual representation, the following households were not considered in figure(s) in this section 4.4.

EROI, scale C	Surplus/ GCA	GCA	Cropping intensity	Labour/ GCA	S/V	Zone	Size-group
0.79	–869873	0.01	1	301150	–2.88851	II. Terai	1 (0–1 ha)
0.28	–247091	0.04	1	163088	–1.51507	IV. Old Alluvial	1 (0–1 ha)
0.75	–41621	0.05	1	161219	–0.25816	IV. Old Alluvial	1 (0–1 ha)
0.99	–2340.8	0.05	1	201449	–0.01162	VI. Coastal Saline	1 (0–1 ha)

Figure 4.4.2: Rate of Surplus Value, against Output, scale C, across CCS size-groups

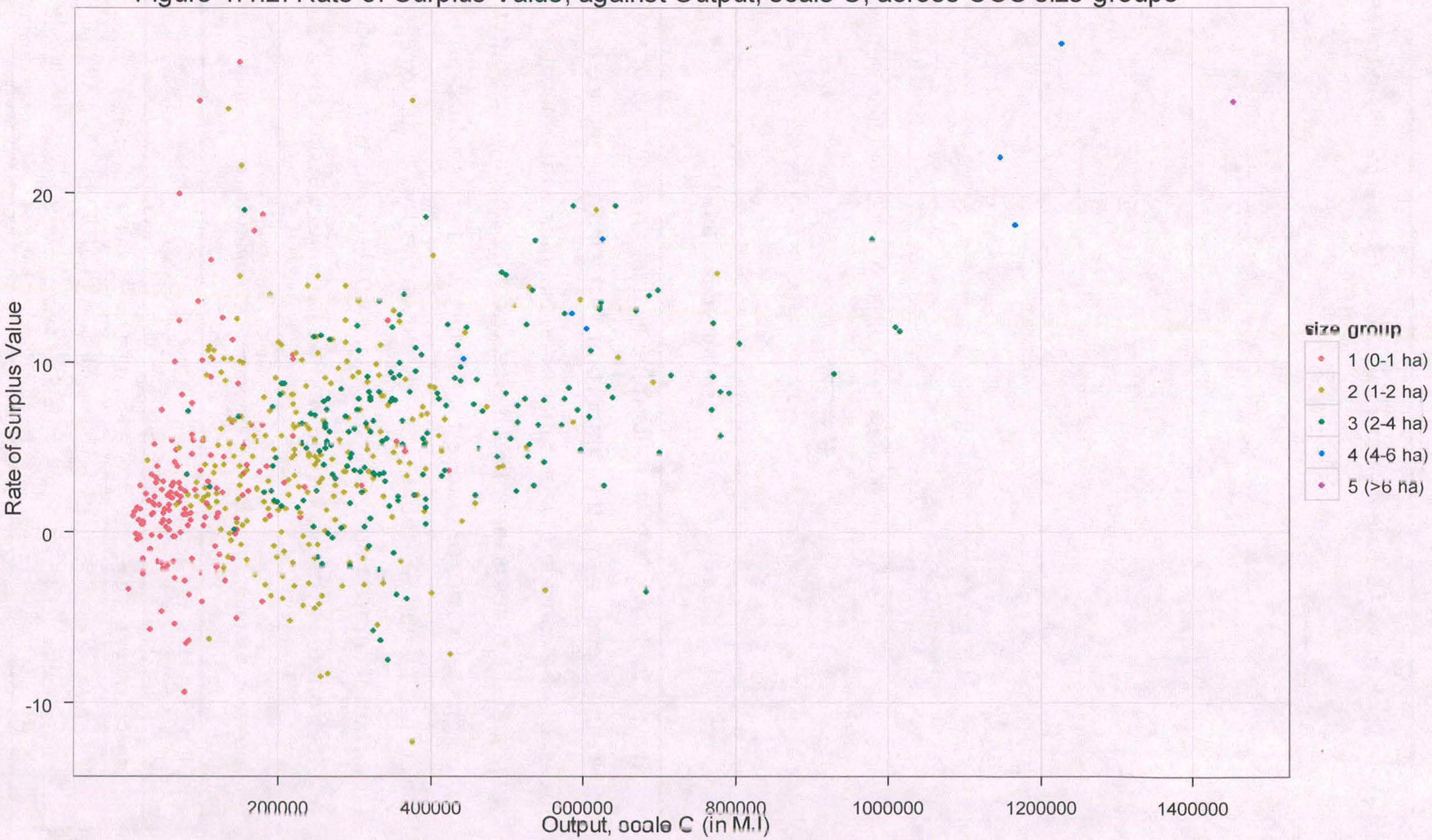
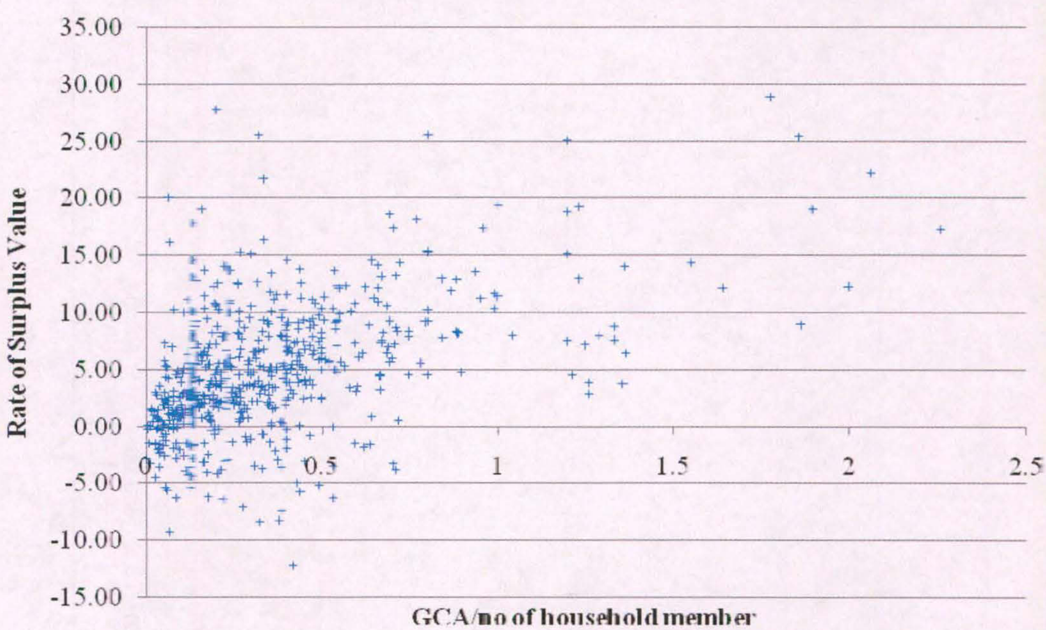



Figure 4.4.3: Rate of Surplus Value, against Output, scale C, across Zones
Rate of Surplus Value
20
10
0
-10
200000
400000
600000
800000
1000000
1200000
1400000
Output, scale C (in MJ)
zone
II. Terai
III. New Allluvial
IV. Old Alluvial
V. Red laterite
VI. Coastal Saline

We may recollect that the negative surplus results only when the energy value of the difference between the gross output and the inputs is negative (or the value created by the labour is less than the value of labour power). Figure 4.4.1 confirms that these farms mostly belong to the two lowest CCS size-groups. Similarly, figure 4.4.2 shows that they mostly belong to zone V and VI. Certainly, with a tiny land, and a not so conducive bio-physical framework, these households had no other means to produce a surplus.

Figure(s) 4.4.4 and 4.4.5 show the rate of surplus value against GCA per household member and NAS per household member.[13] Arguably, figure 4.4.5 makes it amply clear the positive association between the rate of surplus value and the land in possession per household size.

Figure 4.4.4: Rate of Surplus value in relation to GCA per household member (in ha)



Further, as expected per hectare labour of scale C for the low levels of output was very high. Small farm sizes, no doubt, had a role in scaling up the number, but such a phenomenon can be witnessed against output levels of 200,000 MJ also.

[13] Figure(s) A.4.4.1 and A.4.4.2 shows the same relationship with CCS size-group as marker.

Figure 4.4.5: Rate of Surplus value in relation to NAS per household member (in ha)

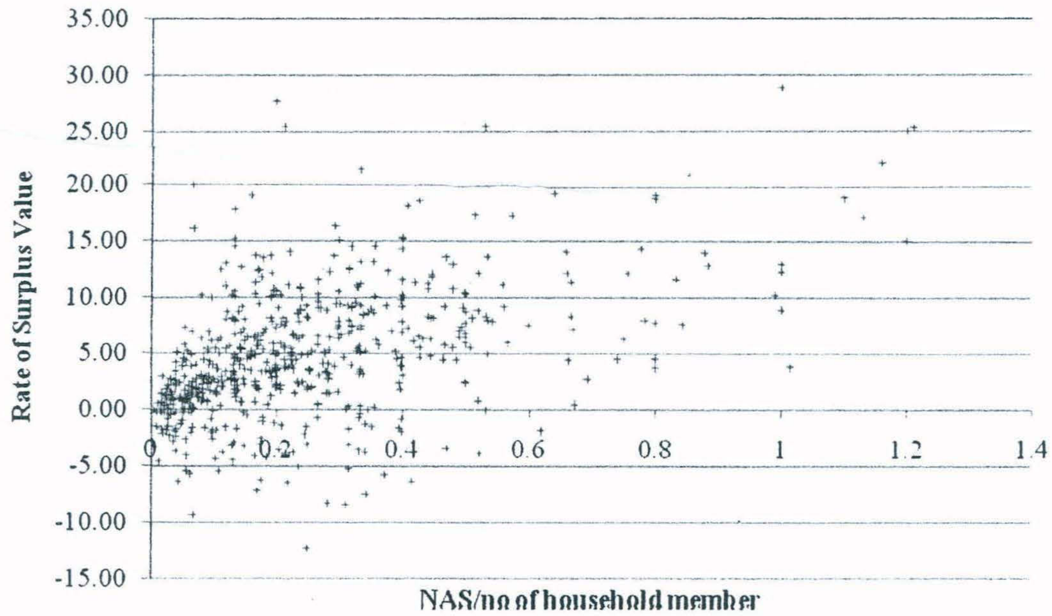


Figure 4.4.6: Per hectare labour, scale C (in MJ/ha) in relation to output (in MJ)

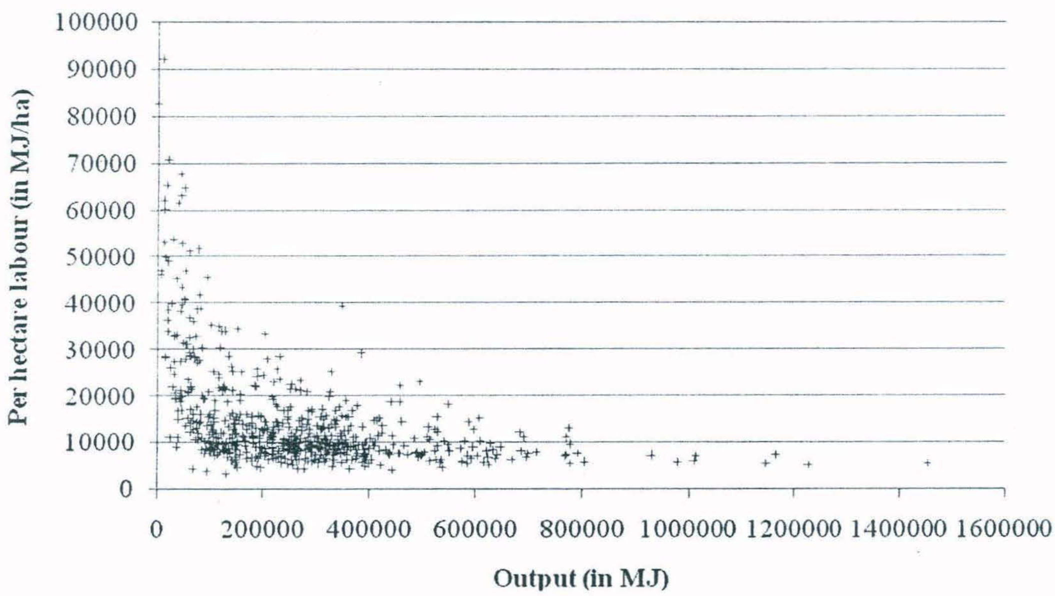


Figure 4.4.7 confirms that such high labour per hectare indeed is associated with the lowest two CCS size-groups. With increase in the area under cultivation (or, if we move from lower to subsequently higher size-groups), labour per hectare reduces, an obvious and known fact.

Figure 4.4.8 portrays a more nuanced relationship between labour per hectare and output with agro-climatic zones as the markers. One may observe the association of a very high labour per hectare with all the zones. Further, for a given per hectare labour, say, around 10,000 MJ/ha, lowest output was achieved in red laterite, followed by coastal saline and then by both the alluvial zones. At the same time, for each of the zones, the negative relationship between per hectare surplus and output is visible enough.

Figure(s) 4.4.9 and 4.4.10 shows per hectare labour of scale C against GCA and NAS per number of household members respectively.

Figure 4.4.9: Human labour, scale C per GCA (in MJ/ha) in relation to GCA/no of household members (in ha)

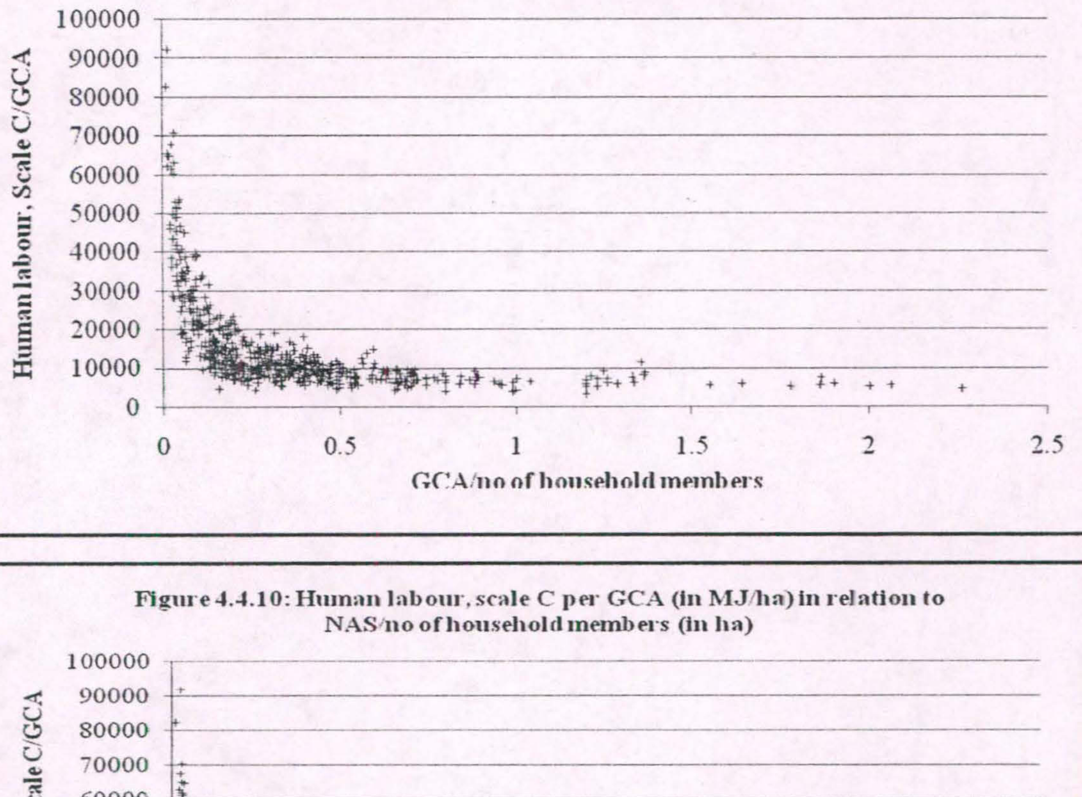


Figure 4.4.10: Human labour, scale C per GCA (in MJ/ha) in relation to NAS/no of household members (in ha)

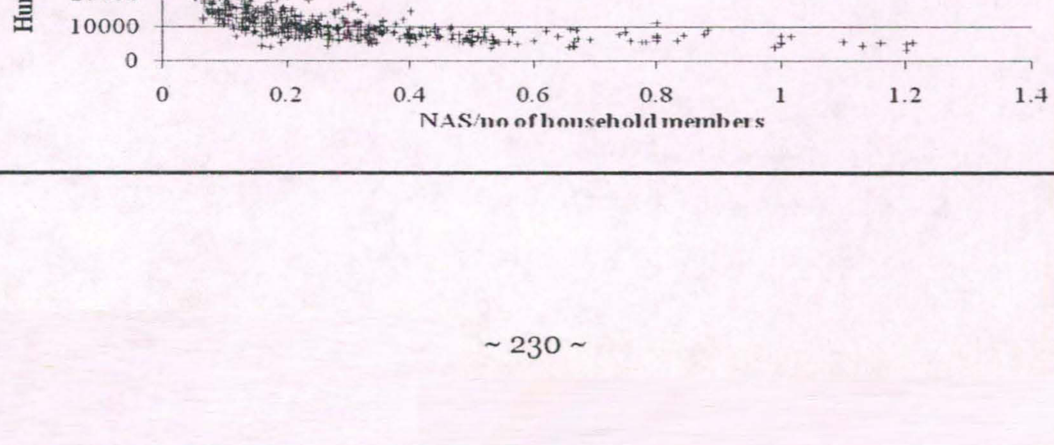


Figure 4.4.7: Per hectare Labour (in MJ/ha), against Output, both in scale C, across CCS size-groups

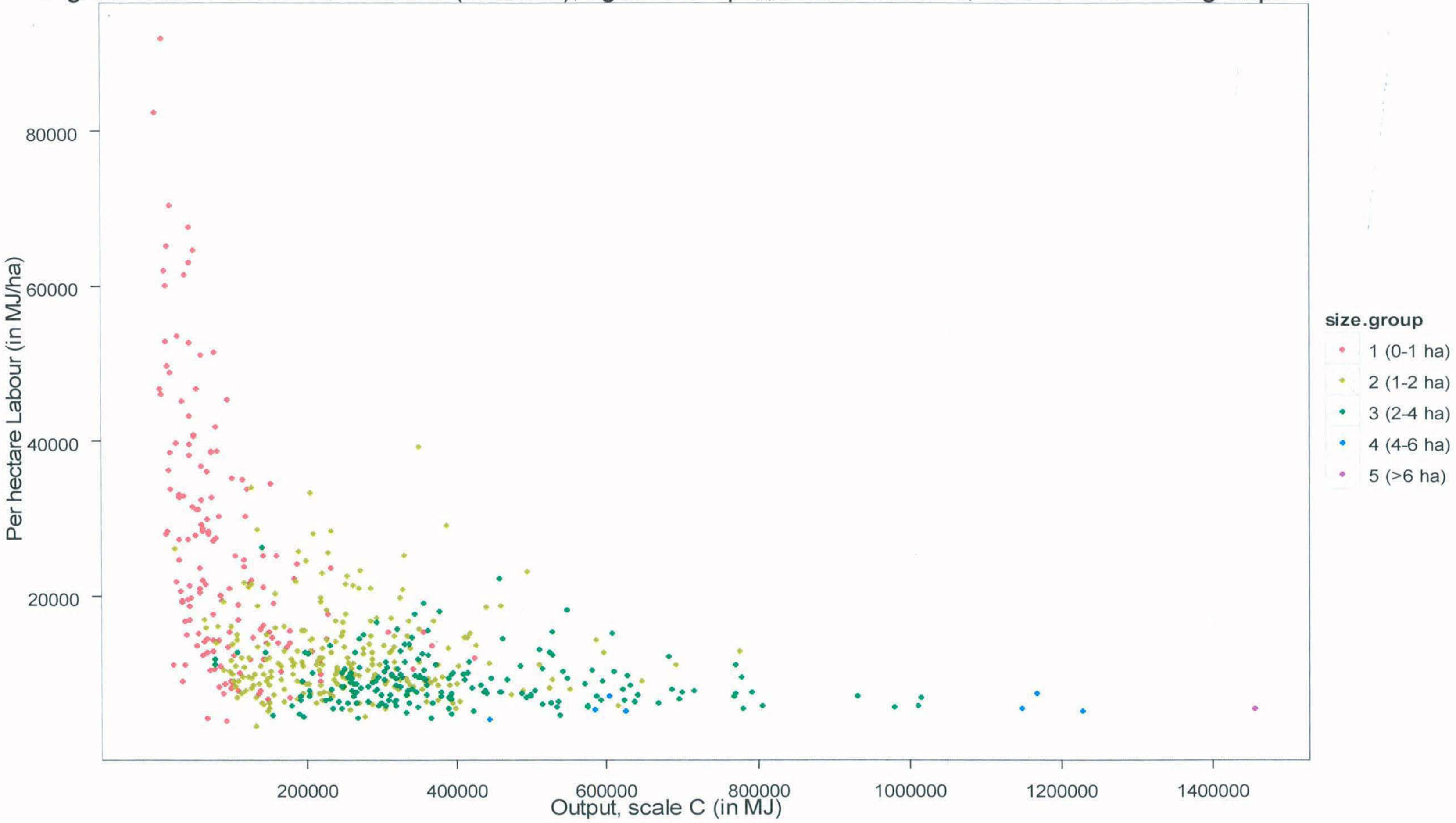
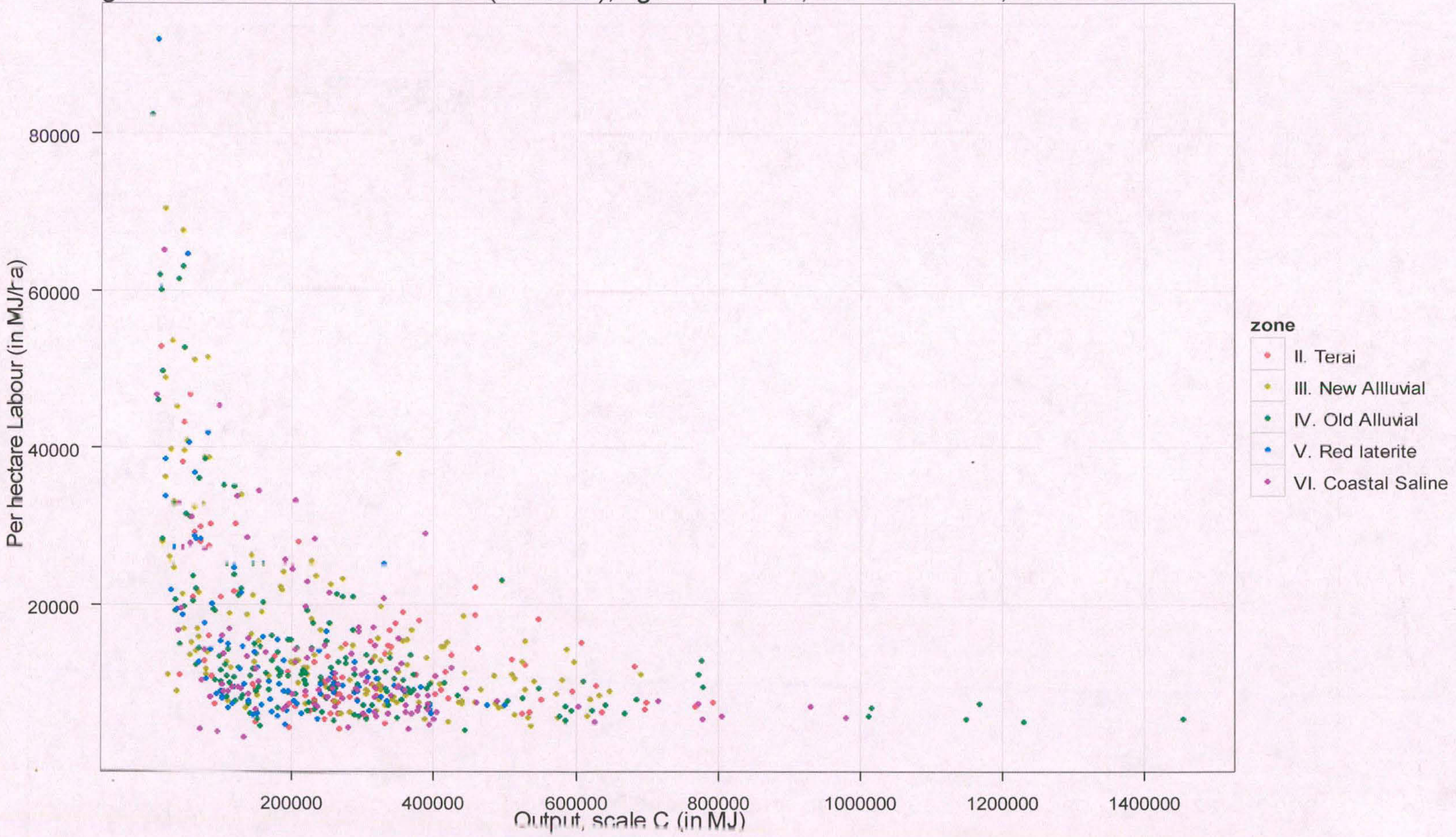


Figure 4.4.8: Per hectare Labour (in MJ/ha), against Output, both in scale C, across Zones



Besides the obvious negative relationship between per hectare human labour in scale C (in MJ) and the land under cultivation per household size (in ha), be it for GCA or for NAS, we may also note the human labour per hectare in scale(s) of A and B against the GCA per household size in figure(s) 4.4.11 and 4.4.12 respectively.

