Geo-Environmental Assessment Of Water Resource In Ong River Basin, Orissa

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DOCTOR OF PHILOSOPHY

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CERTIFICATE

This is to certify that the thesis entitled **"GEO-ENVIRONMENTAL ASSESSMENT OF WATER RESOURCE IN ONG RIVER BASIN, ORISSA"** submitted by **Prakash Chandra Dash,** Centre for the Study of Regional Development, School of Social Sciences, Jawaharlal Nehru University, New Delhi - 110067, India in partial fulfilment of the requirement for the award of the degree of **Doctor of Philosophy,** is his original work and has not been previously submitted for any other Degree of this or any other University.

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DECLARATION

I do hereby declare that the thesis entitled **"GEO-ENVIRONMENTAL ASSESSMENT OF WATER RESOURCE IN ONG RIVER BASIN, ORISSA"**, submitted by me to the School of Social Sciences, Jawaharlal Nehru University, New Delhi for the award of the degree of **"DOCTOR OF PHILOSOPHY"** embodies the result of bonafide research work carried out by me and that it has not been submitted so far in part or in full, for any degree or diploma of this university or any other university/institution.

(Prakash Chandra Dash)

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Forwarded by

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Dedicated to My Parents

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PRAKASH CHANDRA DASH

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ABBREVIATIONS

AEE	Assistant Executive Engineer
AIBP	Accelerated Irrigation Benefit Programme
ALOS	Advanced Land Observing Satellite
AOI	Area of Interest
BKVY	Biju Krushak Vikash Yojana
CD	Completely Dilapidated (Tanks)
CLSRP	Canal Lining & System Rehabilitation Programme
DEM	Digital Elevation Model
DRIP	Dam Rehabilitation and Improvement Project
EE	Executive Engineer
GIS	Geographical Information System
GoO	Government of Odisha
GPS	Global Positioning System
HYV	High Yielding Variety
IMD	India Meteorological Department
IWMI	International Water Management Institute
JE	Junior Engineer
JICA	Japan International Co-operation Agency
MIP	Minor Irrigation Project
MNREGS	Mahatma Gandhi National Employment Guarantee Scheme
OCTDMS	Odisha Community Tank Development & Management Society
OCTMP	Odisha Community Tank Management Project
OIIAWMIP	Odisha Integrated Irrigated Agriculture and Water Management Investment Programme
OIIPCRA	Odisha Integrated Irrigation Project for Climate Resilient Agriculture
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PD	Partially Dilapidated (tank)
PP	Pani Panchayat
PUT	Panchayat Union Tanks
RIDF	Rural Infrastructure Development Fund
RR&R	Repair, Renovation, Restoration of water bodies
SOI	Survey of India
UTM	Universal Transverse Mercator
WB	World Bank
WGS	World Geodetic System
WUA	Water Users Association

CHAPTER I

INTRODUCTION

1.1 Introduction

Development of a region is contingent on a range of diverse factors. Resource endowment is one of such crucial factors, which to a large extent determine the trajectory of development of the area. Such resource may refer to relatively static natural resource endowments as well as the largely dynamic human resource endowment of the region. The nature and interplay of these components produce characteristic development scenarios. Further, the level of development of a region can be understood as the results of the typical interplay of the forces of nature and human actions. Based on various combinations of these two set of factors, the attainment of development of different regions can be characteristically different. Any serious attempt to understand development thus requires the identification, interactions of these forces. This in turn helps one devise effective intervention plans/strategies to pursue a desired development path for the region. The Ong river basin with its eccentricities has been considered for a detailed study to understand the challenges it faces as a region, which natures poses to it and the range of human endevours advanced in its course of development.

1.2 Rationale for selection of the study area

The selection of the basin has been necessitated by the following reasons; in the overall general development, Ong river basin has been a constant laggard for a considerable period of time. This calls for further analysis at the regional level. For quite a long time, the basin has been facing problems of recurrent drought like conditions which many a times aggravates to result in farmer's suicide, a regular phenomena of late. Despite this, the region attracts much less attentions from both the activists as well as the academics. Many of its problems are not very different, either in their scale or in gravity, from those of the nearby KBK region that constantly creates lots of hues and cries, pulling in policy makers and researchers.