Figure 4.4.11: Human labour, scale A per hectare (in MJ/ha) in relation to GCA/no of household members (in ha)

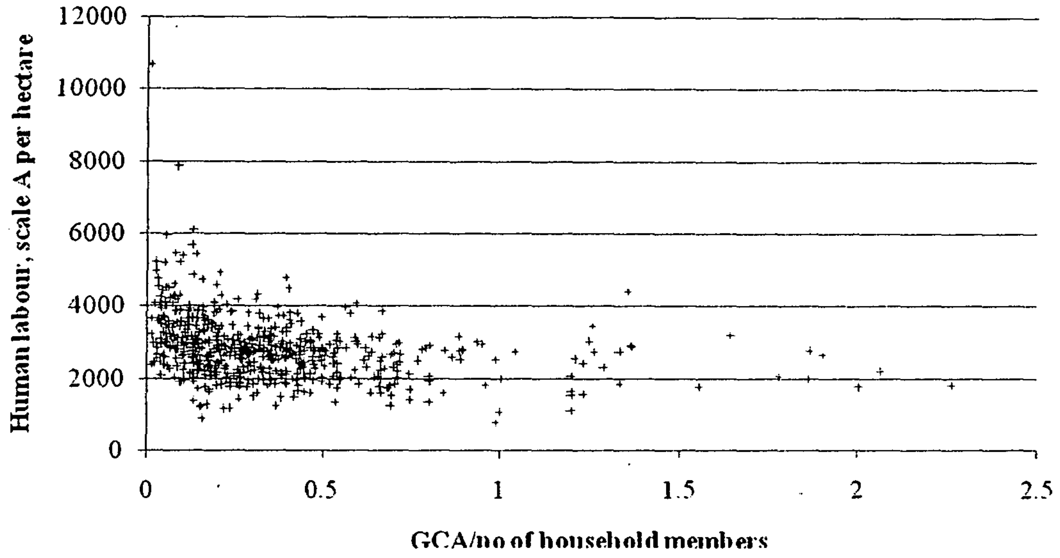
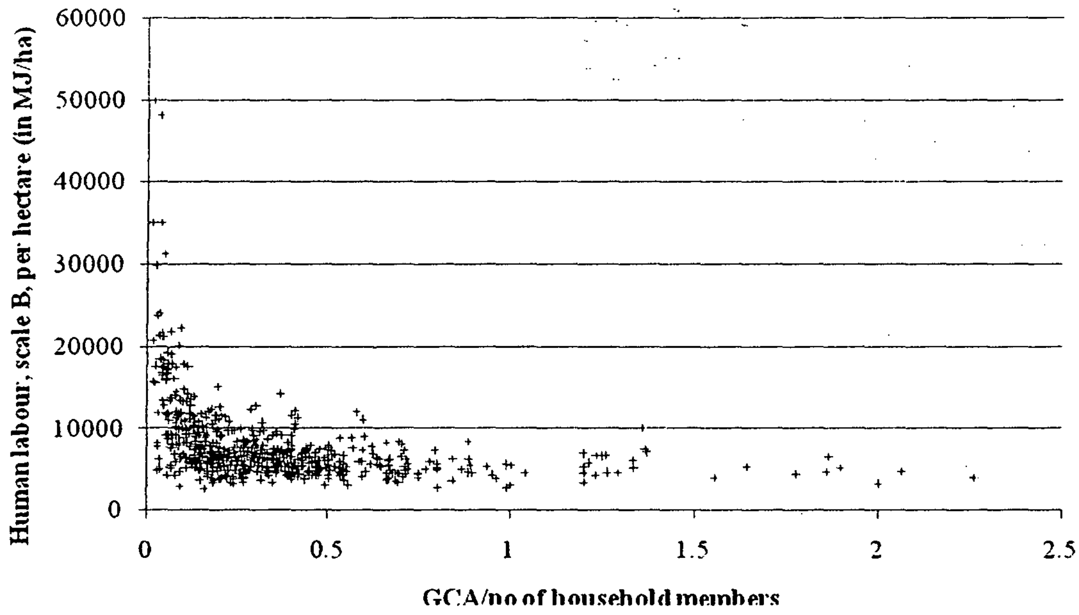


Figure 4.4.12: Human labour, scale B per GCA (in MJ/ha) in relation to GCA/no of household members (in ha)



These figures (4.4.4, 4.4.9–4.4.12)[14] together make it obvious that while rate of surplus value is positively associated with land area per household size, per hectare human labour in the different scales (of A, B and C) is negatively related with land per household size. It appears that per hectare labour against GCA/household size remains relatively static beyond 0.6 ha/no. of members.

4.5. Summary of the Chapter

We may summarise the findings of this section:

1. There exists considerable number of farms with negative surplus, in scale C or the cultivated period or the annual scale that takes into account the entire agricultural year including the non-cultivating period. Most of these households belong to the two lowest CCS size-groups. Further these farms were mostly concentrated in red laterite and coastal saline zone.
2. The threshold for a positive surplus was around 3 ha of GCA, if we look at the overall data, which however greatly varied with respect to agro-climatic zones. Following were the zone-wise threshold(s) in terms of GCA: 4 ha (terai), 0.5 ha (new alluvial), 3.25 ha (old alluvial), 2.75 ha (red laterite) and 2.9 ha (coastal saline).
3. For the annual sustainability, the threshold net area sown was found to be around 2.5 ha. This minimum area under cultivation varied with respect to agro-climatic zones, which had an influence on the associated cropping intensity.
4. A positive annual surplus was independent of the number of household members, as for households with very small size (say, 3), as well as very large size (say, 20) was found to be associated with it. On the other hand, 3 ha of GCA/household size and 2 ha of NAS/household size was found to be the critical limits for ensuring a positive annual surplus in energy terms.
5. Highest surplus in absolute terms and also in per hectare terms was found to be corresponding to a cropping intensity of 1.2–1.5. However, both size-class and agro-climatic environment showed varied relationships.
6. Surplus in all four scales of sustainability was found to be monotonically increasing against gross output. Similarly, output and GCA, and consequently surplus and GCA had shown similar patterns.

[14] Figure(s) A.4.4.3 and A.4.4.4 shows per hectare labour, scale C against GCA per household size and NAS per household size respectively, with CCS size-groups as the additional marker.

7. EROI had shown a monotonic relationship with output, beyond a level of output around 200,000 MJ. With respect to GCA, besides the general rising pattern it had shown a sharp drop in the middle, and a very sharp rise against the largest GCA. EROI curves for the all four scales, be it against GCA or output, had shown a gradual downward movement, with shift from scale B to scale C having the largest shift.
8. Per hectare labour against was fond to be relatively static beyond 0.6 ha/household member. A similar threshold (0.7/ha for GCA/household member and 0.6/ha for NAS/household member) was also found towards ensuring a positive surplus in energy terms.

In the end, a few facts stand out: the first is the large number of farms with a negative surplus, and the consequent negative rate of surplus value. Second is the positive relationships between output on the one hand and either the surplus or the GCA on the other. A related matter was a similar pattern for EROI. Third, towards a positive surplus in energy terms, the average threshold per household member land was found to be 3 ha in terms of GCA and 2 ha for NAS. The variations reflected the developments in the means of production and the associated bio-physical framework.

We may finish this chapter by stating that the results of a negative surplus is stronger than the FMS finding of only a negative profit, with a positive surplus in energy terms across the size-groups.[15]

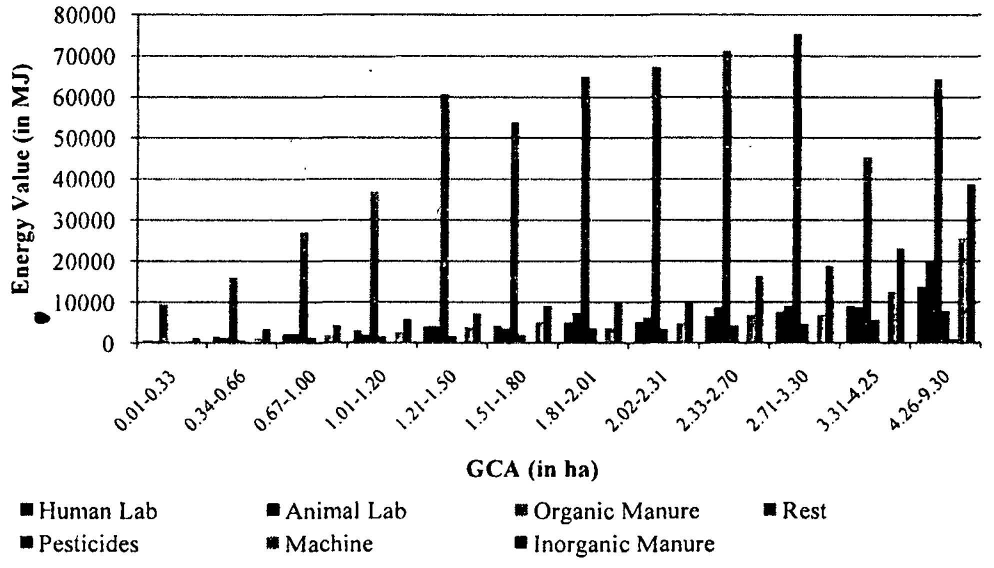
[15] We shall return to it in chapter 6.

> Man is naturally prone to spoliation, and dreads nothing so much as to have to exert his mental faculties in the acquisition of what he needs [...]. Necessity is the only compulsory agent that will ever make him move, and this will come soon enough (Justus von Liebig, 1859, 'Letter X' in *Letters on modern agriculture: with addenda by a practical agriculturist. Embracing valuable suggestions, adapted to the wants of American farmers*, J Wiley, New York, p. 196).

5.1. Input Usage Patterns

In this chapter, our objective is to explore the usage patterns of inputs. In particular, it is for the manures of both organic and inorganic origins, that accounted for the bulk of inputs in energy terms in either scale A or C. To begin with, we may note the distribution of inputs in absolute terms against farms grouped together on the basis of GCA (figure 5.1.1).[1] Predominance of organic manure is obvious, notwithstanding the fact that for no less than 13 of the 59 tehsils,[2] the 2004-05 dataset did not include data on this input. Further, figure 5.1.1 also shows that for the fifth size-group, there was a sudden rise in the use of organic manure, more than the rise due to increase in GCA. In fact, in figure 5.1.2 that plots per hectare input components, such a rise is more clearly visible.[3]

Figure 5.1.1: Distribution of different Inputs, scale A (in MJ) against size-class (in ha)

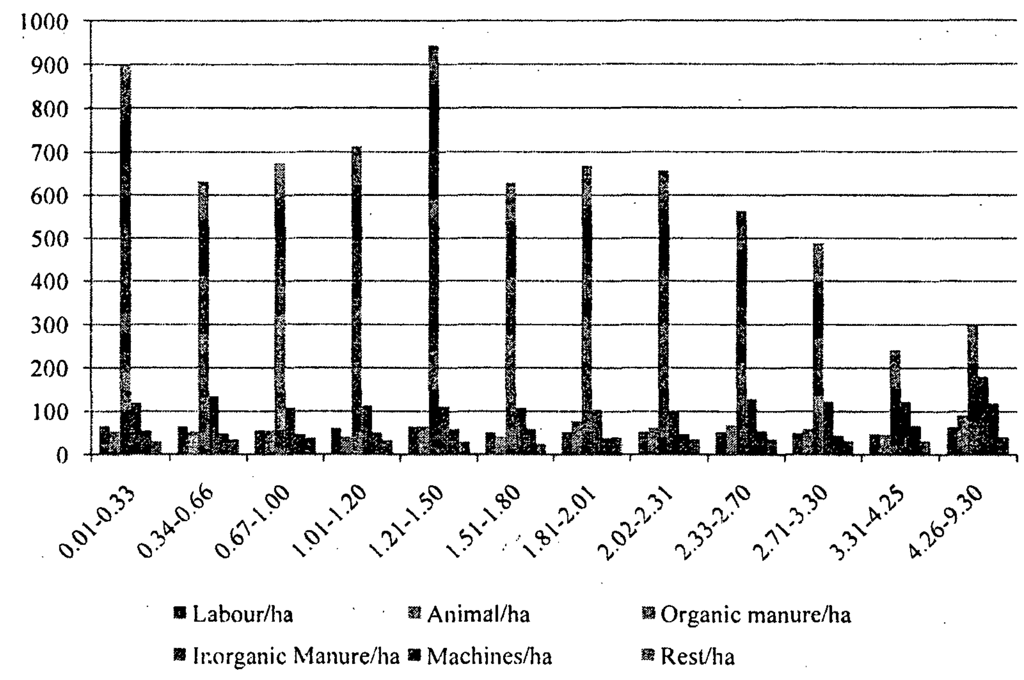


[1] The category rest in figure 5.1.1 includes seed and soil nutrients.
[2] Most of which was located in zone-II, terai, as had been reported in chapter 2.
[3] This is the reason for the sudden rise in the input of scale C as well, as was captured in figure 4.1.7 earlier.

Inorganic manure, on the other hand, appears to be of some significance only in the last four of the 12 size-groups. Further, in the last two size-groups some substitution appears to have been taken place of the organic manure by the inorganic one. Similarly, machine use was of significance only in the last two size-groups. Interestingly, human labour use was also of some significance in absolute terms for the higher size-groups: it had increased along with all other inputs. However, in per hectare terms it remained almost invariant to size-group (figure 5.1.2).

In figure 5.1.2, we may notice the sudden rise in the organic manure per hectare use for the fifth size-group, as stated above. Animal labour per hectare remained almost uniform, like use of human labour per hectare.[4] On the other hand, overall use of organic manure per hectare shows a negative relationship with the land size. In contrast, per hectare inorganic manure use shows a rise only in the last size-group, while maintaining an almost invariant pattern across the size-groups.

Figure 5.1.2: Use of various inputs, per hectare, scale A (in MJ/ha) against size-class (in ha)



Further, from figure 5.1.2 it may appear that the input per hectare had reduced for the last but one size-group. In fact figure 5.1.3 reveals that per hectare input

[4] The category rest in figure 5.1.2 includes seed, pesticides and soil nutrients.

had started falling from the ninth size-group (2.02-2.31 ha), and had increased only in the last size-group. In fact, figure 5.1.3 also shows that for a range, from the fifth (1.21-1.50 ha) till the tenth size-class (2.71-3.30 ha), per hectare surplus was constant even on the face of falling input per hectare. Obviously, for such a phenomenon, output per hectare had to fall at the same rate, as shown by figure 5.1.3.

Figure 5.1.3: Per hectare input, output and surplus, scale A (in MJ/ha) against size-group (in ha)

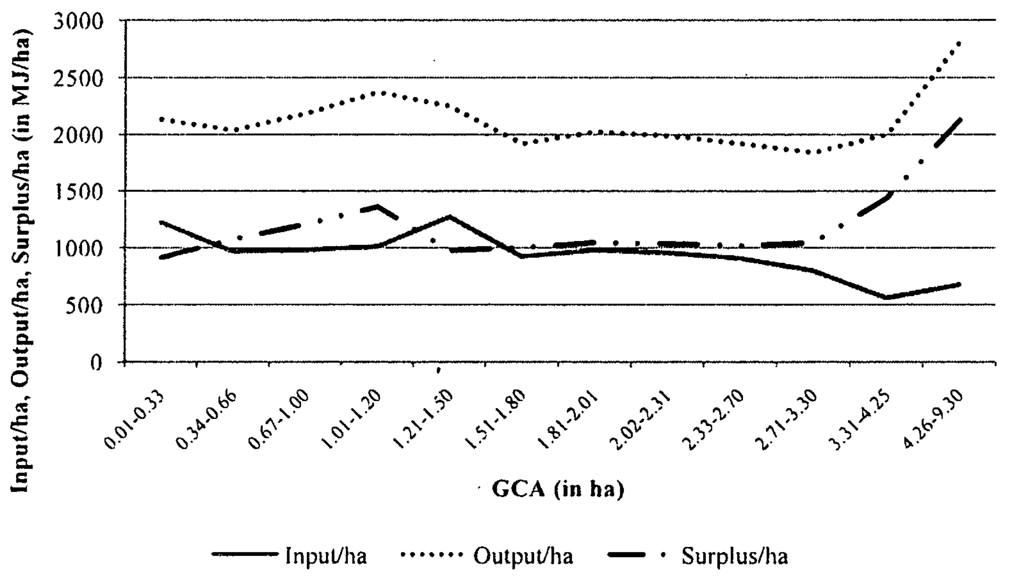


Figure 5.1.4: EROI, scale A, against size-group (GCA) (in ha)

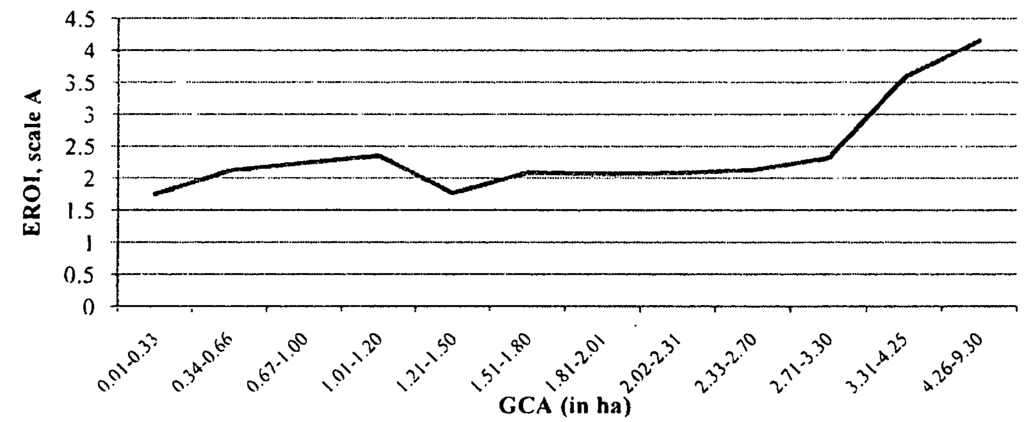


Figure 5.1.4 reflects such a constant surplus per hectare through a uniform EROI of scale A across size-groups. Further, for the last four size-groups, EROI marked a rise; from figure 5.1.3 shows the corresponding input per hectare and output per hectare along with the changes. Notably, from figure 5.1.2 we may also note that

these are the size-groups that had used lesser organic manure per hectare in contrast to all the other eight. Notably, the last two size-groups had shown an increase in the inorganic manure per hectare. Given the average GCA or the total area under cultivation in absolute terms, the use of organic manure in absolute terms (in MJ) for the last size-group was more than most of the other size-groups (column 11 of table 5.1.1), notwithstanding the highest use of inorganic manure in per hectare terms as well in total (column 12).

Table 5.1.1: Use of inputs in scale A (in MJ) across size-groups (in ha)

Gross Cropped Area (in ha)	No. of households	Average GCA	NAS	GCA	Cropping intensity	Input	Output	EROI
	(1)	(2)	(3)	(4)	(5) = (4)/(3)	(6)	(7)	(8) = (7)/(6)
0.01-0.33	54	0.196	8.44	10.61	1.26	12948	22643	1.75
0.34-0.66	51	0.5	18.02	25.50	1.42	24605	52021	2.11
0.67-1.00	48	0.84	33.23	40.25	1.21	39390	88029	2.23
1.01-1.20	46	1.12	44.45	51.82	1.17	52393	122992	2.35
1.21-1.50	48	1.34	53.89	64.39	1.19	82063	145018	1.77
1.51-1.80	52	1.65	63.20	85.69	1.36	78802	164531	2.09
1.81-2.01	50	1.94	77.51	97.35	1.26	95338	197195	2.07
2.02-2.31	48	2.14	74.56	102.57	1.38	98044	204338	2.08
2.33-2.70	51	2.53	90.63	126.42	1.39	114395	242870	2.12
2.71-3.30	52	2.97	109.20	154.53	1.42	122937	284602	2.32
3.31-4.25	50	3.75	118.80	187.65	1.58	104963	375599	3.58
4.26-9.30	40	5.4	120.69	215.32	1.78	145612	604777	4.15

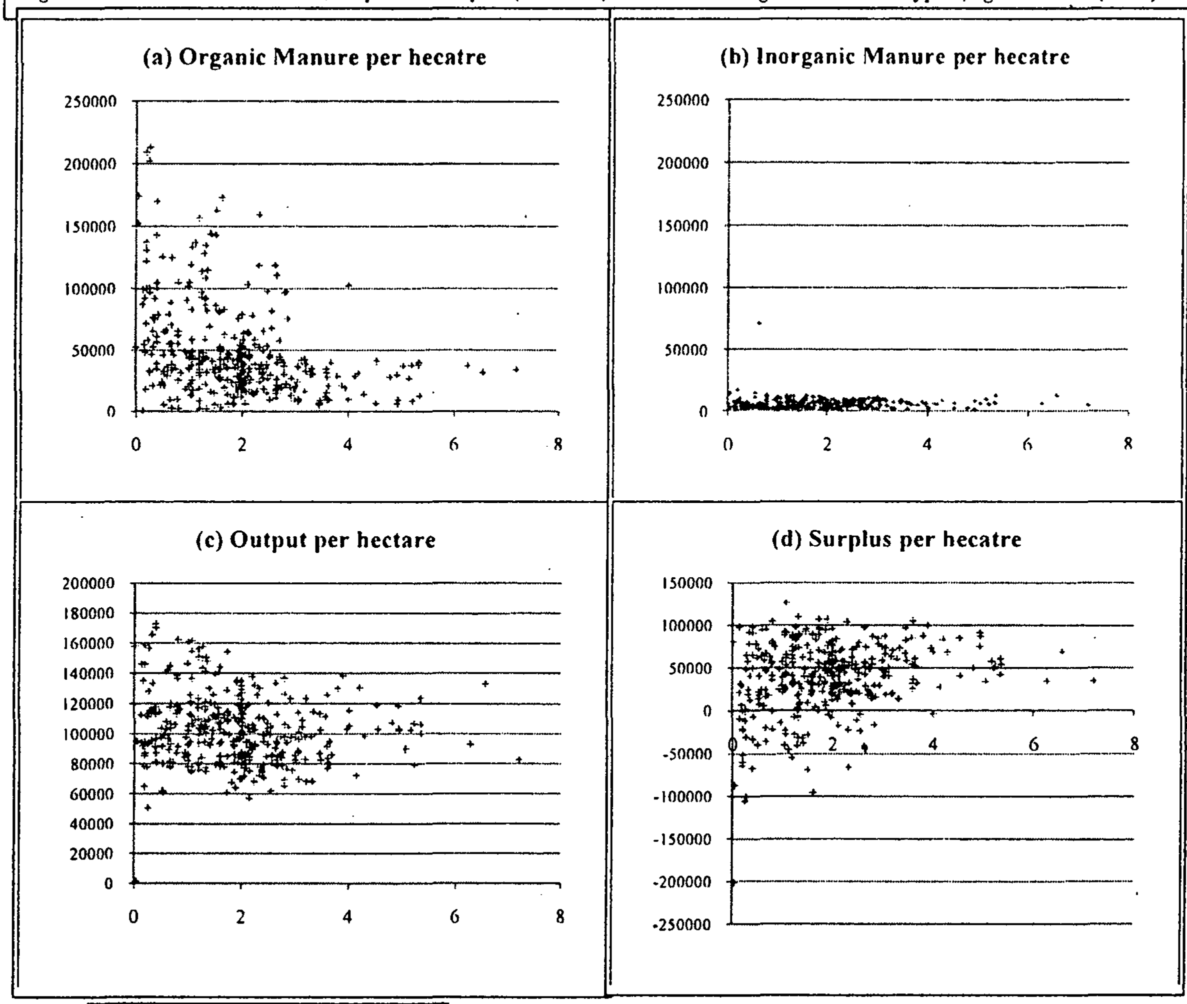
Gross Cropped Area (in ha)	Human Labour	Animal Labour	Organic Manure	Inorganic Manure	Machine	Rest*	Share of Manure in total input	Share of organic manure in total manure
	(9)	(10)	(11)	(12)	(13)	(14)	(15) = (11)/(6)	(16) = (11)/ (11) + (12)
0.01-0.33	700	570	9504	1261	585	326	83.14	88.3
0.34-0.66	1637	1328	16081	3418	1252	886	79.25	82.5
0.67-1.00	2279	2244	27127	4347	1868	1523	79.90	86.2
1.01-1.20	3139	2098	36884	5872	2650	1746	81.61	86.3
1.21-1.50	4127	4218	60696	7269	3840	1910	82.82	89.3
1.51-1.80	4381	3579	53816	9235	5102	2164	80.01	85.4
1.81-2.01	5152	7416	64977	10200	3738	3852	78.85	86.4
2.02-2.31	5390	6377	67285	10442	4839	3709	79.28	86.6
2.33-2.70	6686	8702	71237	16376	6912	4480	76.59	81.3
2.71-3.30	7665	9191	75417	18886	6929	4847	76.71	80.0
3.31-4.25	9055	8830	45286	23119	12651	6019	65.17	66.2
4.26-9.30	13758	19825	64419	38760	25605	8944	70.86	62.4

Notes:
1. * Rest includes Seeds, Pesticides and Micro- and Macro-nutrients

The importance of manure among the inputs can be seen from the column 15 of table 5.1.1: the lowest share was more than 65% (eleventh size-group). On other hand, barring the two largest size-groups, share of organic manure in the total manure (column 16) had remained over 80%. Incidentally, it is these two size-groups that had yielded a much higher per hectare surplus than all the other size-groups. It appears that this association of a higher per hectare surplus and the use of inorganic fertilisers holds some importance towards augmentation of the surplus, in absolute terms or on a per unit area basis.

It may be noted further that barring one, all the other 589 households had used inorganic fertiliser. Admittedly, many plots did not have any such use, but at the household level, it was not so. On the other hand, among the 460 households,[5] only 368 had reported use of organic manure. We may classify these two type of manure use among those households from the 46 tehsils with organic manure data: those which used both inorganic and organic manure (type 1), and the ones which used only inorganic manure (type 2).

Figure 5.1.5: Per hectare manure, output and surplus (in MJ/ha) of scale A among households of type 1, against GCA (in ha)



[5] Leaving aside the 13 tehsils (6, 7, 10, 11, 13, 14, 15, 18, 19, 41, 44 and 60) for which dataset did not include data on organic manure, as stated in 3.2.3.6.2 above.

Figure 5.1.6: Per hectare Inorganic manure, output and surplus (in MJ/ha) of scale A among households of type 2, against GCA (in ha)

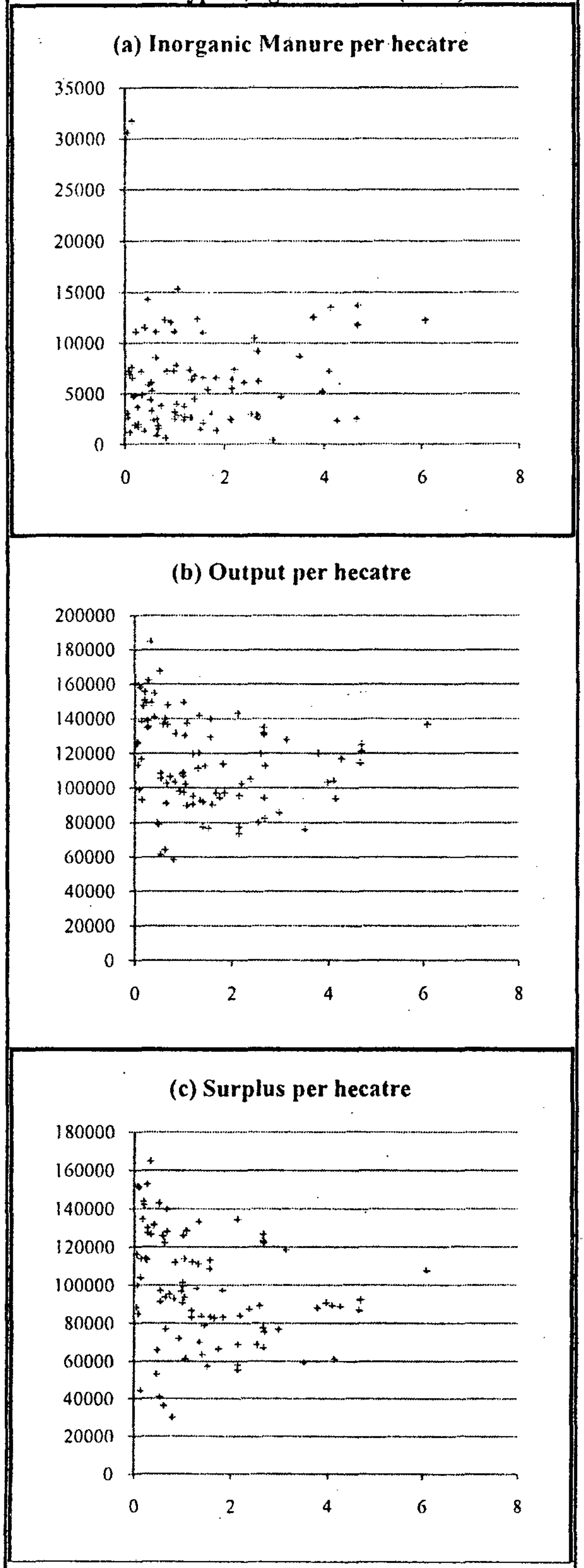


Figure 5.1.5 in the previous page shows per hectare manure use (both organic and inorganic), output and surplus in scale A (in MJ/ha) for the farms using both types of manure (type 1). Besides the obvious higher energy associated with per hectare organic manure in contrast to the inorganic types, we may also notice the households with negative surpluses. In contrast, all of the 92 households which had used only inorganic manure (type 2), yielded a positive surplus per hectare in scale A.

Among all the 590 households, 388 had used both type of manure. We may observe some of the features of these mixed manure use farms from figure(s) 5.1.7 - 5.1.14 that shows per hectare use of manures of both types, per hectare output and per hectare surplus of scale A, with the additional identifiers of CCS size-groups and agro-climatic zones.

Fig. 5.1.7: Per hectare Organic manure, scale A (in MJ/ha) in relation to GCA (type 1 farms), across size-groups

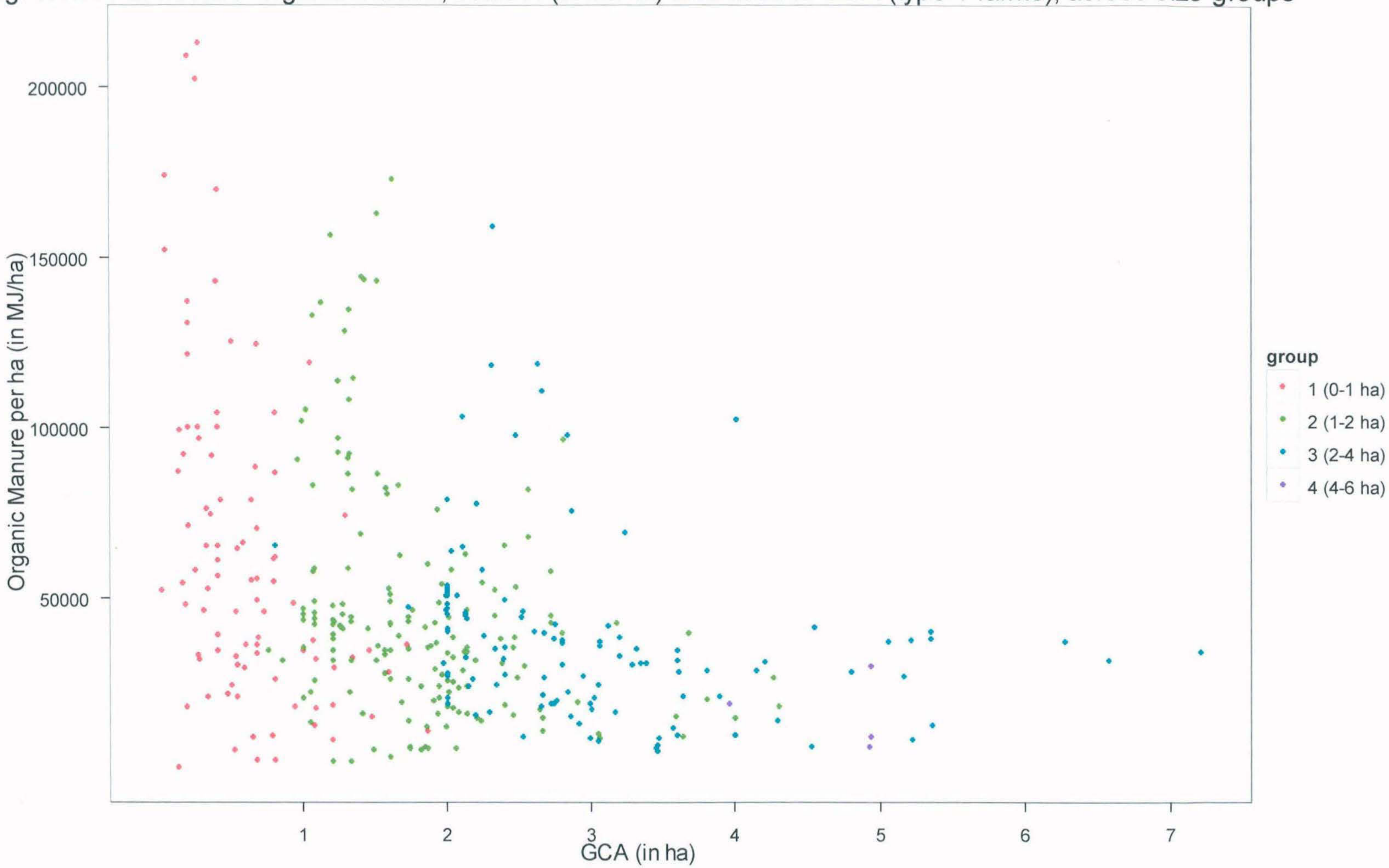


Fig. 5.1.8: Per hectare Inorganic manure, scale A (in MJ/ha) in relation to GCA (type 1 farms), across size-groups

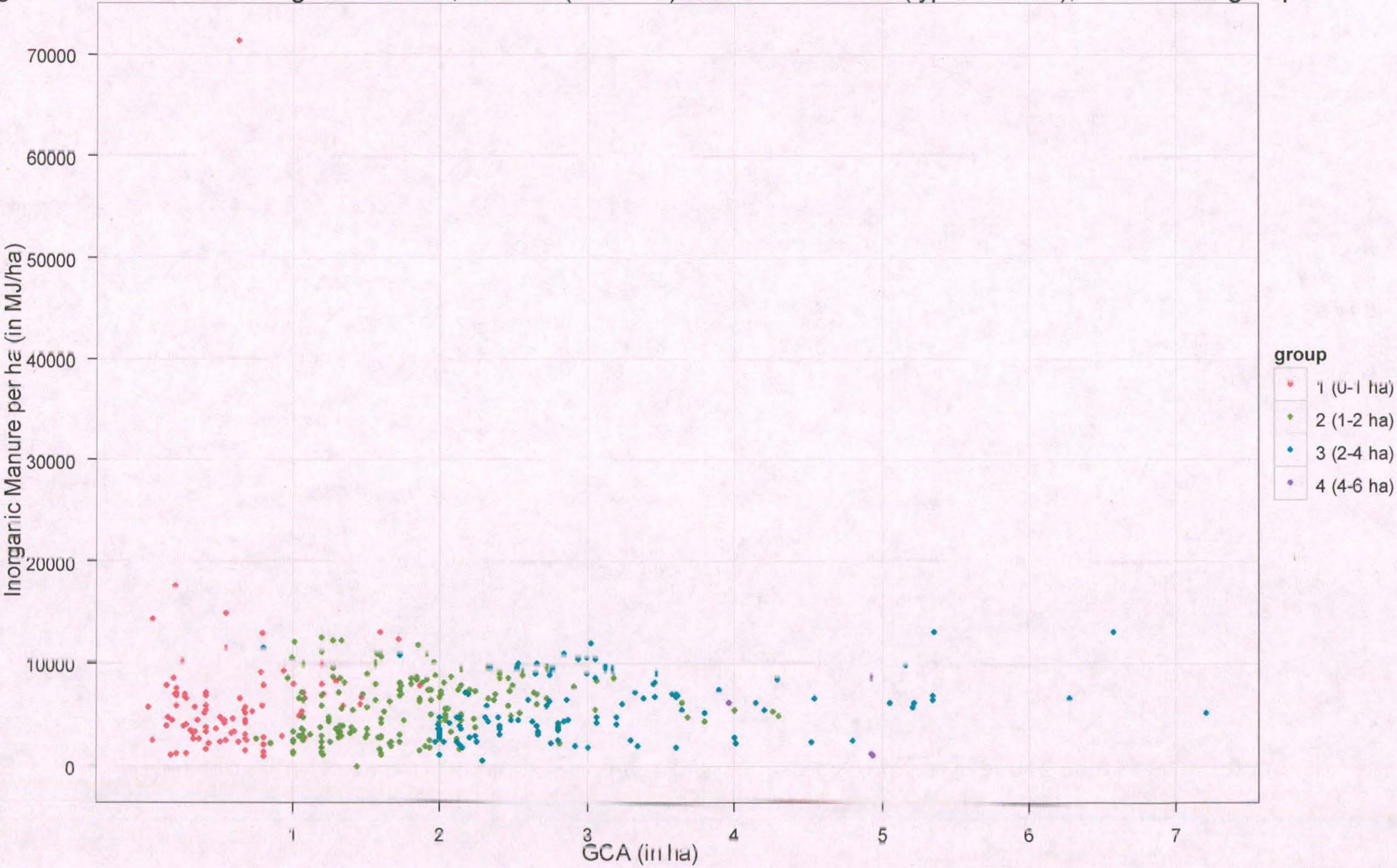


Fig. 5.1.9: Per hectare Output, scale A (in MJ/ha) in relation to GCA (type 1 farms), across size-groups

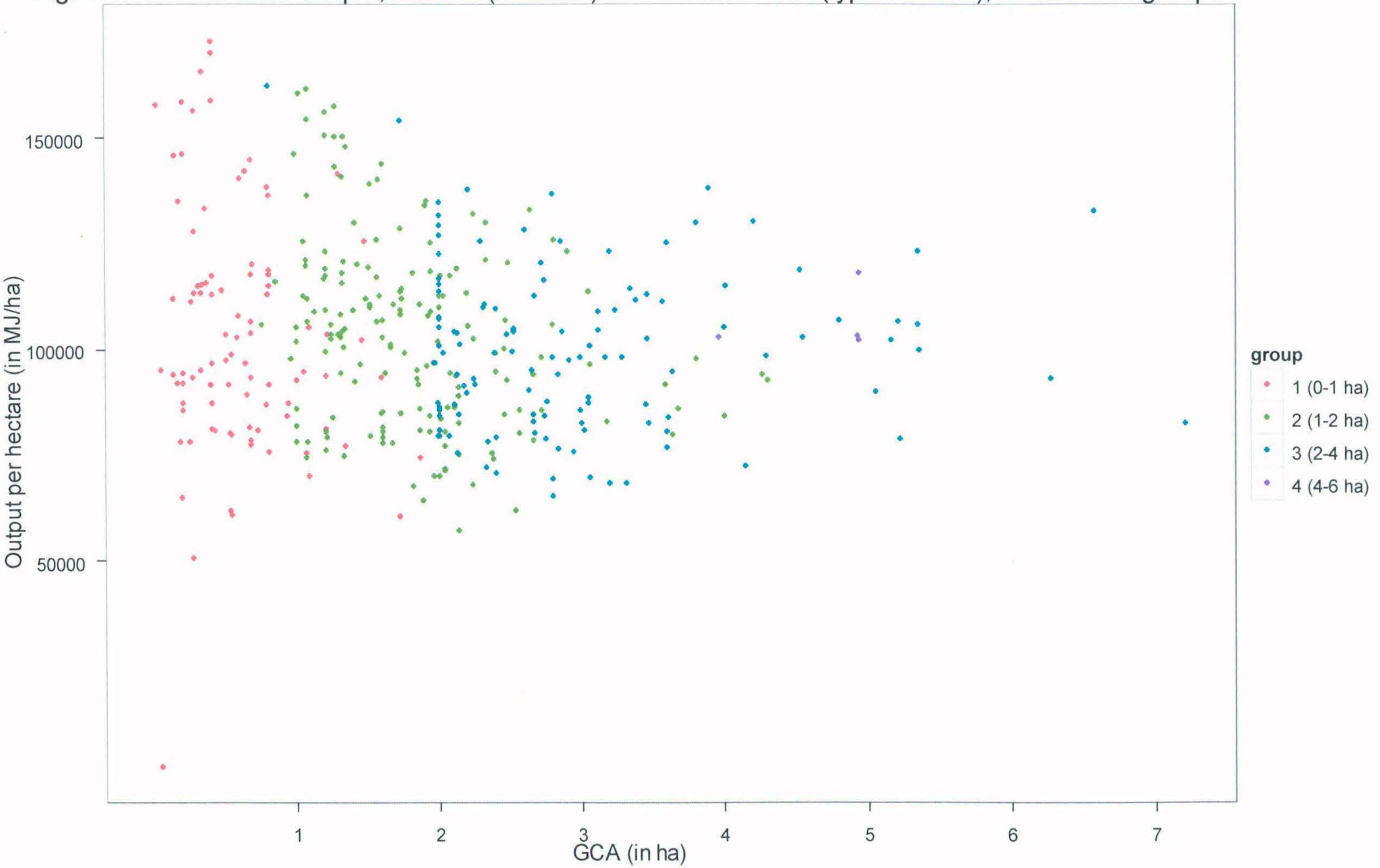


Figure 5.1.10: Per hectare Surplus, scale A (in MJ/ha) in relation to GCA (type 1 farms), across size-groups