This is partly because of the fact that in any district level analysis, where KBK portrays abysmal conditions, Bargarh district, that contains a substantial area of the Ong river basin, does relatively much better. However it is important to note that, there are 12 blocks in Bargarh district, out of which 6 blocks fall in the Hirakud Canal command Area (HCA) with higher productivity and better scores in developmental parameters, where as in the rest 6 blocks which fall under the Ong river basin, there is no major irrigation project with reliable and assured irrigation facilities. The result is that, these 6 blocks under Ong river basin have greater resemblance with the conditionality of nearby notorious KBK districts. This calls for a more detailed regional study of the area concerned.

Another feature that seeks one's attention is that though the topography of the region is highly undulating, the dominant crop cultivated in the basin is rice, a crop for which levelled land is a pre-requisite. Thus, the transformation of naturally undulating topography to a flat bedded paddy field needs to be thoroughly deliberated upon in terms of their challenges and efficacy.

It's not only topography but also the climatic conditions of the area too imparts heightened risks to rice cultivation, with high water-sensitivity, on a large scale in view of the absence of assured irrigation due to lack of any major/medium irrigation project in the area, as already mentioned previously. This calls for a regional scale analysis of the extent of risk and the extant mechanisms for the redressal of such risks.

All these peculiarities and an utter absence of any substantive study at the regional scale study at the basin level make a compelling case for studying the Ong river basin for better understanding and interventions for regional development.

1.3 Background and Literature Survey

A considerable share of working population in the study area is engaged in subsistence agriculture, with many of them live on a minimal standard of life. The typical challenges to agriculture like out dated agricultural techniques, lack of infrastructures, marginal use of modern inputs, inappropriate and underuse of fertilizers etc. (Rao and Gulati, 1994), etc. afflict the region. Any change in the agricultural scenario, will thus expose a majority of the farmers with huge negative welfare implications. As already pointed out, of late the area has witnessed recurrent farmers' suicide cases year after year. Incidences of drought is nothing new in the state of Odisha, but what has captured the attention of late has been a clear spike in the number of farmers suicides. The challenges posed by erratic monsoon coupled with absence of a reliable source of irrigation has made western Odisha, of which a larger area coincides with the Ong river basin, vulnerable to drought like condition for quite a long time. "During the first decade of the 21st century, quite a few farmers' suicides were being reported mostly from the drought prone districts in the state -- Sambalpur, Bolangir, Kalahandi and Bargarh -- in its western part. But in 2009, a severe drought, accompanied by a caterpillar pest attack, took a heavy toll on the farmers. More and more news about farmers' suicides started appearing in the media. More than 50 farmers committed suicide in the year. Two years later, 2011 also proved to be a drought year leading to farmers' suicides. Till this time (2014), most of the suicides were restricted to western Odisha; 2015 saw the most widespread drought in the state, when 27 of the 30 districts were affected and the number of farmers who committed suicide shot up to 200. However, in 2015 too, the maximum number of farmers who killed themselves were from western Odisha" (Indo-Global Social Service Society, 2017). "Statistics released by the State Relief Commissioner's (SRC) office reveals that Bargarh was one of the worst hit district " that covered all the blocks falling under Ong River basin. (Orissa Post, 2017: Oct 24).

It is important to note here that, the region has been facing serious challenges for quite long. "Lack of irrigation forced farmer suicides as most of those who committed suicides were from rain-fed areas (IGSSS, 2017)… while the Government feels that it is difficult to attribute to this phenomenon (suicides) to only farming and have cited other reasons and evidences, media, civil society and farmer leaders attribute the agrarian crisis to this spate of suicides in 2015. State Special Relief