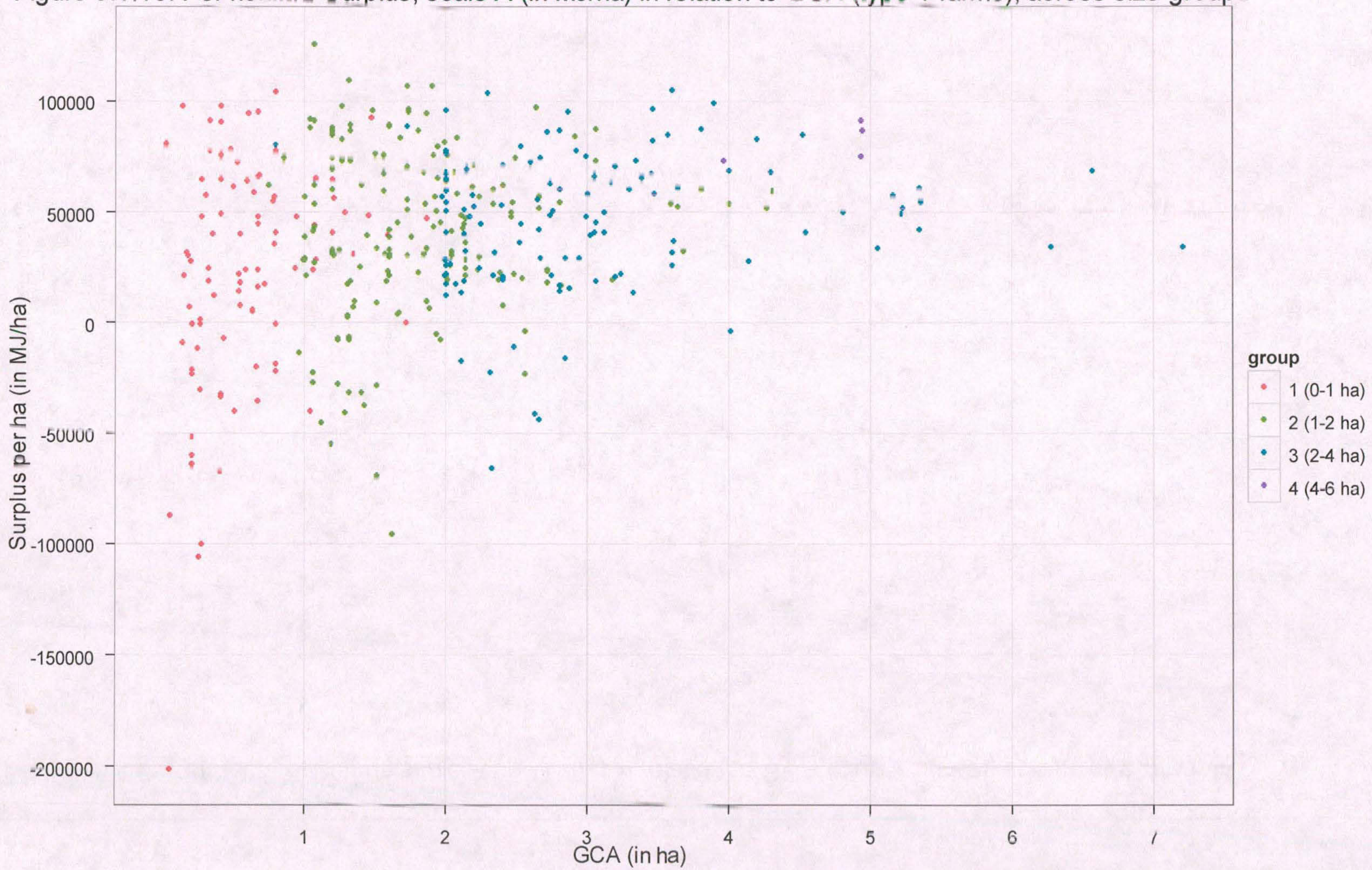
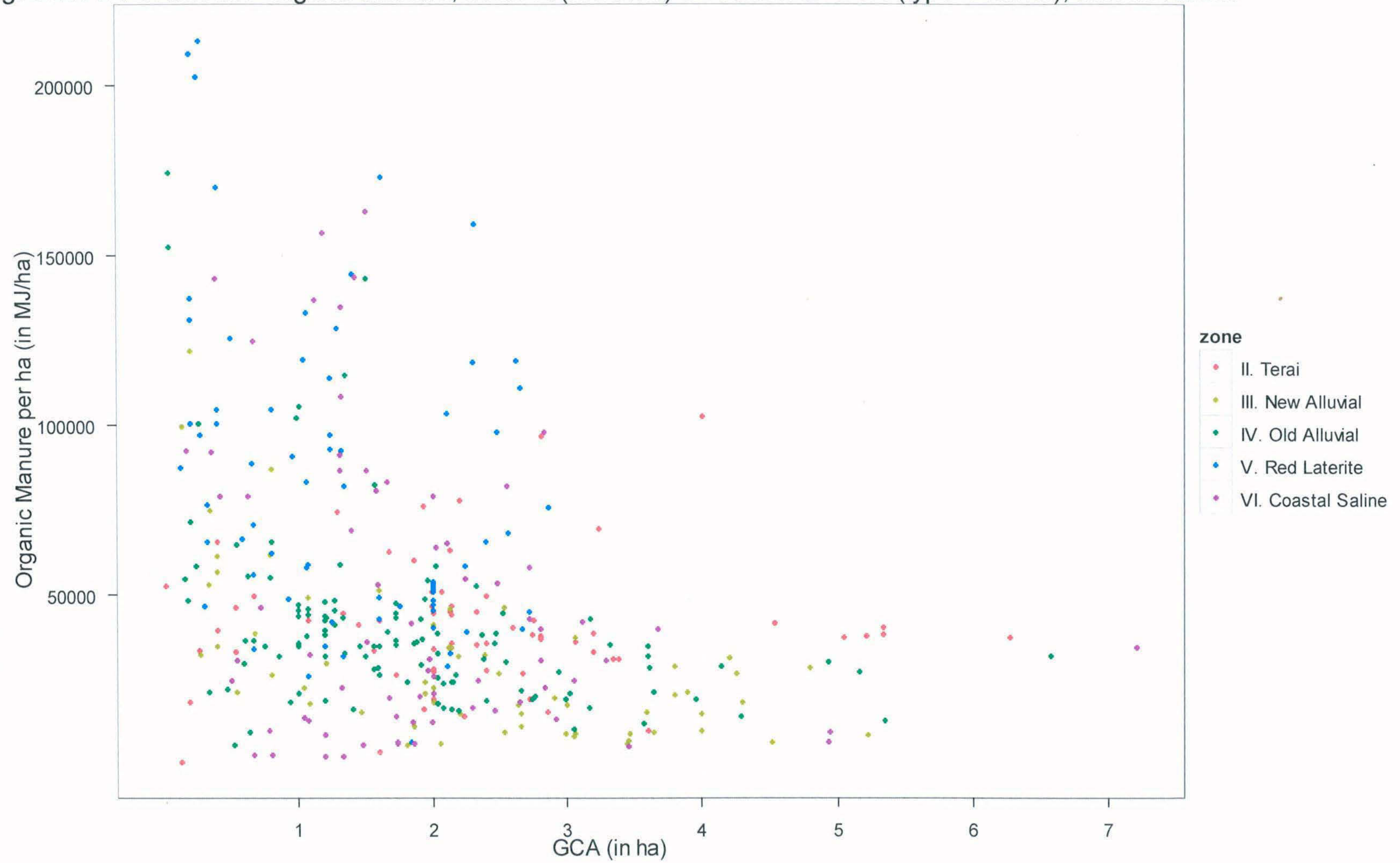


Fig. 5.1.11: Per hectare Organic manure, scale A (in MJ/ha) in relation to GCA (type 1 farms), across Zones



ig. 5.1.12: Per hectare Inorganic manure, scale A (in MJ/ha) in relation to GCA (type 1 farms), across Zones

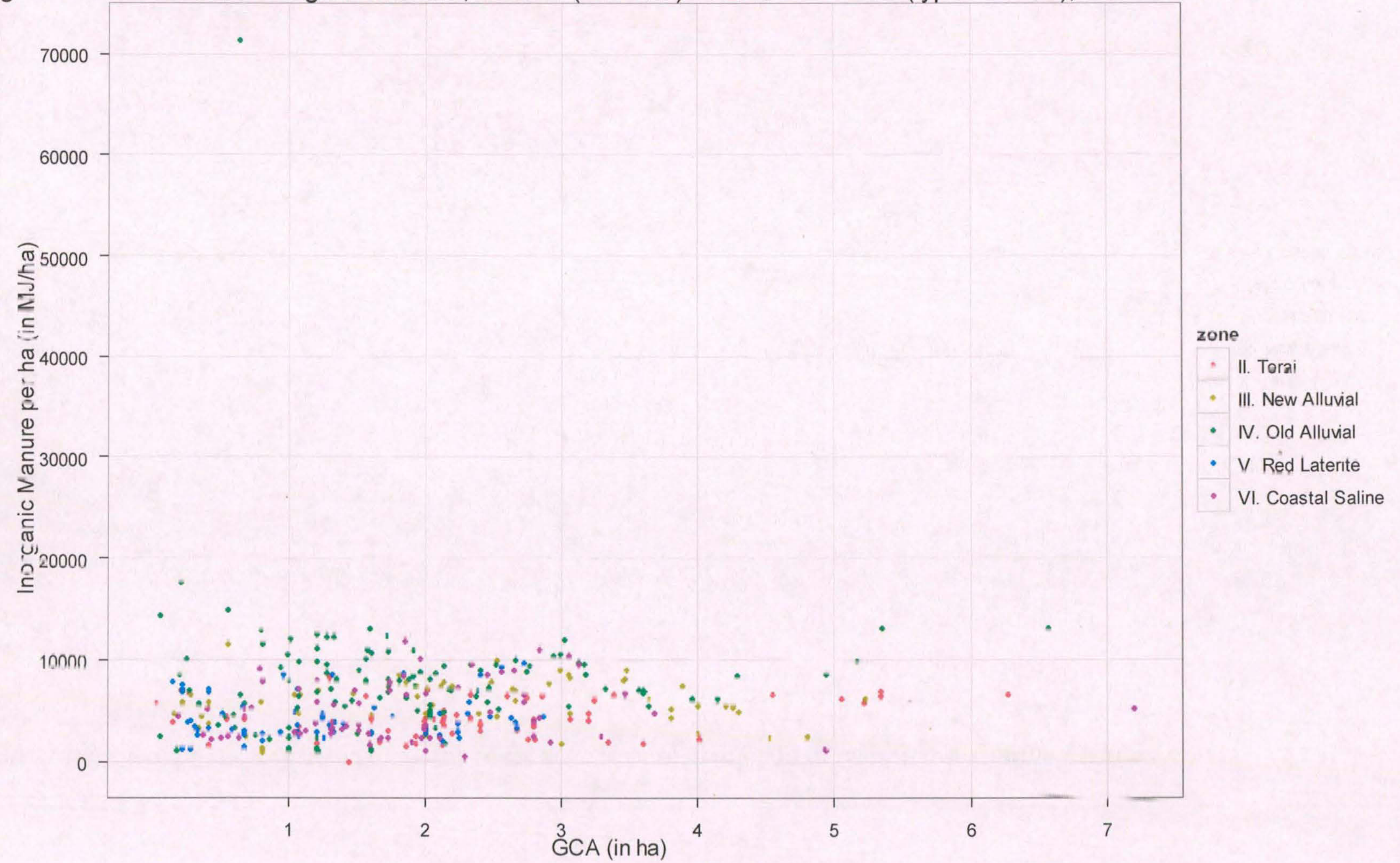


Fig. 5.1.13: Per hectare Output, scale A (in MJ/ha) in relation to GCA (type 1 farms), across Zones

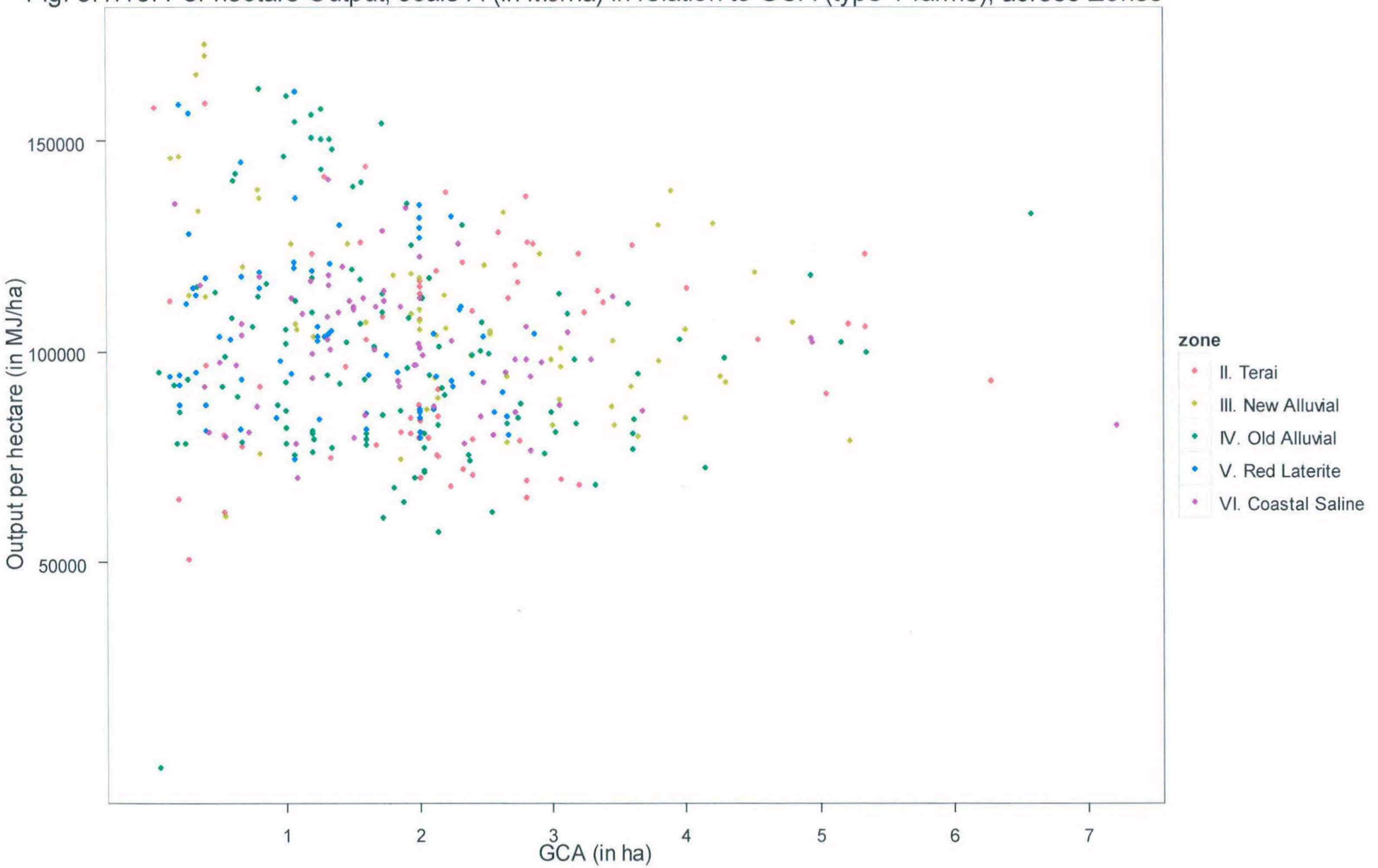
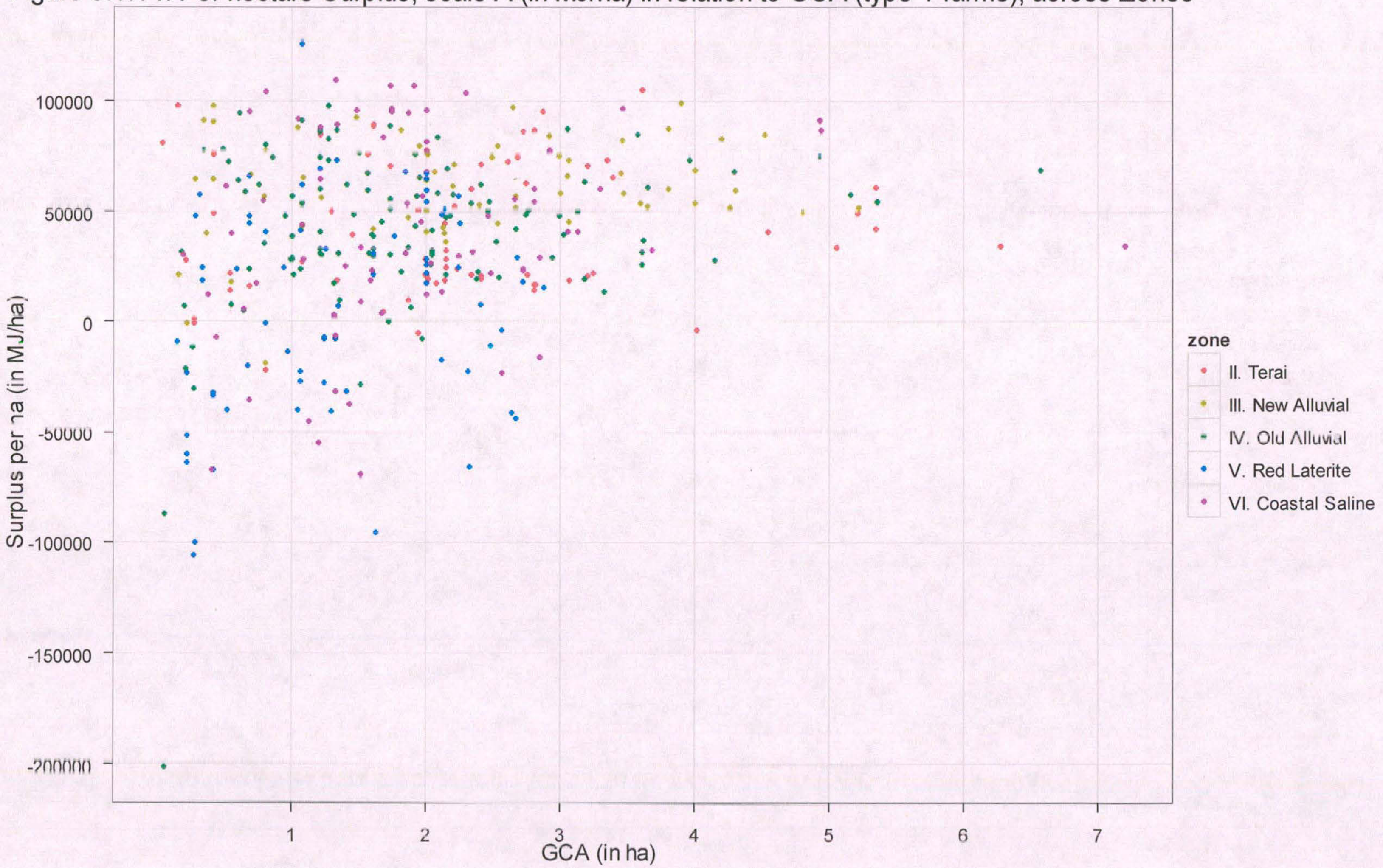
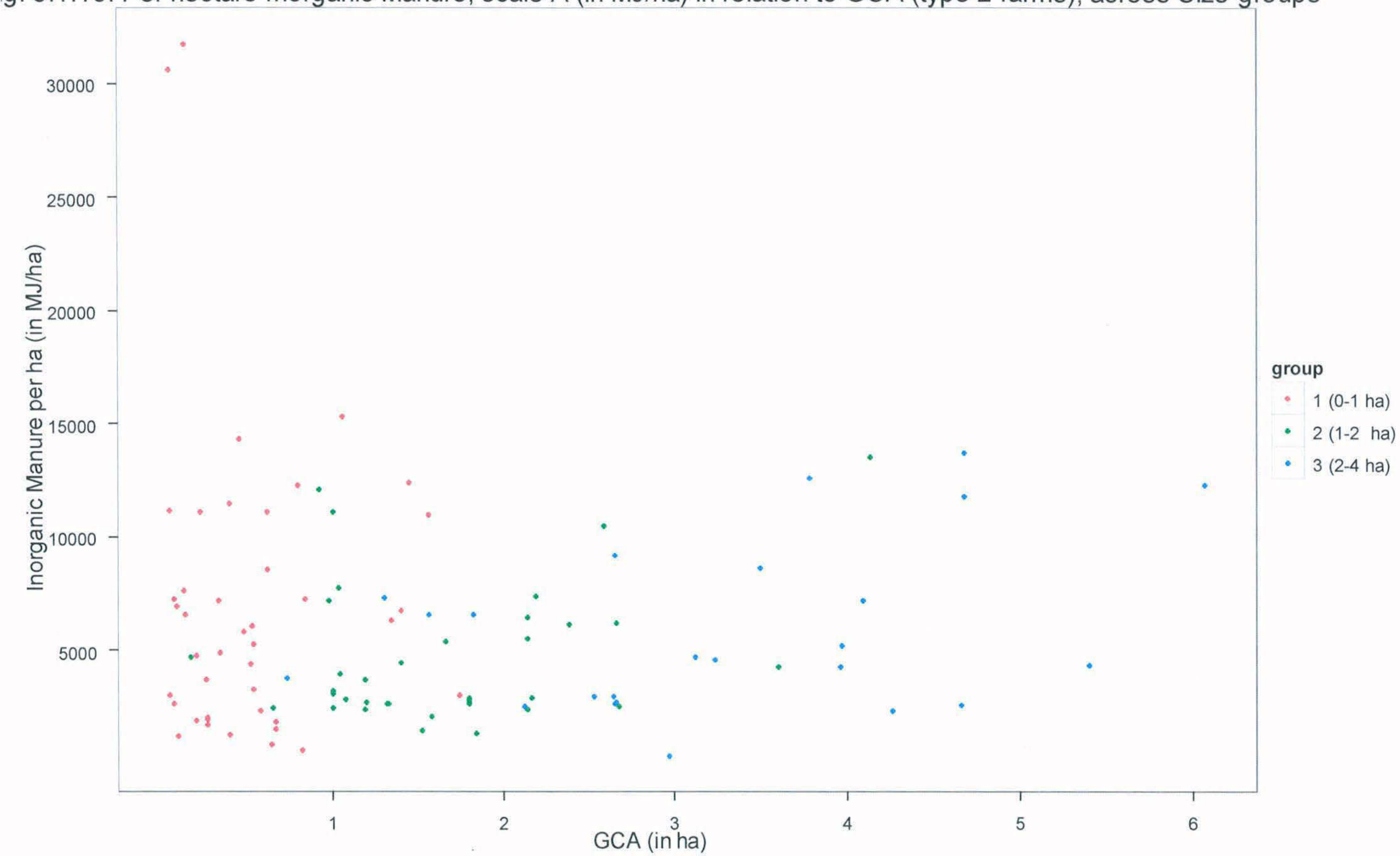


Figure 5.1.14: Per hectare Surplus, scale A (in MJ/ha) in relation to GCA (type 1 farms), across Zones



ig. 5.1.15: Per hectare Inorganic Manure, scale A (in MJ/ha) in relation to GCA (type 2 farms), across Size-groups



For the 101 households (excluding those which reported no use of organic manure), inorganic manure per hectare, output per hectare and surplus per hectare have been plotted against GCA (like in figure 5.1.7) with additional markers of CCS size-group and agro-climatic zones in figure(s) 5.1.15-5.1.20.

Fig. 5.1.16: Per hectare Output, scale A (in MJ/ha) in relation to GCA (type 2 farms), across Size-groups