Commissioner on 29th October 2016, has informed that the 41 reports of farmers' suicides received by Government from across the state, were found to be cases of 'mainly family disputes and excessive liquor consumption'. Government of Odisha does not feel that the suicide by the farmers is linked to crop failure. (Drought Assessment Report, SANDRP). It is almost a pattern that, strangest of reasons are cited by the govt. ascribing farmers suicides like family quarrels, failed love affairs, disabled children, disease burden of family members and insanity and even 'impotency.' (see Pradaeep Maharathi's reply in state assembly on 21st August 2015 or that of Dr. Radhamohan Singh's reply in the Rajya sabha on 24th July 2015). For the Govt the cause is anything but agricultural. "These denials raise a more fundamental question as to what can be termed as farmer's suicide. Further, can a farmer's suicide be labelled as such only after there is clinching proof that he committed suicide only because of crop loss or a debt burden? This has led to a definitional issue of who is a farmer? Is it a person who does only farming, does not mix farming with his family, who does not borrow for the illness of his/her family members, does not have any consumption loans even if the return from agriculture is not enough for his family to survive? That is asking for too much from the farmers and amounts to saying that the farmers are not supposed to have families and, if they do, they should not be spending on health, festivities, education of their children" (IGSSS, 2017). Similar angst is all pervasive and perhaps to not allow the Govt to take recourse in such denials, a study conducted by the Population council of India in 2018, revealed that drought like situation pushes the farmers to the wall, creates considerable mental stress and may be a trigger to commit suicide. The study quotes from an FGD, "We are not able to understand why people get psychological problems. This may be due to the drought. Today we are sitting here and discussing about this and are able to understand different aspects of drought. Earlier we could never think that due to drought a person can suffer mentally or die. Nowadays, this is happening very frequently" (Patel, 2018). Sri Lingaraj Pradhan*, Convenor of the Paschim Odisha Krushak Samanwaya Samiti, a JNU alumni and a well-known farmer leader* in the state, says that "the rate at which the cost of inputs like seeds, fertilizers, water, labour and pesticides have increased has not been matched by the selling price of paddy".

The accentuated difficulties brought about by drought like conditions or a general suppressed productivity condition, forces a lot many farmers to opt for out migration from the area in search of work as a coping strategy. There are accounts galore narrating the over-exploitative work conditions emigrant farmers have to bear at the hands of their employers. They are forced to do over work, face inhuman living conditions of the make shift huts lacking sanitation facilities. Many a times when entire families migrate, the ill effect is on children's education. In a nut shell, there is a huge impact on their physical and mental life conditions due to this. The increasing incidences of farmer suicides and the heightened vulnerabilities of the farmers make a compelling case for understanding the irrigation dynamics (structural and institutional) in the study region.

There have been many efforts undertaken by both central and state govt.s for such agriculturally difficult areas. Unfortunately, due to lack of reliable irrigation facilities, Green revolution technology sort of stopped nearby and didn't reach the region. The necessary agricultural intensification could be seen in the Hirakud Canal Command area, but none of this could be pursued in the area under Ong river basin. Agriculture under monsoonal climate regime is fraught with huge risks, various studies have shown that, an access to adequate and reliable irrigation act as an effective hedge against vagaries of monsoon. Provisions of irrigation bring in a characteristic change in the way agriculture is pursued, viz. first, cropping period lengthens- thereby increasing cropping intensity; secondly, previously uncultivated area are brought under the plough; and thirdly, many of the previously unviable crops e.g. sugarcane, rice which are water intensive find their way into the list of crops cultivated in a region. It has been proved time and again through many empirical studies that there exist substantial differences in the productivity and cropping intensity between irrigated and unirrigated land (Kerr, 1988; Dhawan, 2002). With its burgeoning population, India has, thus, consistently given a greater emphasis to irrigation development (Thorat, 2000) under successive five year plans, primarily focussing on the expansion of large irrigation infrastructures. But despite these efforts so far only 40% of the cropped area has been brought under irrigation at the national level, which point to inadequate investment in irrigation. Further, post 1980s, there was witnessed a depressed government expenditure in the irrigation sector, resulting in the deceleration in the irrigation potential created through major and medium irrigation projects. Due to fund crunch, there was witnessed a thinning of resources over the numerous canal irrigation projects, with a substantial share of resource being spent on the salaries of the government department personnel looking after these big projects (Raju et al., 2004, World Bank, 2008).

In contrast to the canal irrigation from Major and medium projects, tank irrigation under minor irrigation schemes requires lower spending on man power looking after them, as in many cases they are primarily managed by the users at large. Tanks largely found in the central and southern Indian states of Maharashtra, Karnataka, Madhya Pradesh, Chhattisgarh, Odisha, Andhra Pradesh, Telengana and Tamil Nadu too witnessed some kind of decline in their maintenance primarily due to their negligence. This occurred largely after they got transferred from the local users to the governments in most cases (Sengupta, 2000). Negligence of tank maintenance by the users reduced the storage capacity of the tanks and subsequently reduction in area irrigated as well as farm yields. Such decline in irrigation in tank irrigation led many farmers to opt for bore well irrigation in a big way in many parts in the country.