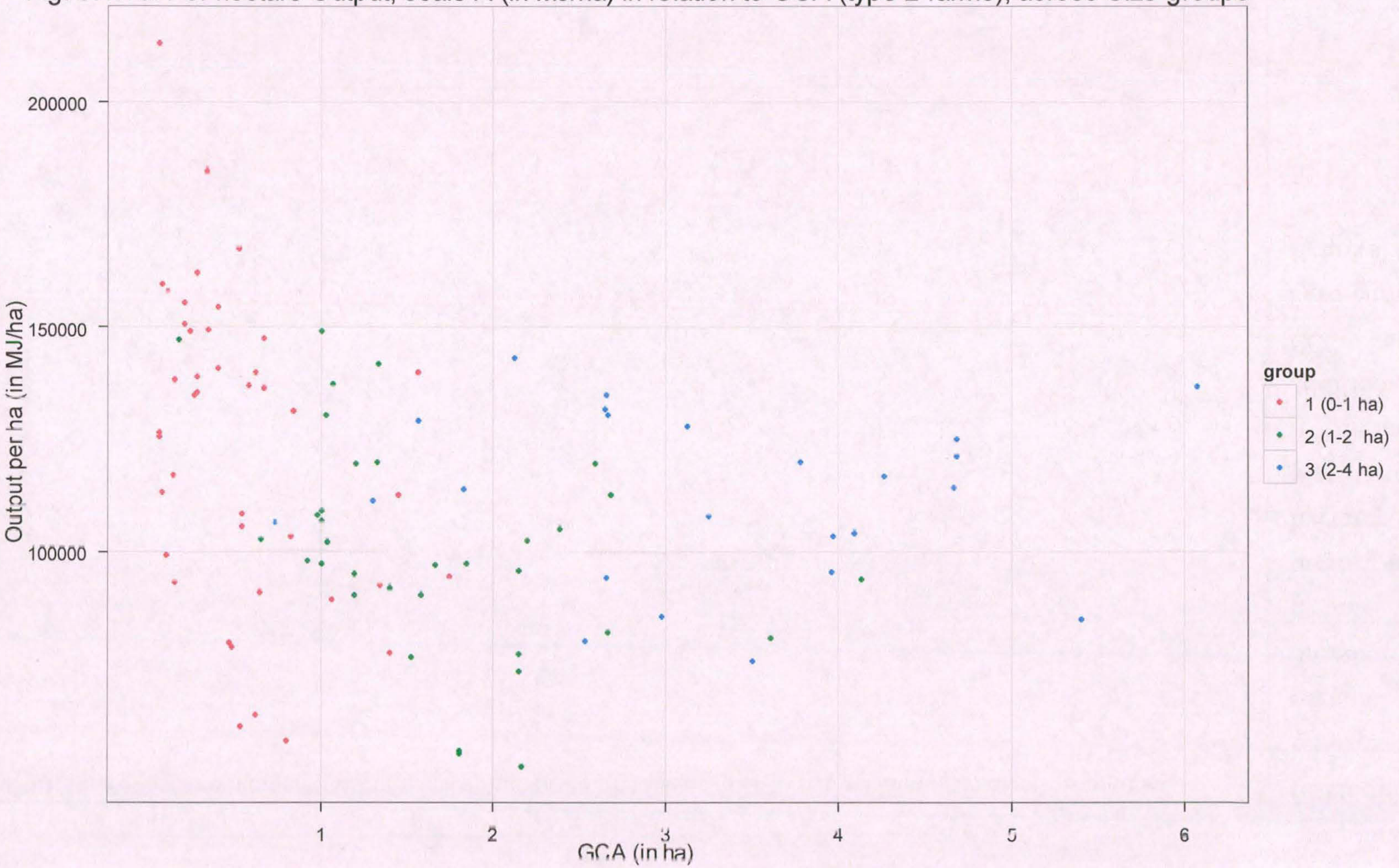
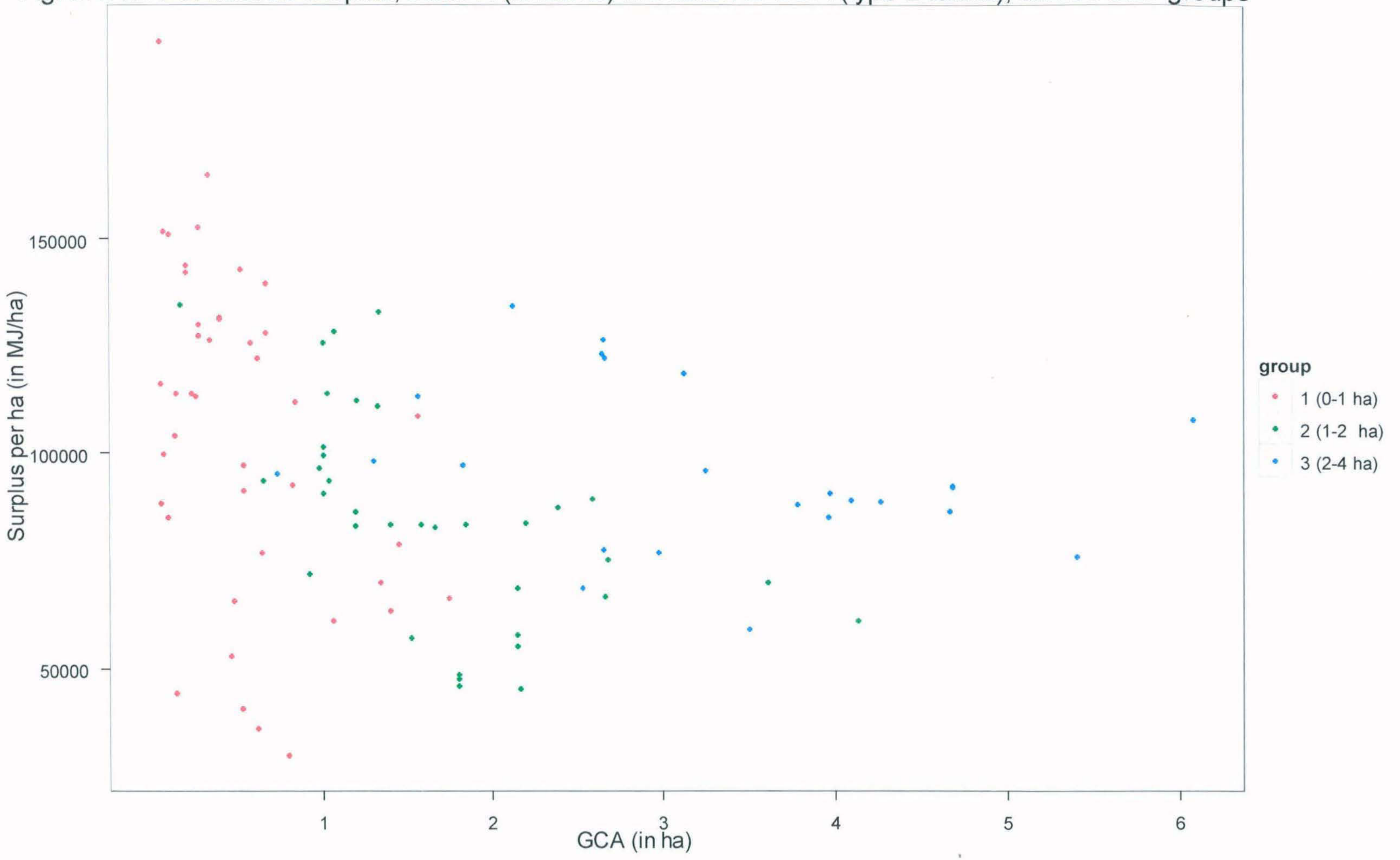


Fig. 5.1.17: Per hectare Surplus, scale A (in MJ/ha) in relation to GCA (type 2 farms), across Size-groups



ig. 5.1.18: Per hectare Inorganic Manure, scale A (in MJ/ha) in relation to GCA (type 2 farms), across Zones

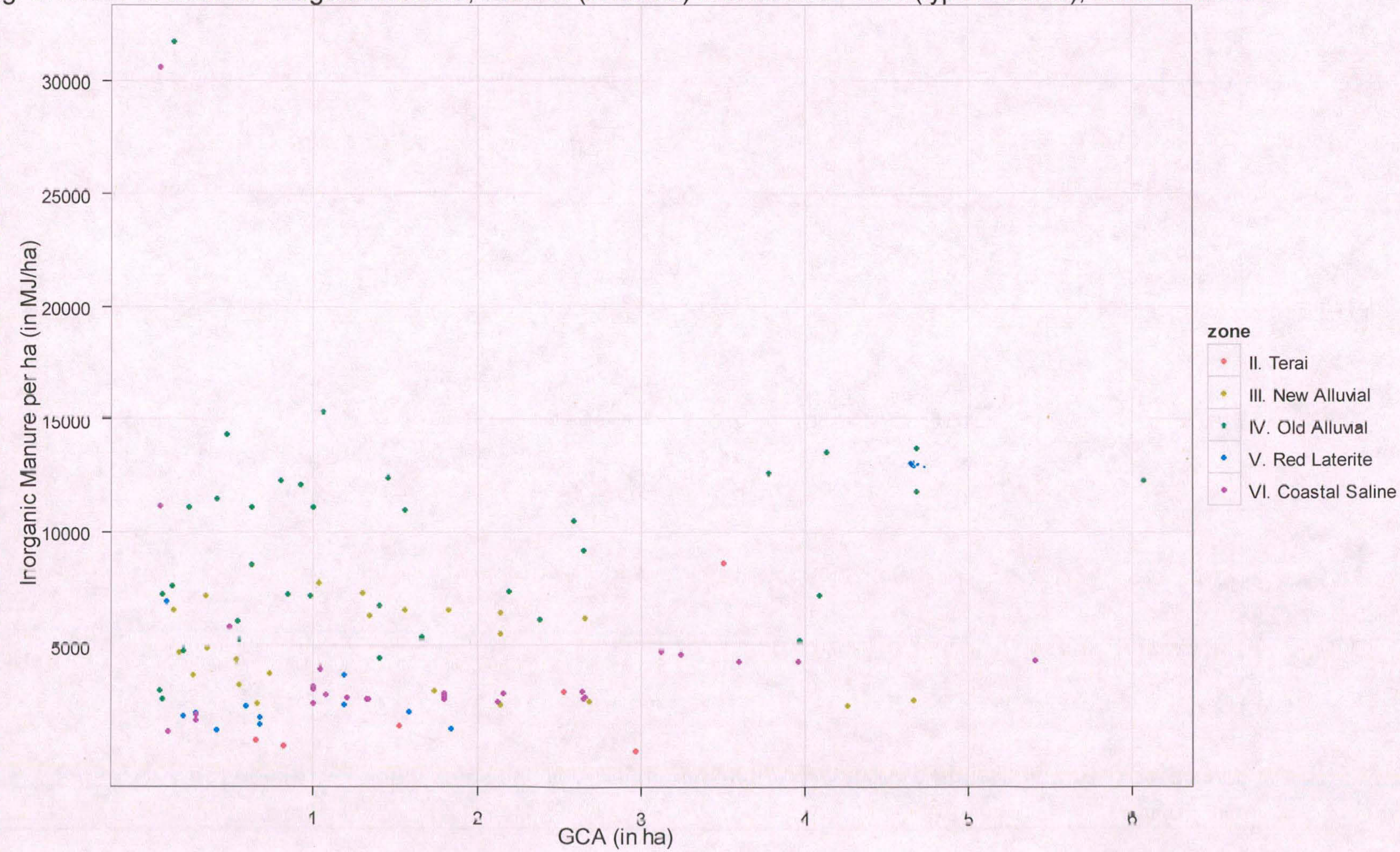


Fig. 5.1.19: Per hectare Output, scale A (in MJ/ha) in relation to GCA (type 2 farms), across Zones

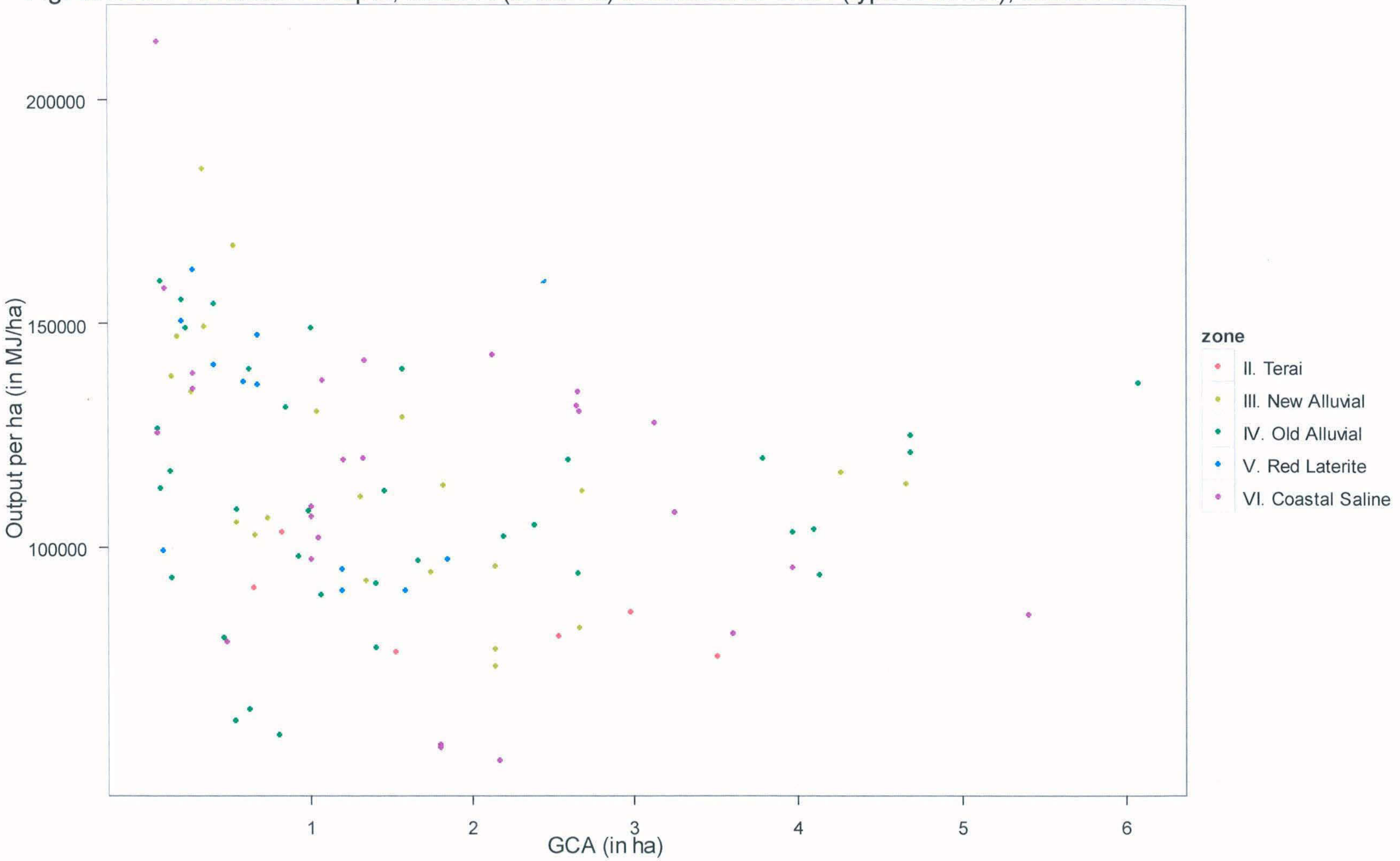
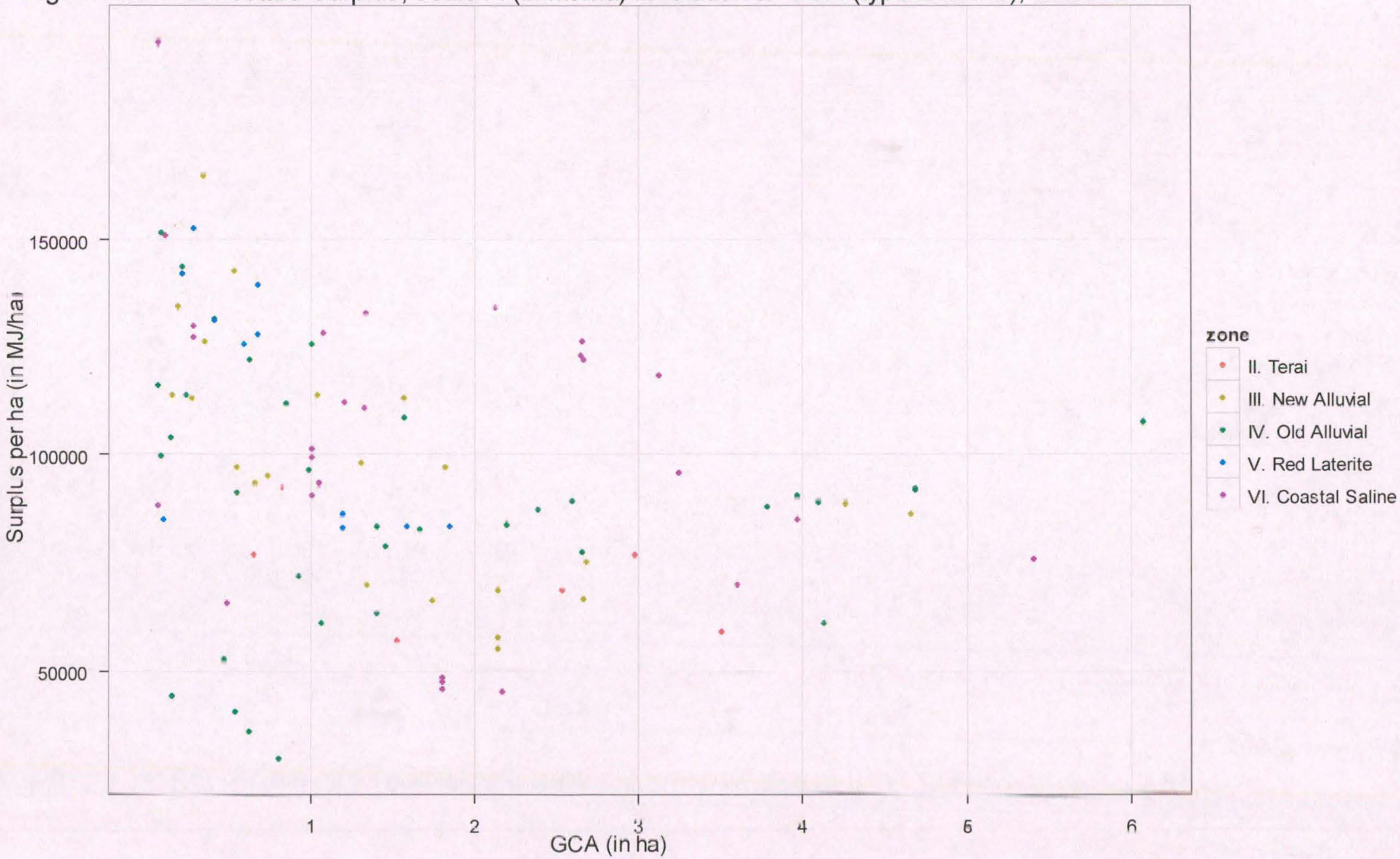


Fig. 5.1.20: Per hectare Surplus, scale A (in MJ/ha) in relation to GCA (type 2 farms), across Zones



5.2. Output Composition

We may recall that for the selected household, the energy value of by-products were higher than that of the main product (table 3.3.14). This was not an exception. Figure 5.2.1 and 5.2.2 show main product and by-product against GCA for all the 590 households; both of them show this across size-class or GCA.

Figure 5.2.1: Main product and by-product, scale A, aganst GCA (in ha)

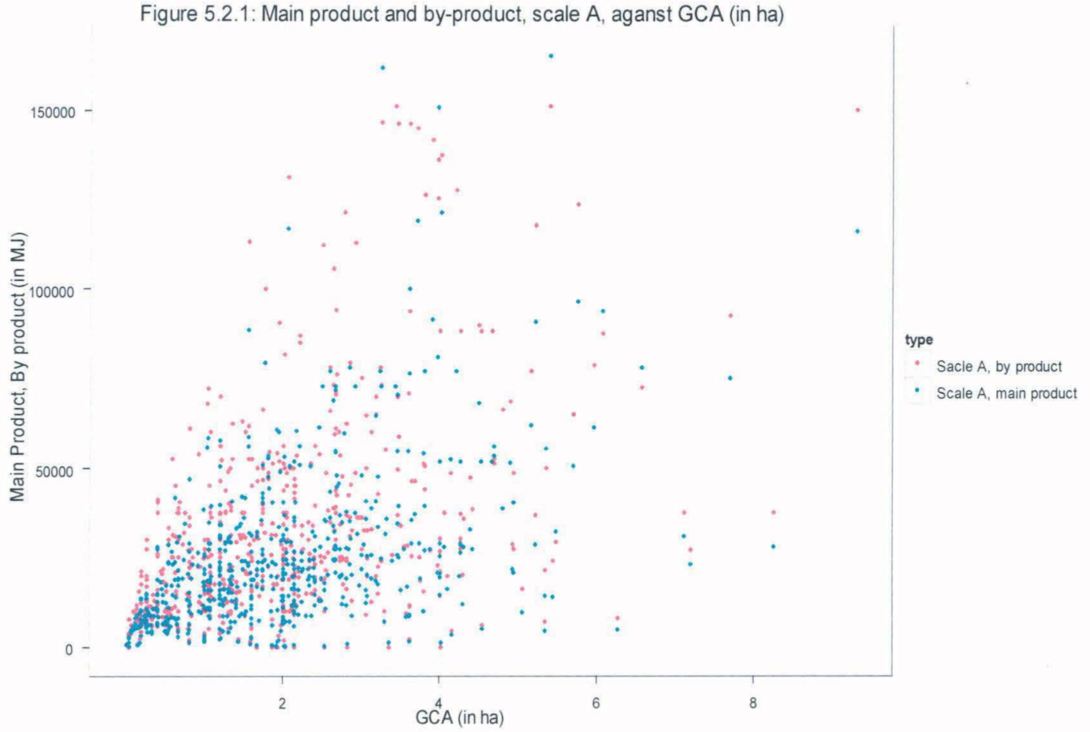
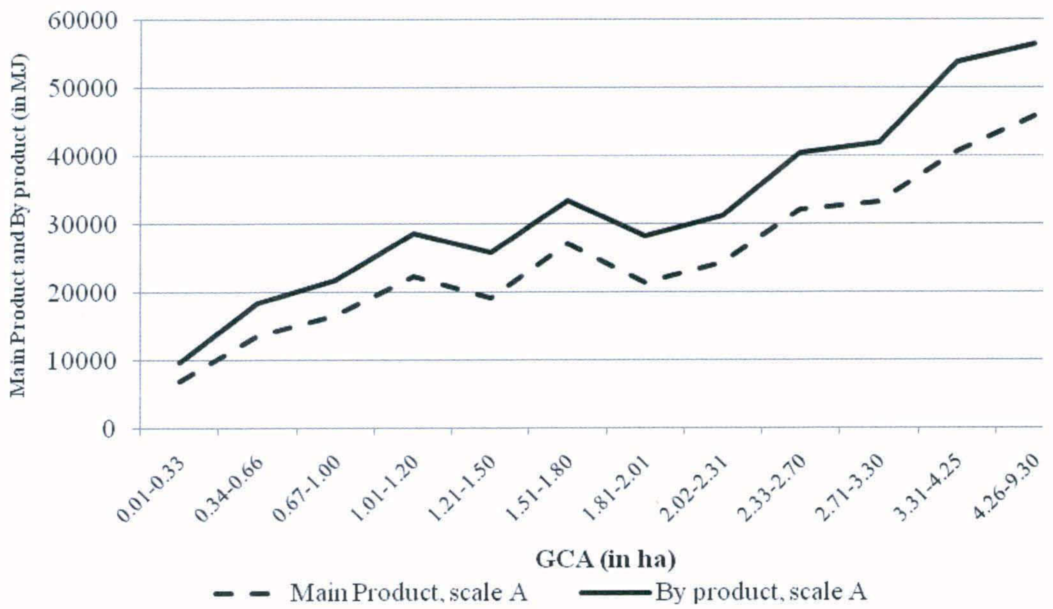


Figure 5.2.2: Main product and by product (both in MJ), scale A in relation to GCA (in ha)



In fact, this is one of the literally fertile areas, in which newer methods can assist in towards the return of nutrients back to the soil without any use of materials/inputs that are ecologically harmful. In this process, certainly, the necessity of inorganic sources of manure may reduce use of which-though effective towards yield-is associated with many problems. These facts of enormous quantity of by-products and its potential in returning the nutrients to the soil taken away are well established. In fact, indiscriminate burning of by-products adds to the atmospheric pollution rather than making a positive ecological impact. Certainly, there remain ample possibilities of effectively using this 'free gift' and improving the human society-nature metabolism. Further, the average cost of preparing composts using the by-products will be lower if farmers' organisations can bring its members together for a common facility. Finally, use of scientific principles can improve the quality of such composts and the impact on the yield.

This is not a novel idea. Call by the Scottish 'practical capitalist farmer and an advanced agronomist for his time', James Anderson (see, Anderson 1776, 1777) towards adoption of 'rational and unsustainable agricultural practices' (see, Foster 2000: 144) or that of 'rational principles' by the American Josse Buel (see, Buel 1847: 26-27) or by the Scottish agricultural chemist James F W Johnston for 'a rational system of culture, capable of being carried on for an indefinite period without injury to the land' (see, Johnston 1851: 355-58, v.1) or by the American political economist Henry Carey's to halt the practices that 'rob [...] the earth of its capital stock' (Carey 1858: 210-215, v. II; also see, Foster 1999) can be summed up as the following: 'Every act of the farmer which violates the laws of nature must justly be branded as an *act of spoliation*' (Liebig 1859: 175; emphasis as in original). The 'rational principle' could best be expressed in 'the law of compensation, which makes the recurrence or permanency of effects dependent upon the recurrence or permanency of the conditions which produce them. [...] the most universal of the laws of nature' (Liebig 1858: 254-55). Certainly, rather than robbing the soil its capital stock, its continuous replenishment can ensure the conditions which are more conducive towards a sustainable agriculture.

We may conclude this chapter by stating the following:

1. Organic fertilisers has a larger use-value than the inorganic fertiliser for a given level of output. The respective uses are determined by the size-group as well as the agro-climatic zones.
2. Use of only inorganic fertilisers has resulted in a positive surplus. On the other hand, there were many farms with a negative surplus which had used both organic and inorganic manure.
3. Finally, in order to 'compensate' the soil for the nutrient losses, it is important to return to it the by-products which has very little use given the reduction in the number of animals in the recent times. Further it is also important to take steps so as to improve the efficiency of organic manures in improving the yield per unit of its use.

Traditional and 'Modern' farming: a comparison between 1956-57 and 2004-05

> Why do we need to measure things? [...] We need physical measures to know what we have, what we have gained, what we have lost, where we are and where we are going. Why do we numerical measures? Because we need to compare quantities more exactly than 'big' or 'small' or even 'bigger than' or 'smaller than'. This sack of potatoes may be heavier than that one, but how much heavier? [...] Quantitative measures are critical for recipes, whether in cooking or chemistry. (Robert U Ayres and Leslie W Ayres, 1998, 'Preface: Why quantify?' in *Accounting for Resources–1*, Edward Elgar, p. xv)

Sustainability of agriculture, in this thesis, has been defined in terms of the ability of the plot of land in meeting the energy requirements of the labourer engaged on it for crop cultivation and the members of the particular household in possession of such land, with variations under different scales. On the other hand, a number of agricultural practices have been termed as 'sustainable', 'organic', 'alternative', 'agro-ecological', 'traditional', 'ecological', 'low-intensive', etc. Irrespective of the nomenclature, these systems of production have been claimed to be sustainable, in contrast to the alternative systems that typically involve more chemical intensive practices. In the literature, claims and counterclaims exist in abundance on the ability of these practices to 'feed the world', on their lower ecological impact, their higher intensity of labour-use per unit of land or output, etc.[1]

Undoubtedly, there exist definitional ambiguities on the term 'organic', or 'sustainable' in the popular discourse on systems of production in agriculture. Notwithstanding such ambivalence, the practices prevailing in West Bengal during 1956–57 were certainly organic, in letter as well as in spirit. As the *Studies in the Economics of Farm Management* (FMS) 1956–57 dataset for West Bengal has shown, the percentage of farms using chemical fertilisers was minuscule, among all farms. There was no use of tractors, irrigation with pumps or pesticides. On the other hand, the average number of animals per farm was more, and so was the number of animal labour days.

This chapter evaluates the sustainability of farming in 1956–57 following the FMS, and compares it with 2004–05. In the latter part of the chapter, based on

[1] See, Badgley et al. (2007) for an evalutation of these claims based on secondary data from 293 'examples', across the world; also see, Pretty et al. (2008) for a similar survey covering '286 recent interventions in 57 poor countries'. See also, OECD (2003). See, Wu and Sardo (2010) for a critical analysis on the sustainability of these practices. See, Shi-ming and Sauerborn (2006), for the trajectory of developments towards these practices with particular reference to China. See, Alvares (1996) and Planning Commission (2001) as examples for early endeavours in India, among the activists' and at the policy discussions.

the observations from the fieldwork in West Bengal during 2009–2011, a few suggestions will be offered on the question of sustainability of farming.

6.1. Energy balance analysis of FMS 1956–57

FMS needs no introduction. Nevertheless, in appendix A, we have provided a brief review of its early beginnings and the phase of transition before its discontinuity after the arrival of the Cost of Cultivation Scheme (CCS). While it had begun in the year 1954–55, we have chosen 1956–57, the third year of the study period in West Bengal, due to the 'modifications [that] have been made in the light of experience of the first and second year's investigations' (DES 1958: preface).

We may note that the dataset was made available on the basis of size-group of farms and not individual plots like the CCS. The implicit assumption behind such agglomeration was that all the farms belonging to one size-group possessed the average characteristics. Certainly, the intra-group variations were lost, as a result (see, Bharadwaj 1974: 8–9 for details). The assumption was that all the characteristics of the specific size-group were applicable for each of the individual units within it.

The following analysis includes only aman paddy, the dominant crop in both the districts of Hooghly and the then undivided 24 parganas, covered by FMS in the State. While there were many farms engaged in double-cropping (DES 1958: table 3–14), the average cropping intensity was rather low: on average in Hooghly, it was 1.13, and in 24 parganas, it was 1.03. We have selected the lowest size-group (0.01–1.25 acres, or G1 (subsequently higher groups was designated as G2–G8) in Hooghly district for illustrating the calculations. Further, due to the absence of plot-wise temporal information, annual sustainability could not be evaluated.

The analysis was carried out only for the cost accounting sample, for reasons of the superior data quality over the other method, namely the survey. Table A.6.1.1 shows the location of the villages of the two districts in the 1956–57 dataset along with the corresponding tehsils in the 2004–05 one. The inter-temporal comparison, carried out later, will be confined to only these two districts.[2] In

[2] This correspondence exercise was carried out by Shree Debobroto Ghosh, of CCS, BCKV.

other words, the comparison will be restricted within an identical spatial boundary.

6.1.1. Food-calorie as an index of measuring the level of life

We may recollect our discussion above on the validity of the food-calorie as an indicator for the measurement of level of living of the selected household. We may also recollect that in 2004–05, for the three lowest MPCE classes of rural West Bengal, the percentage of expenditure on food varied between 70.2 and 71.8, while it was 35.5–38.2 for cereals. In 1956–57, for G1, G2 and G3 percentage expenditure on food was 75.5, 77.76 and 74.88 respectively, and on cereals, it was 52.98, 48.4 and 46.6. Some of the characteristics of the representative size-group, G1 has been captured in table 6.1.1.

Table 6.1.1: Annual household budget of the illustrative size-group (G1), 1956–57

Source table no	Item	Quantity
8.1	No of persons per family	4.25
8.1	Expenditure per family (in ₹)	710.55
8.1	Per capita expenditure (in ₹)	167.19
A–68	Expenditure on total food (in ₹)	536.44
A–68	Expenditure on cereals (in ₹)	376.45
8.4	% of farm produced food to total food consumption in cereals	23.85
8.4	% of farm produced food to total food consumption in all food	22.88

Source: DES (1958)

6.1.2. Quantification of the Surplus

Table A.6.1.2 explains the calculation for scale A and includes the source of data, derivation and the assumptions, of the energy balance analysis of aman paddy cultivation by G1; <FMS.xlsx> shows it for all the size-groups. Likewise, in table A.6.1.3 and A.6.1.4 the corresponding calculations for scale(s) B and C for G1, have been shown. The duration of the season was taken as 120 days based on DES (1956: table 2–4), i.e. the report of the first year of the first phase of FMS in West Bengal. Figure 6.1.1 presents the EROI under the three scales of sustainability for Hooghly district for all size-groups, followed by the results of both the districts together in figure 6.1.2.

The results of scale A, are in conformity with the reported levels of household cereal consumption. Given the average village price of paddy in 1956–57 (₹ 12.6 per mound), and its predominance—if not the 'monopoly'—in the cereal basket of the rural population in this part of rural India, an expenditure of ₹ 376.45

resulted in a consumption of 29.88 maunds or 1115.25 kg of paddy (of which 23.85% was from the own cultivation) by G1. Given the average number of 4.25 persons per family, per capita per day consumption was 0.72 kg, which was equivalent to 2532.06 Calorie. Leaving aside the intra-household diversity of activities, and disparities of various kinds, certainly the average food-calorie or the energy income of the members of the household implied an annual energy balance, given the Calorie norms in table 2.3.2, as for all age-sex-activity combinations, the average is around 2,500 Calorie. For the higher size-groups, the cereal consumption was higher.

Figure 6.1.1: EROI, aman paddy, Hooghly district, 1956-57

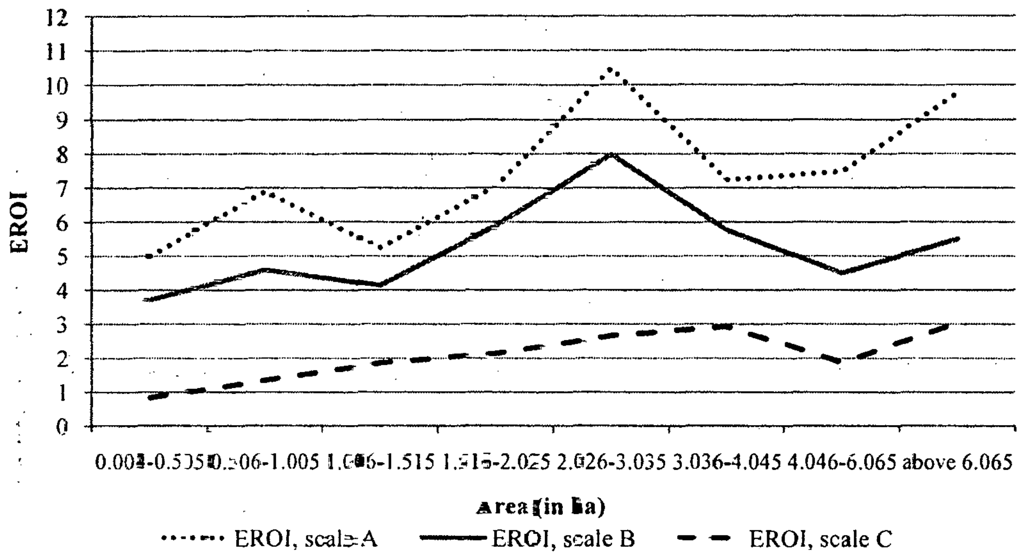
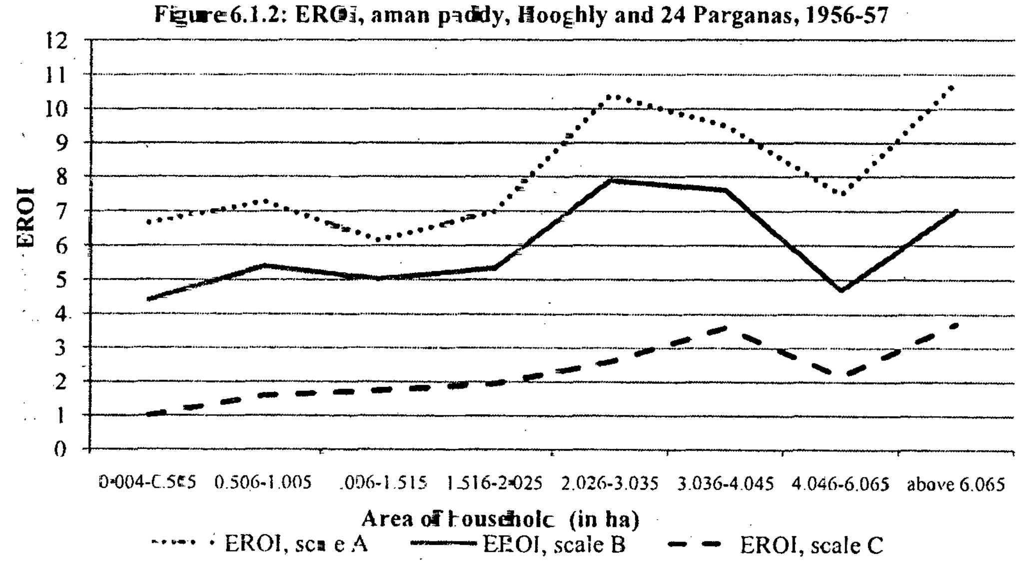


Figure 6.1.2: EROI, aman paddy, Hooghly and 24 Parganas, 1956-57



Before the inter-temporal comparison, we may note the phenomenon of negative profits for the lowest size-group and the associated surplus; the latter was positive for all size-groups, as shown in table 6.1.2.

Table 6.1.2: Average per acre Cost of Cultivation of Aman paddy in West Bengal, 1956–57

	Cost concepts*				Rent on leased land	Rent on owned land and owned fixed capital	Imputed value on family labour
	A1	A2	B	C			
Hooghly	(1)	(2)	(3)	(4)	(5) = (2)–(1)	(6) = (3)–(2)	(7) = (4)–(3)
G1	67.34	92.9	162.3	217.93	25.56	69.4	55.63
G2	93.45	123.88	194.99	243.02	30.43	71.11	48.03
G3	95.57	147.6	194.8	236.23	52.03	47.2	41.43
G4	54.51	121.86	158.75	225.6	67.35	36.89	66.85
G5	75.38	146.14	211.64	256	70.76	65.5	44.36
G6	74.18	179.95	272.31	306.24	105.77	92.36	33.93
G7	70.27	70.27	135.95	166.87	0	65.68	30.92
G8	147.77	147.77	212.96	219.53	0	65.19	6.57
24 parganas							
G1	40.07	46.03	106.13	146.91	5.96	60.1	40.78
G2	53.63	80.73	129.22	179.18	27.1	48.49	49.96
G3	38.36	74.6	104.93	161.51	36.24	30.33	56.58
G4	56.17	58.26	115.64	155.63	2.09	57.38	39.99
G5	45.9	84.61	124.34	162.52	38.71	39.73	38.18
G6	33.02	74.09	113.76	156	41.07	39.67	42.24
G7	87.36	111.26	147.49	155.05	23.9	36.23	7.56
G8	49.76	49.76	144.41	195.5	0	94.65	51.09
	Yield (in mound)	By-product	Output^	Input	Surplus	Rent + Interest	Profit
Hooghly	(8)	(9)	(10) = 12.6 x (8) + (9)	(11) = (1) + (7)	(12) = (10) – (11)	(13) = (5) + (6)	(12) – (13)
G1	13.11	47.58	212.766	122.97	89.796	94.96	–5.164
G2	18.18	65.44	294.508	141.48	153.028	101.54	51.488
G3	21.08	84.64	350.248	137	213.248	99.23	114.018
G4	18.04	51.06	278.364	121.36	157.004	104.24	52.764
G5	20.95	75.97	339.94	119.74	220.2	136.26	83.94
G6	21.6	76.02	348.18	108.11	240.07	198.13	41.94
G7	20.15	99.73	353.62	101.19	252.43	65.68	186.75
G8	20.9	62.14	325.48	154.34	171.14	65.19	105.95
24 parganas							
G1	16.56	56.2	264.856	80.85	184.006	66.06	117.946
G2	18.4	52.1	283.94	103.59	180.35	75.59	104.76
G3	16.48	49.79	257.438	94.94	162.498	66.57	95.928
G4	13.24	39	205.824	96.16	109.664	59.47	50.194
G5	17.57	60.57	281.952	84.08	197.872	78.44	119.432
G6	21.16	56.54	323.156	75.26	247.896	80.74	167.156
G7	13.64	35.86	207.724	94.92	112.804	60.13	52.674
G8	19.79	40.79	290.144	100.85	189.294	94.65	94.644

Source: DES (1958: table A–28, A–29)
Note:
^ Price of paddy was assumed as ₹ 12.6/mound following DES (1958: table 2–1).
* Cost concepts in the table follow DES (1958: 81). These are used by the DES (see, appendix C for a trajectory of the definitions of each of them) for fixing MSP, and are not related to our scales.

6.1.3. Comparison of 1956–57 with 2004–05

It may be recalled that the method of energy balance analysis can only assist in arriving at the surplus and not its distribution. As a result, our comparison will be restricted to the indicators employed in chapter 3. Moreover, given the limitation of the data, as stated above, we shall focus on only EROI and the surplus.

It may be emphasised that districts of Hooghly and 24 parganas had been and still are the most productive districts of the State.[3] This is in conformity with the results of the *National Index of Agricultural Field Experiments* for West Bengal, for 1954–59 (ICAR 1965). Thus, it is of interest to explore the extent to which such 'gifts' of nature had been harnessed for human use on a temporal scale. We argue here that any comparison between two or more practices/systems of crop production must necessarily be done within an identical bio-physical framework. Further, such comparison needs to be carried out with an identical set of clearly defined indicators, like the alternative scales in the thesis. It is important to reiterate here that, given the inherent flexibilities within the method of energy analysis, without such specificities, comparison will yield only meaningless results. It is precisely for this reason, that comparisons of results between two or more studies even on the same location may not always be a fruitful exercise.

Finally, any general conclusion needs to be read with caution, given the diversity in practices within any of the systems of production—chemical intensive, organic, ecological and so on; either at a given point of, or across, time. Alternatively, the results of the inter-temporal comparison, as has been done in this section, remain particularly valid for the specific agro-climatic boundary. In a different location, but with similar systems of production, the results may remain valid, but the extent of change is likely to differ. Similarly, within the same location, with a different variety of systems, the results could be different. A general conclusion on the comparison of sustainability of 'organic' and 'modern' agricultural production systems, require a much wider sample, effort, time and resources, which is beyond the scope of the thesis.

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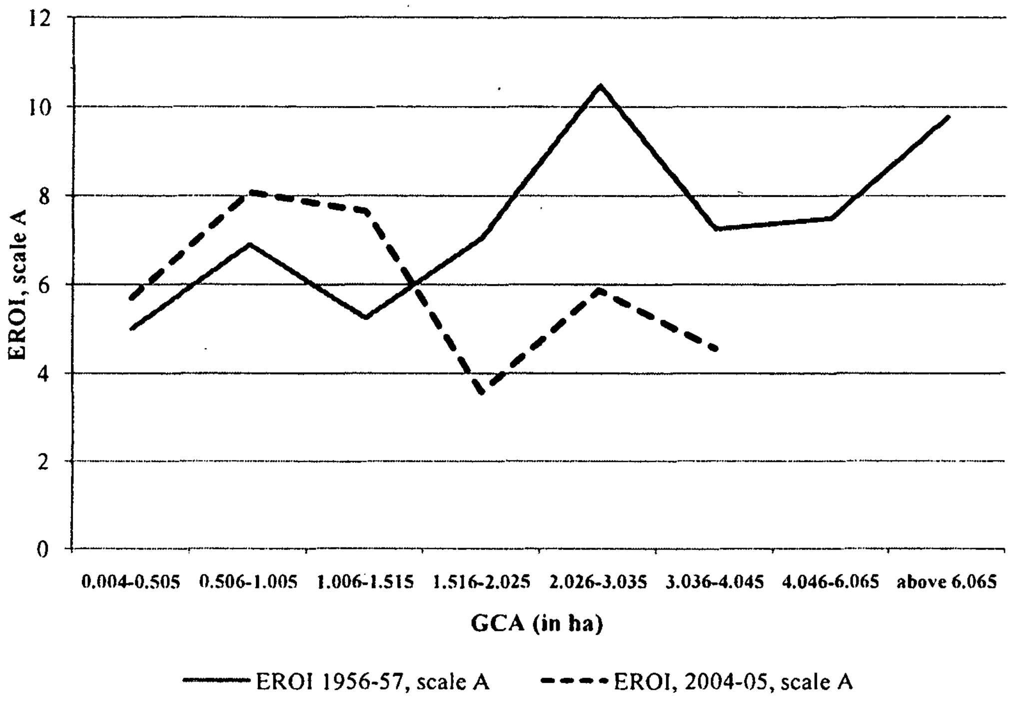
[3] While the selected tehsil/blocks in 2004–05 belong to 3 agro-climatic zones, one can only make a reasonable guess on the corresponding bio-physical framework 50 years back. As the delineation of agro-climatic/agro-ecological zones started only in the late 1970s, as noted in table A.1.7.2, it is not possible to know the exact nature of the surrounding environment of the crop production system. Nevertheless, given the relatively higher land productivity of this region in the State at present, one may conclude that it was even better 50 years back.

As stated earlier, for the purposes of comparison, plots have been selected from the 2004-05 sample, only from the corresponding tehsils as shown in table A.6.1.1, cultivating aman paddy. All together, 88 households, cultivating a total area of 186.13 ha during season 1 were taken into consideration.[4] For the comparison, with 1956–57, farms were grouped together, following the size-group ranges as in FMS 1956–57. It may be noted that due to fragmentation/division of land in the last 50 years, no farms could be found corresponding to the top two size-groups in the sample.[5] The largest GCA was 3.89 ha.

Figure 6.1.3–6.1.5 shows the inter-temporal comparison of EROI of the three scales of A, B, and C for Hooghly and 24 parganas, for aman paddy.

Figure 6.1.3: Comparison of EROI, scale A, 1956-57 and 2004-05, Hooghly and 24 parganas



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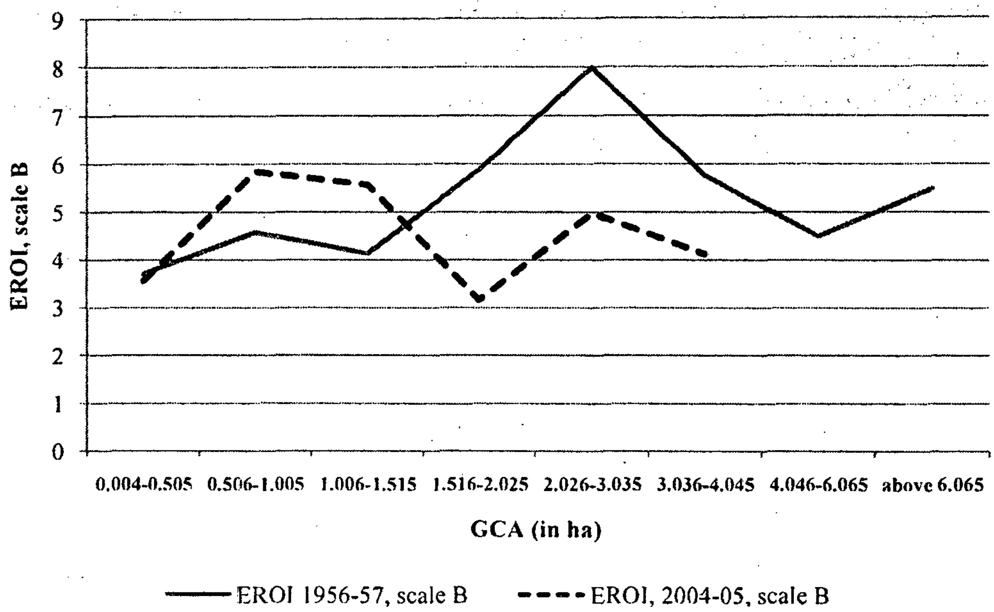
[4] <selected 2004–05 for comparision.xlsx> contains all the relevant information, for these farms.

[5] It may be noted here that in the cost accounting sample of FMS 1956–57, the highest three size-groups had 6, 5 and 2 farms respectively:

District	3.036–4.045 ha	4.046–6.065 ha	Above 6.065
Hooghly	3	2	1
24 parganas	3	3	1

Figure 6.1.4: Comparison of EROI, scale B, 1957-57 and 2004-05, Hooghly and 24 Parganas

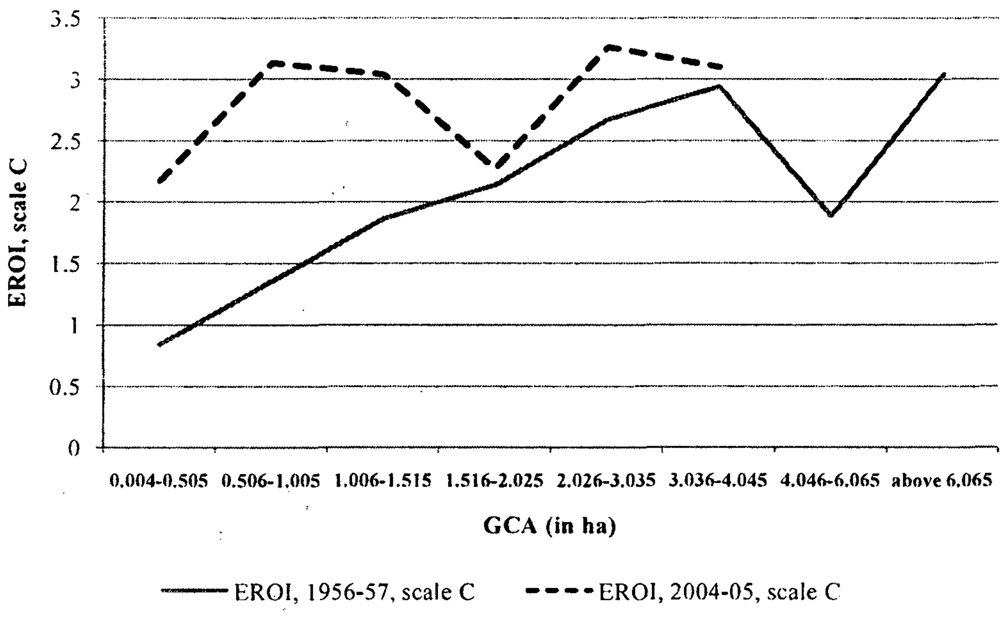


We may recall that scale A, considers only the days of activity, and thus EROI of this scale may be interpreted as the operational efficiency. In figure 6.1.3, we can observe two things: the first is the apparent inefficiency of the large farms in energy terms, compared to 50 years ago, which is in line with the results in the literature on the agricultural energetics from the more industrialised countries. The other is the apparent 'efficiency' of the small farms (below a threshold of around 1.75 ha) at present compared to what was the case in the past. We had a discussion in chapter 4 about such claims of 'efficiency' of small farms. In this connection we may additionally mention the possibility of an undervaluation of the energy expenditure by the human labour in these farms, most of which are from the household. We may recollect the discussion in 2.3.5 above on the unsuitability of BMR based approaches for taking account of the work capacity of the individuals; the more appropriate method is the one based on VO2 Max or oxygen inhaled or carbon dioxide exhaled, which however, requires measurement of every individual. While micro studies on agricultural labour can certainly use this method, for larger population size, BMR based approaches, as followed by FAO or ICMR are used.

Given the positive association between the land size, output and number of animals, in possession, such higher intensity (and not just duration) of human labour is the only option for the households in the lower size-groups, for meeting the power requirements. In contrast, in 1956-57, it was the animals that had provided most of it. Thus, the 'true' EROI, of scale A for 2004–05 could be lower than what has been portrayed in figure 6.1.3, for the small farms. As a result, across the board, EROI of scale A, in relation to land sizes, in 2004–05 will be lower than the one in 1956–57, implying overall operational inefficiency in the more recent times, in energy terms.

In fact, in figure 6.1.4, EROI of scale B, for the lowest size-class for 2004–05 appears lower than that the one in 1956–57, even without making such 'corrections' mentioned above. We may recollect that in this scale, the maintenance of labour for the inactive days of the labourer net of hired out days was considered for the duration of the season along with the active days. Again, from the figure 6.1.4, it is quite clear that as a proportion, the Calorie requirements during the inactive days have increased over the last 50 years, for the smallest size-classes. This indicates that per labourer, the number of active days for the smallest size-classes was lower than the average for all the farms.

Figure 6.1.5: Comparison of EROI, scale C, 1956-57 and 2004-05, Hooghly and 24 parganas



In contrast to the other two scales, for scale C, the relationship between EROI and GCA for 2004–05 appears distinctly above the one for 1956–57. We may recollect that in this scale, necessary Calorie for the dependents and animals (for non-active days net of hired out) for the duration of the season was added in the total input along with the energy values for dung in the output. The inter-temporal shift of EROI of scale C, certainly points to the greater viability of the households in the more recent time, in energy terms. However, one may also look at the fact that beyond the three smallest size-classes, EROI of scale C curves of 1956–57 and 2004–05 appear very close to each other.[6]

In fact, such closeness indicates that the supposed improvement in the 'viability' tapers off after a threshold GCA. We may recollect that in scale C, so far as the dependents are concerned, only those within the household/farm that had undertaken the crop cultivation in question, were taken into consideration. In other words, Calorie requirements for the dependents of the hired labourers were not added.

It is an established fact that in the large farms, earners are less—in terms of crop cultivation as an occupation—as a proportion of the number of household members. Alternatively, number of days of hired labour in absolute terms or in proportion to the total labour is also much more for these farms in contrast to the smaller ones. Thus, an increase in such a share in the recent times, in comparison to 1956–57, will imply a lesser fall in EROI from scale B to scale C for 2004-05.

The other possibility is that the net addition by the animals in the total input (dung net of Calorie requirements during the inactive days) in scale C was less during the recent times than what was in 1956–57. Given that, fifty years ago, number of inactive days for animals was much less, in most likelihood, the apparent higher 'viability' of the large farms in 2004–05 (in contrast to 1956-57 for the same size-class, or smaller farms in 2004-05) is based on its use of hired labour. Inclusion of the Calorie requirements for the dependents of the hired labour, in a newly constructed scale, say, D, will certainly result in a significant fall in the EROI for these farms, than the ones in the lower size-groups. In other

[6] For the top two size-classes, we cannot make any inference due to absence of such farms in 2004–05, as stated earlier. Further, as the previous note (5) has shown, even for 1956-57, there were very few farms in the top-two size-classes as well.

words, the scales of sustainability in this thesis are insufficient to comment on the sustainability of the crop production systems in these farms; they were appropriate for the farms mainly engaging household labour. Surely, such an endeavour will require coverage of other sectors and just not agriculture, for a more precise estimation of the value of the labour power, in energy terms. This remains an area of future research.

We may also look at the input compositions in the two periods, to explore further the causes behind the different results of operational efficiency and viability in energy terms. Figure(s) 6.1.6–6.1.7 shows the input composition in percentage terms for scale A for 1956–57 and 2004–05 respectively. Figure(s) 6.1.8–6.19 does the same for scale C.

In figure 6.1.6, we may note the predominance of Calorie requirement for the animals as a percentage of total inputs in 1956–57 across the size-groups. This is an expected result, given the absence of any other inanimate power sources at that time. Further percentage of human labour also had increased with the size-groups. In fact, Calorie requirements of these two inputs together, even in scale A, had accounted for around 75% of the total inputs.

In 1956–57, contribution of manure was much smaller, in comparison to 2004–05, portrayed in figure 6.1.7. In fact, the percentage of manure (organic and inorganic together), in 2004–05 was far higher than the percentage of organic manure alone in 1956–57. There are two plausible causes behind such a rise: the first is related to the much higher cropping intensity in the recent times warranting such augmented flow of nutrients. The second had necessitated for compensating the soil of its nutrient stock due to the past cultivation. In a sense, the latter is for compensating the cumulative 'robbing', and the former is meant for the period of cultivation in question. Such higher nutritional 'support' to the soil, in any case, is at par with higher yield over the years.

The predominance of organic manure, even higher than the inorganic manure, in 2004–05, in fact, was already noted in the previous chapter. Besides, in figure 6.1.7, the fall in the share of labour may also be noted as we move from lower to higher size-groups. Given that the large farms employ less household labour, with this additional evidence, it is certain that the higher viability of large farms in energy terms in 2004–05 was based on its use of greater proportion of hired labour, of the total labour. It is most manifested in the analysis of scale C.

Figure 6.1.6: Input composition, scale A, in percentages, 1956-57

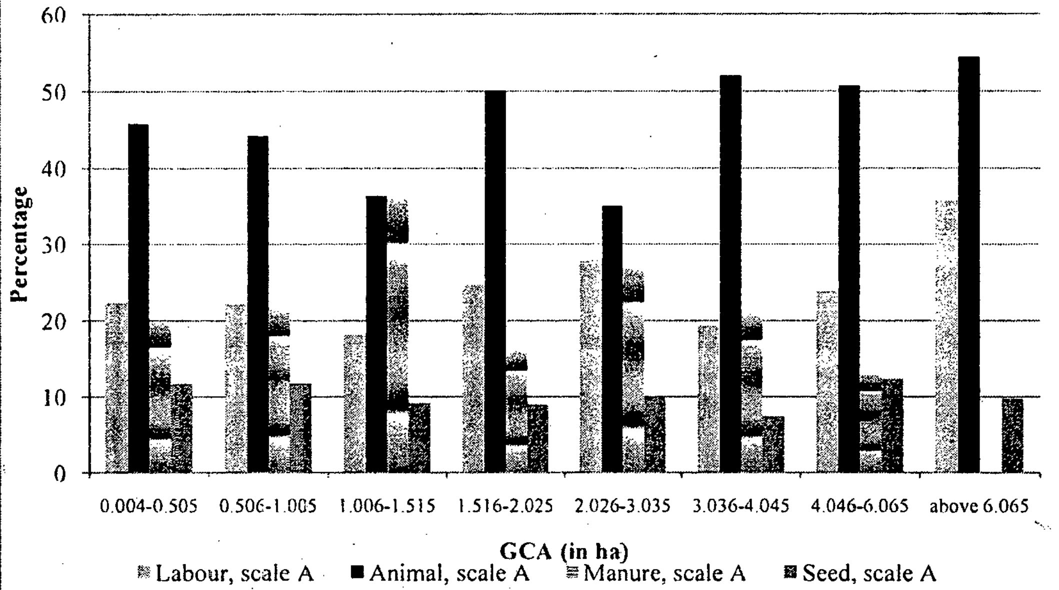
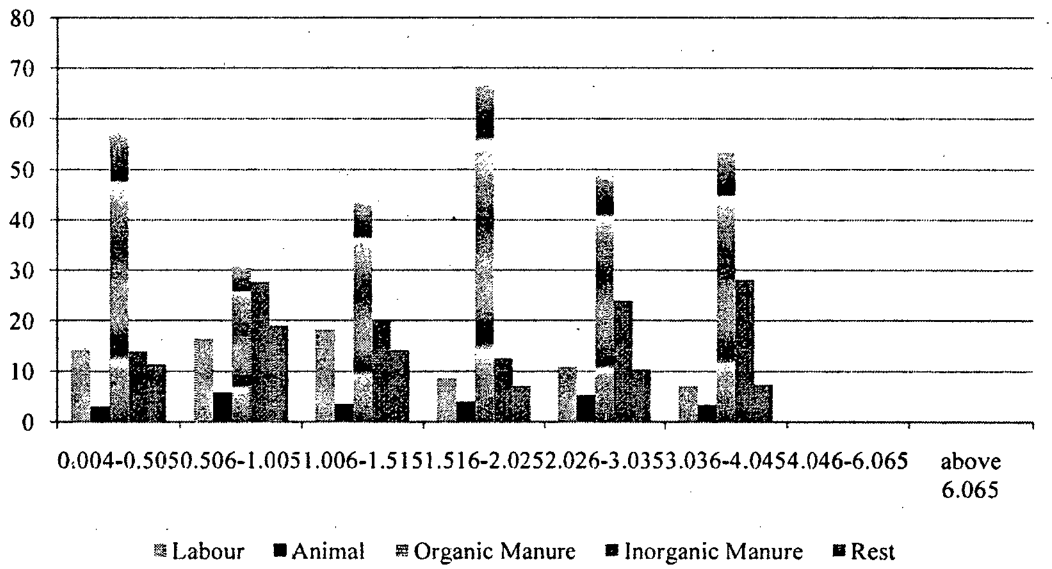


Figure 6.1.7: Input composition, scale A, 2004-05



On the other hand, patterns of input use of scale C in figure(s) 6.1.8 and 6.1.9, for the two time periods, show a different pattern altogether than the one in scale A. To begin with, percentage of labour showed a distinctly similar pattern across the years for the smaller size-groups. On the other hand, while in 1956–57, percentage of labour appears as an inverse-U, in 2004–05, it is a negatively sloped line.

Figure 6.1.8: Input composition, scale C, 1956-57

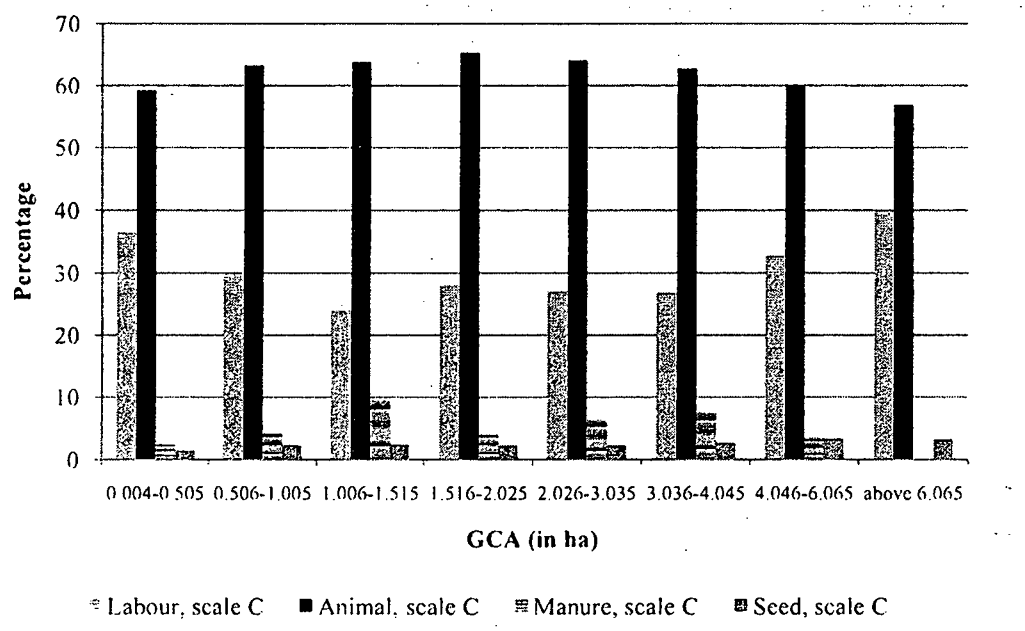
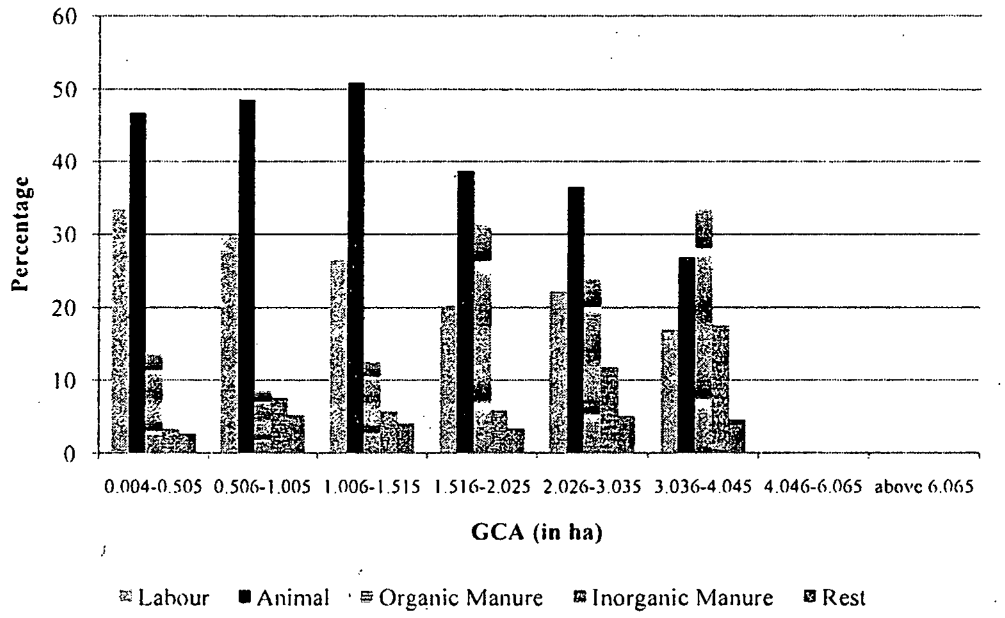


Figure 6.1.9: Input composition, scale C, 2004-05



Further, we may note the almost uniform share of Calorie requirements for animals in scale C, in 1956–57, across size-groups. Indeed, for the lowest three size-groups, in 2004–05, share of animals was close to what was fifty years ago. However, keeping in mind that pattern in scale A (figure 6.1.7), it seems that proportion of active days for the animals was rather less in 2004–05.

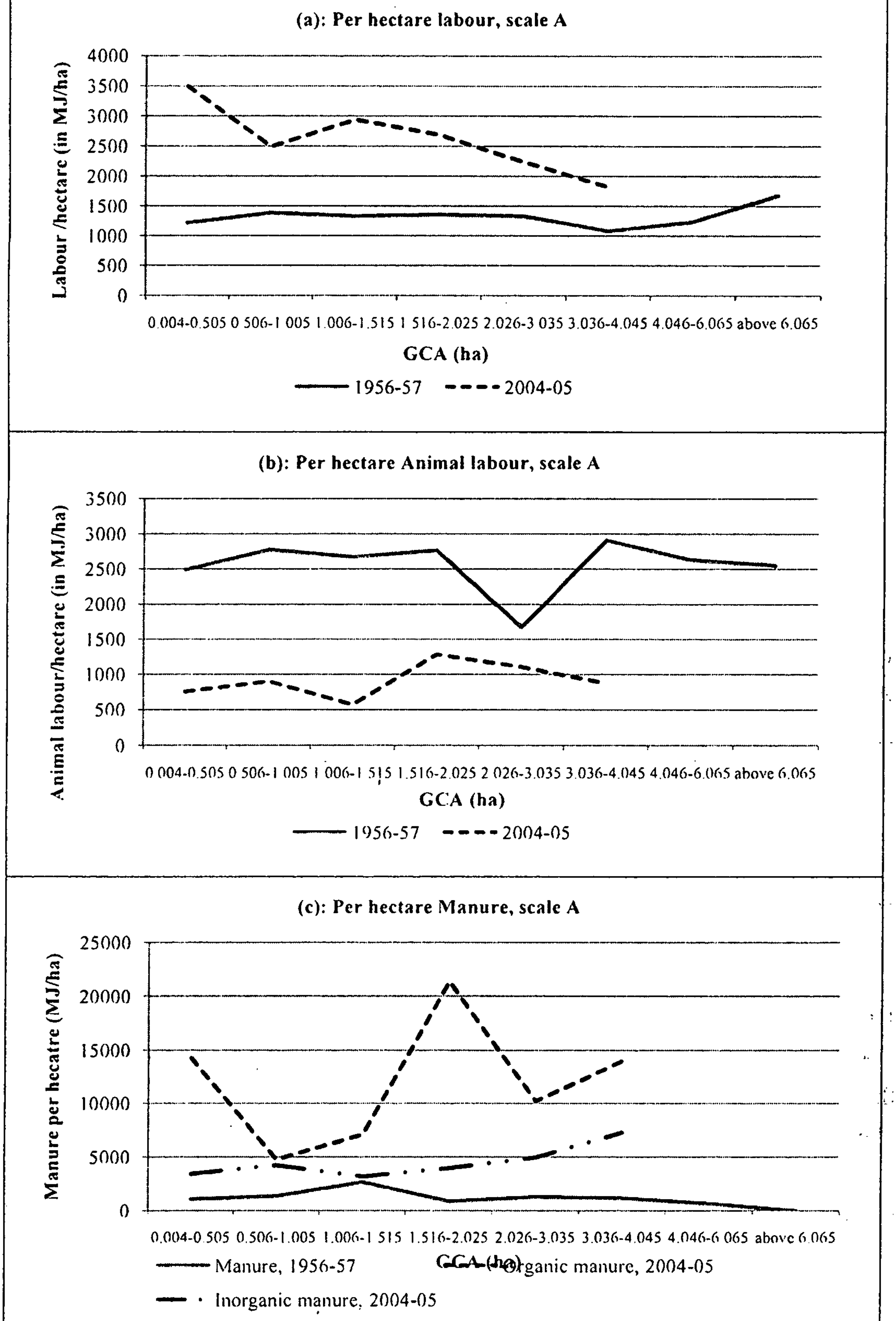
The evidence on the proportion of human and animal labour, together, points to the fact that, in energy terms, their combined contribution has reduced with the rise in land sizes, in 2004–05, for scale C. On the other hand, in 1956–57 they were almost identical across size-groups.

Figure 6.1.10 and 6.1.11 show usage patterns of various inputs per hectare for scale A and C respectively, over the time-scale. In terms of activity, or operation (scale A), labour per hectare in 1956-57 was rather uniform across size-groups [see, figure 6.10 (a)]. On the other hand, while the line corresponding to 2004-05 is above the one in 1956-57, it gradually falls with the increase in land size. Given the fact that, Calorie requirements for labour in scale A, as a proportion of inputs had come down over the years, figure 6.10 (a) certainly implies fragmentation of land. Per hectare labour in scale C, as in figure 6.11 (a) shows a very similar pattern as in scale A, albeit a scaled-up one.

Calorie requirements for animals, on the other hand, show a different pattern in the two scales. Figure 6.10 (b) indicates much larger use of animals in 1956-57 in contrast to 2004-05, as noted earlier. On the other hand, figure 6.11 (b) shows that Calorie requirements for the animals during the entire season, that includes both active and inactive days is much larger in 2004-05 than what was in 1956-57. There is a similarity in the pattern of per hectare feed requirements for animals and the food requirements for the human labour in scale C: a gradual fall with the rise in land sizes.

Figure 6.10 (c) shows the manure usage pattern as we had noted earlier; it is of much higher use in the recent times. On the other hand, figure 6.10 (d) portrays that while the per hectare energy value of seed was much lower in 1956-57 and almost invariant to land size, in 2004-05, per hectare energy value of seed, pesticides and machine usage has reduced with land size. Latter phenomenon is mainly related to the indivisibilities in the use of some of the inputs: with higher land size, the average energy cost became lower.

Figure 6.1.10: Inputs per hectare, Scale A, 1956-57 and 2004-05, aman paddy, Hooghly and 24 parganas (in MJ/ha)



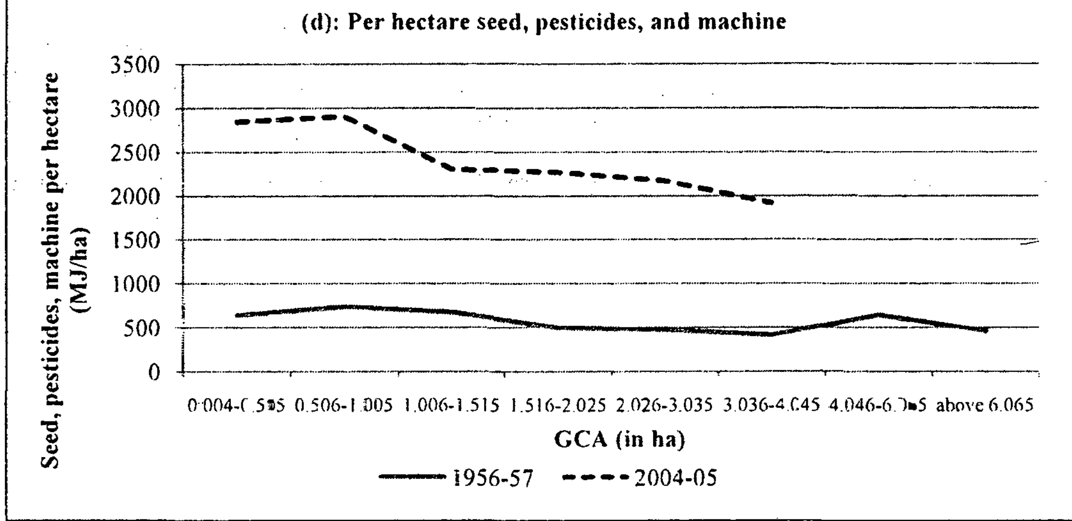
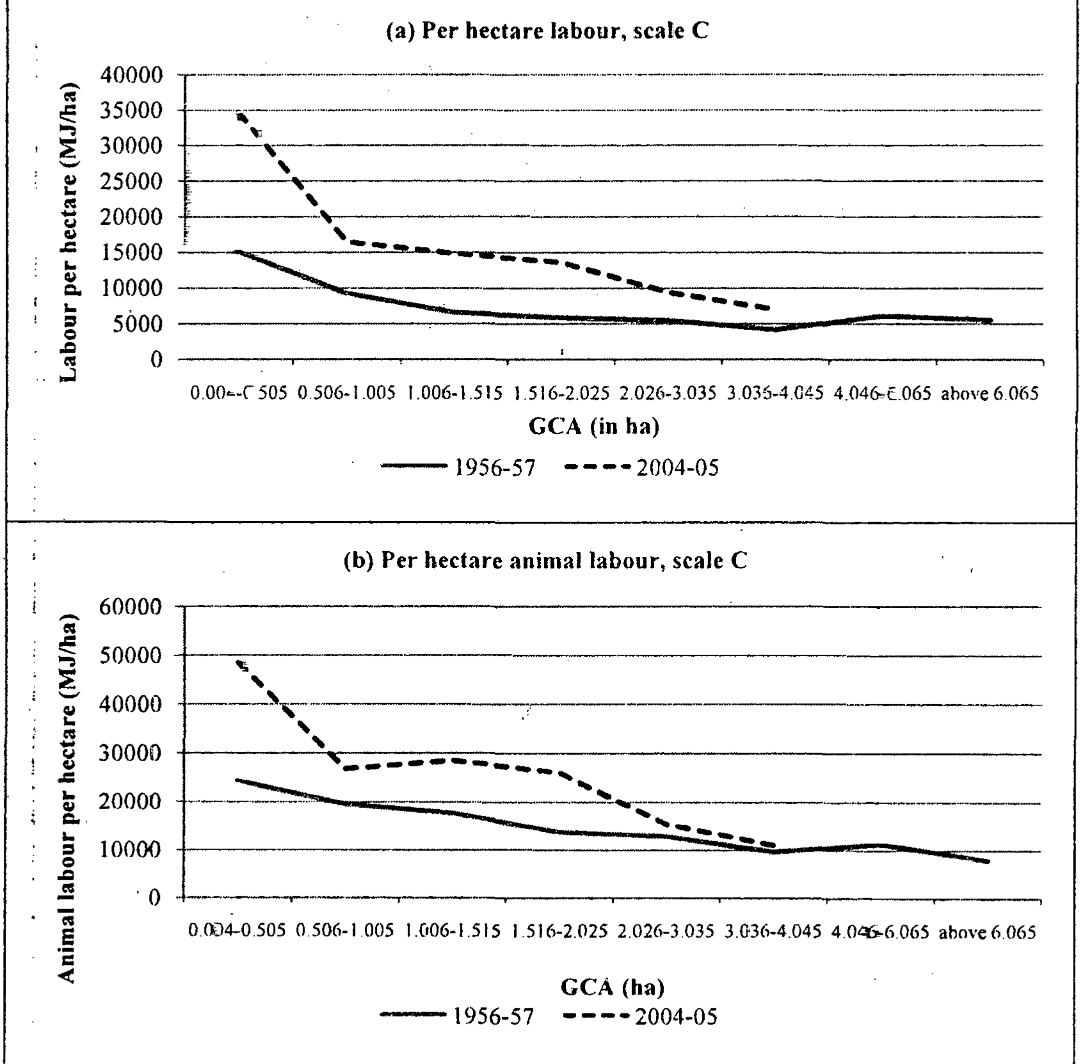


Figure 6.1.11: Inputs per hectare, Scale C, 1956-57 and 2004-05, aman paddy, Hooghly and 24 parganas (in MJ/ha)



We may recollect from the chapter 3 that a high EROI could be achieved from a small area of land, and be also associated with a small quantity of surplus. We may also note that the agricultural surplus had been found to be positively related with the gross output. In particular, lower levels of output were found to be associated with a negative surplus, or a situation where the labour was not being able to receive the required energy to maintain the balance. We may also note from table 6.1.2 that in 1956-57, there were no size-groups with a negative surplus.

Figure 6.1.12: Per hectare Surplus, Scale A, aman paddy, Hooghly and 24 Parganas

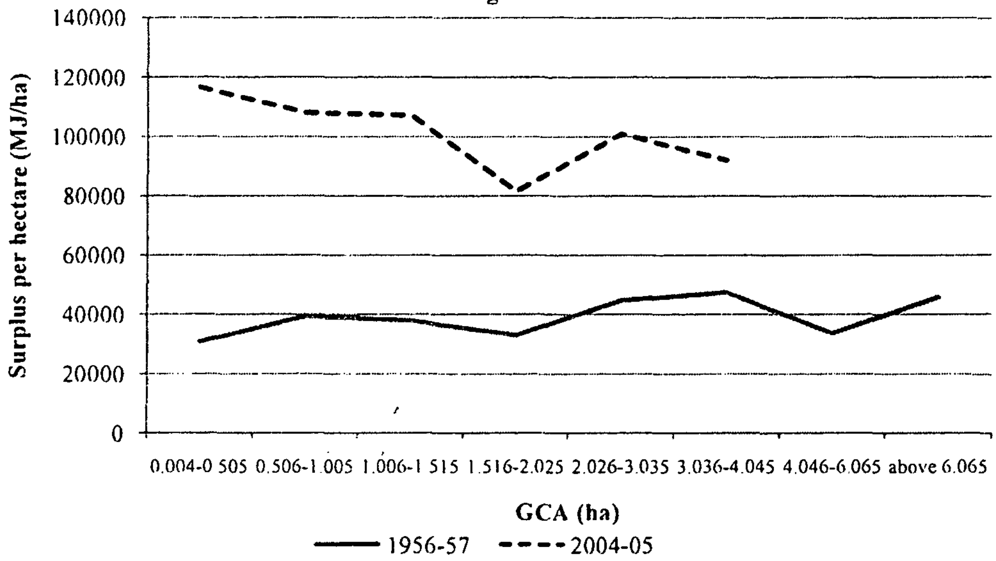


Figure 6.1.13 : Per hectare Surplus, Scale C, aman paddy, Hooghly and 24 Parganas

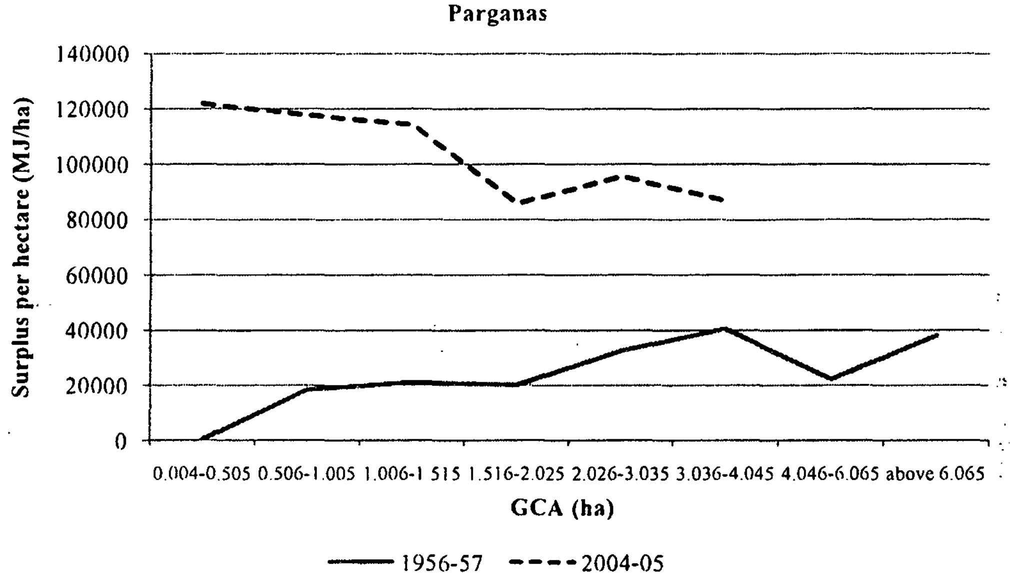
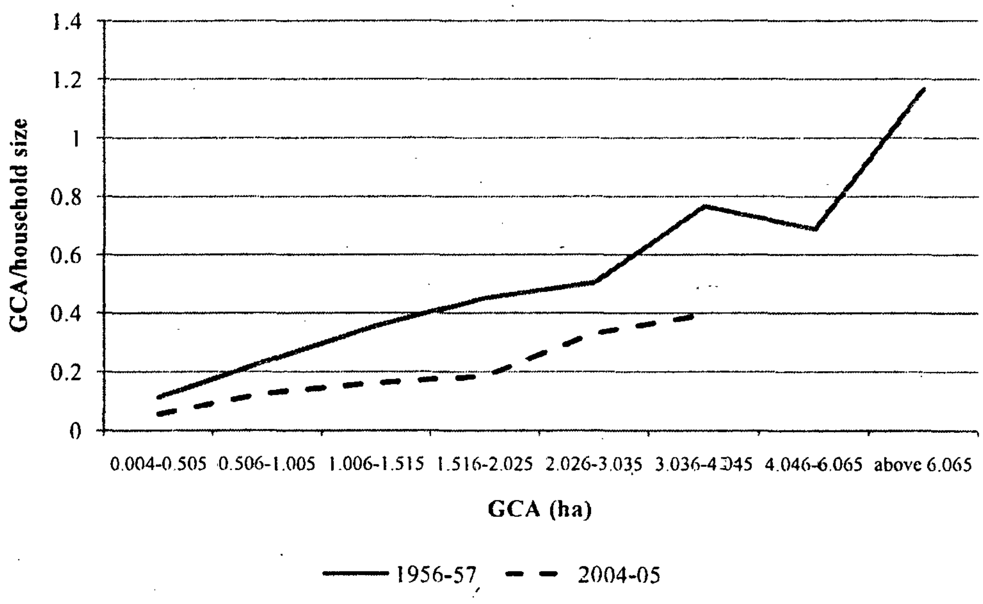


Figure 6.1.12 shows the per hectare surplus in scale A, for the two periods. Figure 6.1.13 does it for scale C. Certainly, with time, per hectare surplus has increased a few times across the land sizes. There are at least three interesting aspects that may be brought to the attention. The first is the apparent similarity between the per hectare surplus of scale A with scale C in 2004-05. This is due to the fact that, the energy value of the dung from the animals in possession of the household for the entire season was taken into account in scale C, which in most cases was more—in energy terms—than the Calorie requirements of the dependents during the entire season and the feed for the animals during only the inactive days net of hired out ones. For the very small farms, such possibility does not exist simply because it was not viable for them to maintain animals.[7]

The second is the apparent un-viability of the farms in the lowest size-group in 1956-57; in accounting terms, this size-group had a positive, but a very low surplus. We may recollect that these are precisely the farms, with a negative monetary profit as well, a phenomenon, on which the farm size-productivity debate was carried out since the late 1960's.

Figure 6.1.14: GCA per household size, 1956-57 and 2004-05, Hooghly and 24 parganas, aman paddy

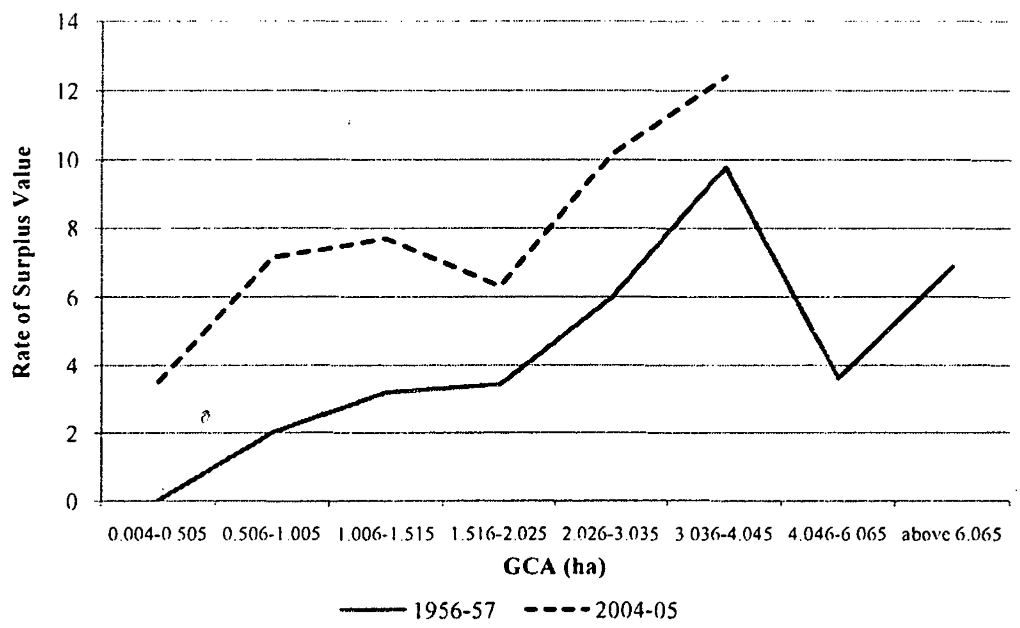


[7] Further, the districts of Hooghly and 24 parganas being close to Kolkata, the State capital, and also due to its better bio-physical framework, crop cultivation has a long history. As a result, various types of markets have emerged including contractual tillage by animals.

Third, we may also note that, while per hectare surplus is higher in the recent times, so has been the per hectare labour. In fact, as shown by figure 6.1.14, smallness of the holdings has been one of the major impending factors towards sustainability of agriculture. At the same time, it may be also emphasised that in 2004-05, in contrast to 1956-57, in the districts of Hooghly and 24 parganas, the per hectare labour had increased, and even then, per hectare surplus is much higher across the size-groups than what was 50 years back. This is due to increase in the intensity of cultivation in the resent times. Per hectare input have gone up no doubt, but, per hectare output have gone up much more, implying higher per hectare surplus. Certainly, the 'traditional' methods of cultivation cannot meet such higher levels of intensity.

Fourth, the higher rates of surplus value (in scale C) in the recent times can also be seen from figure 6.1.15, that plots it against land sizes over the years across the size-groups. Again, it shows that with higher land sizes, labour can produce a much larger surplus, than what is possible while working on smaller land. This indeed, confirms the previous point.

Figure 6.1.15 : Rate of Surplus Value, scale C, Hooghly and 24 Parganas



6.2. A few questions on the sustainability of the Organic agriculture

In the literature on the comparison of farming practices, one unequivocal conclusion had been that of higher labour intensity per unit land area in the 'organic' varieties, be it in terms of land, or output (for example Badgley et *al.* 2007). It is obvious that, with less use of the dated labour, the number of days of living labour is bound to be higher. For sure, in such 'organic' practices, there are possibilities of higher employment.

We have noted in chapter 5, that the organic manure was negatively associated with surplus while inorganic manure was positively associated for 2004-05. Indeed, the rich agricultural history of India, China, Europe and American continent have shown the importance of chemical fertilisers to augment or even maintain the yield. Undoubtedly, there are associated adverse ecological impacts associated with the excessive use of the chemical fertilisers, but that does not mean that it can be dispensed with. Certainly, there is a need for farmer's organisations to educate the cultivators on this aspect, given the complete collapse of the agricultural extension services. Further given the recent decontrol of the fertilisers (as well as pesticides), one has serious doubt over the quality of these products, on which there is a need for an organised vigil.

Further, while a much higher quantity of organic manure is used in comparison to the inorganic ones in the recent times, across levels of output or land size, increase in the supply of dung based manure is difficult to come by, given the across the board reduction in the number of animals. Given the widespread adoption of tractors across size, days of engagement for animals has been less, implying higher number of inactive days. Lesser number of hired out days implies higher expenditure on feed on the part of the household in possession of the animal. In fact, many households in 2004-05 dataset have been found to be with one bullock; its use certainly required co-operation/exchange with someone else with an identical need.

On the other hand, given the enormous amount of crop residues, most of which ends up in exhumation followed by an increase in the atmospheric carbon dioxide, it is important to use these 'free' gifts more appropriately. Given the decrease in the number of animals, the quality of such 'unprocessed' manure will be inferior, no doubt. Nevertheless, for sure, a number of nutrients will find its way to its origin--the soil--in the process. There are definite benefits of economies of scale, in such depositing of crop residues in the village commons, and once again, farmer's organisations can be instrumental towards this as well. The benefit will be economical, social as well as ecological.[8]

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The author's fieldwork in a number of districts of the State of West Bengal during 2009–2011 had revealed certain other aspects necessitating such cooperation among the cultivators. Interviews were conducted with a number of farmers, agricultural scientists from the State agricultural University, officials from the agricultural department of the State handling matters related to organic farming,[9] enumerators engaged in collection of data throughout the year directly from the farmers, as well as research staff of the Cost of Cultivation Scheme in the state. In spite of the varied engagements, one overwhelming conclusion was that farmers in the State have realised the importance of judicious use of fertilisers, though owing to economic rather than ecological reasons. However, hardly anyone is willing to abandon its use completely. Indeed, as a number of diagrams in the previous chapter had shown, in general, use of both types of manure has been rather common.

At the same time, while a government sponsored programme had resulted in the adoption of 'organic' practices in its numerous field stations across the State, in none of them it was continued for more than a year.[10] Such a continuity was important as the yield usually falls immediately after transition from a more chemical intensive practice; only after 3–5 years a comparable yield is reached. In the transition period, there remain remnants from the past practices and thus the result is not free from the 'impurities'. Due to this methodological problem, it was

[8] Incidentally, in the debate on sustainability one finds more focus only on one of its tripods, the ecological. Certainly, economically unprofitable agricultural systems were never to be accepted by the farmers, and securing at least the same profit as the other alternatives is a prerequisite.

[9] The West Bengal Government had launched a 'Bio-village programme' in 2004–05. By 2007–08, there were 75 such villages. In 2009, it had resolved to set up one bio-village in each of the 341 blocks in the state in the next two years. The objective behind setting up bio-villages was to create role models for adaptation to organic farming. Interestingly, an apparent shortage of human resources at the government, had led to consultancy services to non-governmental organisations for the execution of the programme.

[10] Stations were selected on an annual basis in groups, mainly for demonstrating the practices to the farmers.

not possible to evaluate the sustainability of these practices despite having data of a reasonable quality.

However, there were reported cases of continuity in some of the organic practices, though that took place under some peculiar circumstances. Consider the low-lying plots of land that receive plenty of water, mixed with the 'wasted' fertilisers from the adjoining plots, or the plots adjacent to the cattle-shed benefitting from the organic manure. Certainly, these plots did not require any direct chemical fertiliser.[11] Thus, these 'success stories' were indeed exceptional in nature, and no general conclusion could be drawn from them. Further, while one of the many aspects of chemical intensity could be covered by these 'accidents', the case of pesticides had appeared to be much more difficult.[12]

Being a normal year, in the 2004–05 dataset, the incidence of the insect related problems was much less, as noted earlier. However, such was not the case in the other years. Faced with a pest attack, and with the use of chemical pesticides in the adjoining plots of land, the farmers did not have much of an option, but to follow the bandwagon. This phenomenon has been reported from the other parts of the country as well, including the State of Punjab, presently faced with a massive ecological problem. Organisations spearheading the organic farming movement like *Kheti Virasat Mission*, had found it to be extremely difficult to convince the individual farmer to adopt ecologically less damaging practices of pest control.[13]

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In summary, the following points may be stressed. Over the last fifty years, there had been distinct changes in the efficiency of farming operations, in energy terms, as well as of the sustainability/farming of agriculture as a livelihood. While the per hectare input has increased implying an increase in the intensity of cultivation, per hectare output has increase even more in proportional terms. As a

[11] Interestingly, most of these plots had been kept by the farmer for cultivating food crops for the consumption of the household.

[12] Use of fossil fuel use is the third aspect. The State as such attracts decent rain and thus the energy expenditure on irrigation was comparatively less. <scale A.xlsx> may be seen for exact percentage share of inputs across plots on maehinery.

[13] Presentation at Inception Workshop on Capacity-building in National Planning for Food Security—Punjab State, India, jointly hosted by GIST Advisory and UNEP, October 24, 2011, New Delhi.

result, per hectare surplus has increased. However, given the higher number of persons per unit land area, across the land sizes, even the increased per hectare surplus could not ensure the sustainability of cultivation for all households, and especially the ones with a tiny holding.

The practices in 1956-57, no doubt had been free of any chemical inputs, and therefore was free from the associated adverse ecological impact, by definition. However, it is possible to conceive of situations, where replacement of a chemical input by its organic substitute many result in more use of labour per hectare. Consider for example, replacement of chemical pesticides by mechanical weeding. Given the fact that *per se*, 'organic' practices require more labour per hectare, such substitution will increase it further. Noting the 'self-exploitation' of labour in the very small farms, certainly it is not advisable to adopt such practices in these farms. On the other hand, EROI as well as surplus of scale C increases with land sizes; and so is the rate of surplus value, across the two periods under study in this chapter. Finally, the organic practices, in order to be sustainable, need to find ways and means to increase the intensity. Such a challenge, while using only organic inputs, is a real one, for which there is a much greater need of cooperation between agronomists, natural scientists including ecologists, farmers' organisations and with active support from the State.

> Show me the man who makes no mistakes, and I will show you a man who has done nothing (Justus von Liebig, 1803-1873).

In this chapter, we may summarise the results alongwith offering a few suggestions for policy. In this thesis, four alternative scales of sustainability had been proposed, defined and used in order to analyse the crop production undertaken by 590 households spread across 59 tehsils and 5 agro-climatic zones in 2004-05 of the State of West Bengal and 100 households in 1956-57, located in the districts of Hooghly and 24 parganas.

First, in the evaluation of West Bengal agriculture in 2004-05, through the method of energy balance analysis, many households had been found with a negative surplus in energy terms. Given that a Calorie norm was assumed against the necessary energy intake for human labour and the members of household in accordance of age-sex-activity, the actual surplus could be even more given the widely reported under-nutrition and decrease in the per capita food consumption in the country. Further, owing to the taxonomies of the method no account was taken for property relations, and thus other factor incomes, say, rent. Even while the bulk of the farmers cultivated their own land, the imputation of a notional value for rent will certainly reduce the energy surplus accruing as non-rent income to the peasant household; and where rent is actually paid, this would entail the accrual of lower absolute amounts of actual surplus to those particular peasant households.. In sum, the number of households identified in this thesis with a positive surplus in energy terms are defined in a very specific manner.

Second, the phenomenon of negative surplus in energy terms was found across three of the lowest CCS size-groups (0-1 ha, 1-2 ha, and 2-4 ha), with a majority belonging to the first two. This is alarming, to say the least, in terms of sustainability of labour engaged on the land for crop cultivation. Further, such occurrence of a negative surplus was found in all the agro-climatic zones of the State, with varying intensity. Only a few of the households located in the new alluvial zone were found to be with a negative surplus. In contrast, many of the households situated in the relatively inferior bio-physical framework of red laterite and coastal saline zones were found to be with a negative surplus. As a consequence, the critical minimum area (in terms of net area sown) or a threshold for ensuring a positive surplus was found to be different across agro-climatic zones. Similarly, a threshold output in energy terms was also identified beyond which a positive surplus emerged. For obvious reasons, obtaining the required level of output is dependent on the state of development of the means of production, and the bio-physical framework supporting the production.

Third, the gross cropped area per household size was found to be having a significant influence on the surplus during the cultivating period. A range of 0.6-0.7 ha/household member was found to be the threshold for ensuring a positive surplus.

Fourth, in spite of the massive negative ecological effects associated with the use of inorganic fertilisers, it had been found to be having an important bearing on the quantum of the surplus on energy terms. In fact, in per hectare terms while organic manure had been found to be of higher value than the inorganic ones, its efficacy is not beyond doubt. There are possibilities of improving/modernising this input towards improving its surplus generating power. Further given the enormous quantity of by-products that can be used as organic manure most of which lay waste, there are definite economic and ecological benefits associated in an endeavour that will involve natural and social scientists towards a better utilisation of this inseparable component of the crop production.

Finally, in 2004-05, in comparison to 1956-57, per hectare surplus in scale A and C of this thesis was found to be much higher across the size-groups, even for the very small farms. Such a result was achieved with the increase in the intensity of cropping, enabled by the modernisation of the methods of production that included chemical inputs. While traditional variety of organic farming as used in 1956-57 cannot be used for such intensification, it is possible to modernise the organic farming methods, practiced all around the world towards an outcome that will ensure sustainability of the labour engaged alongwith a much lower ecological impact.

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