In the Ong river basin, there are no large and medium irrigation projects, and tanks are the focus of the present study. Compared to large irrigation projects, tanks are less capital-intensive and have wider geographical coverage. In the study area, there are innumerable small tanks providing dispersed water storage in many villages. As per the estimate of the All India Report on Agricultural Census (1990-91), the area irrigated by tanks accounted for about 10% of the net irrigated area among marginal farmers, where as it accounted for only about 3.5% among large farmers. Thus, tank irrigation is crucial for small and marginal farmers who are largely dependent on it. Continuous decline of tank irrigation has affected in the most negative way to the resource poor farmers as they can't afford alternative source of irrigation i.e. bore well (Janakarajan, 1993; Palanisami and Easter, 2000; Palanisami and Meinzen-Dick, 2001).

As already noted, declining tank irrigation system pushes farmers to go for bore well irrigation, whenever and wherever they can afford it. Borewell irrigation has certain relative advantages over tank irrigation in that, farmers overcome the issue of uncertainty and inadequate water supply. Another big advantage that bore well provides is the timing of irrigation. However, all these advantages are valid for farmers shifting from tanks to bore wells, only in the short run. In the long run, many of these advantages give rise to a complicated scenario. As Dhawan (2000) suggests, owing to the nature of groundwater, the following problems crop up; a. "since ground water is an open access resource in India, large and financially better off farmers are incentivised to extract proportionately more water leaving less for the other farmers", b. increased competitions amongst farmer to draw more water lead to lowering of water table and the cost of drawing water increases, increasing the overall cost of cultivation making farming economically unsustainable, c. in still longer run, significant drop in water table also makes farming ecologically unsustainable, initially for the marginal and small farmers but ultimately for the large farmers as well. Beyond all these effects, a huge collateral damage that bore well irrigation inflicts on tanks irrigation is that, the farmers who shift from tanks to borewells, do not contribute to the maintenance of the tanks, setting in the process of their further decline, as more and more farmers opt for well irrigation. So left to its own, an initial minor neglect of tanks sets in a process that takes it to its ultimate demise. Not only that, complete dilapidation of tanks in a locality also greatly diminish the scope for ground water recharge (because tanks are also sites for water recharge), that threatens the availability of ground water for bore wells too (Chowdhury and Behera, 2018). Thus, one can say that, even if tanks may not be great in terms of their economic efficiency, they definitely go a long way in serving for overall ecological efficacy for a water scarce region. Thus, the revival of tanks is not a matter of some choice, but it's a matter of great necessity. Realising this, the Odisha state government has taken various initiatives concerning their revival and for better maintenance like, handing them over to Water Users Associations (or Pani Panchayats), or through introducing special purpose vehicles like Orissa Community Tank Management Programmes (OCTMP) etc. Such efforts need to be assessed in so far as their efficacy to achieve their objectives. In the present study such assessment has been undertaken from a geo-environmental perspective. Usually, Geo-environmental studies mainly focus on the pollution occurring underground, be it of soil or water resources, mostly conducted by civil engineers and environmental engineers. However, in this study, the term geo-environmental has been used in its broadest sense to refer to all those endeavours undertaken by man altering the existing local geo-environment. Thus, making difficult terrain usable through structural interventions along with institutional innovations have been recognized as geo-environmental innovations inviting the attention of the reader. Similarly, geo-environmental assessment would thus pertain to the study of characteristic natural environment and identifying and understanding the associated advantages and disadvantages emanating from it; the assessment further extends to anthropogenic measures in pursuit of harnessing the inherent benefits provided by nature as well as measures undertaken by human being in an effort to overcome the disadvantages thereof; all through these pursuits, emphasis would be placed on assessment of environmental and institutional dimensions of human endeavours.

1.4 The study Area

Ong river is one of the important right bank tributaries of the river Mahanadi. It originates at an elevation of 457 mt. from the southern outskirts of the North east-South west running hills situated to the west of its basin. The Ong flows for a total length of about 204 km to join the Mahanadi on its right about 11 km above Sonepur. The Ong drains an area of 4855 km^2 lying in the interior of the main sub-basin.

Geographic Location of the Sub-basin

The catchment of Ong River upto Salebhata (where the only CWC gauge site exists) covers an area of 4588 km^2 and will be the area of this study. It lies between 20°42' to 21°30' North Latt. and 82°30' to 83°45' E long. The catchment is spread over the district of Mahasamund of Chhatisgarh state and district of Bargarh, small portion of Nuapara and Bolangir of Odisha state.

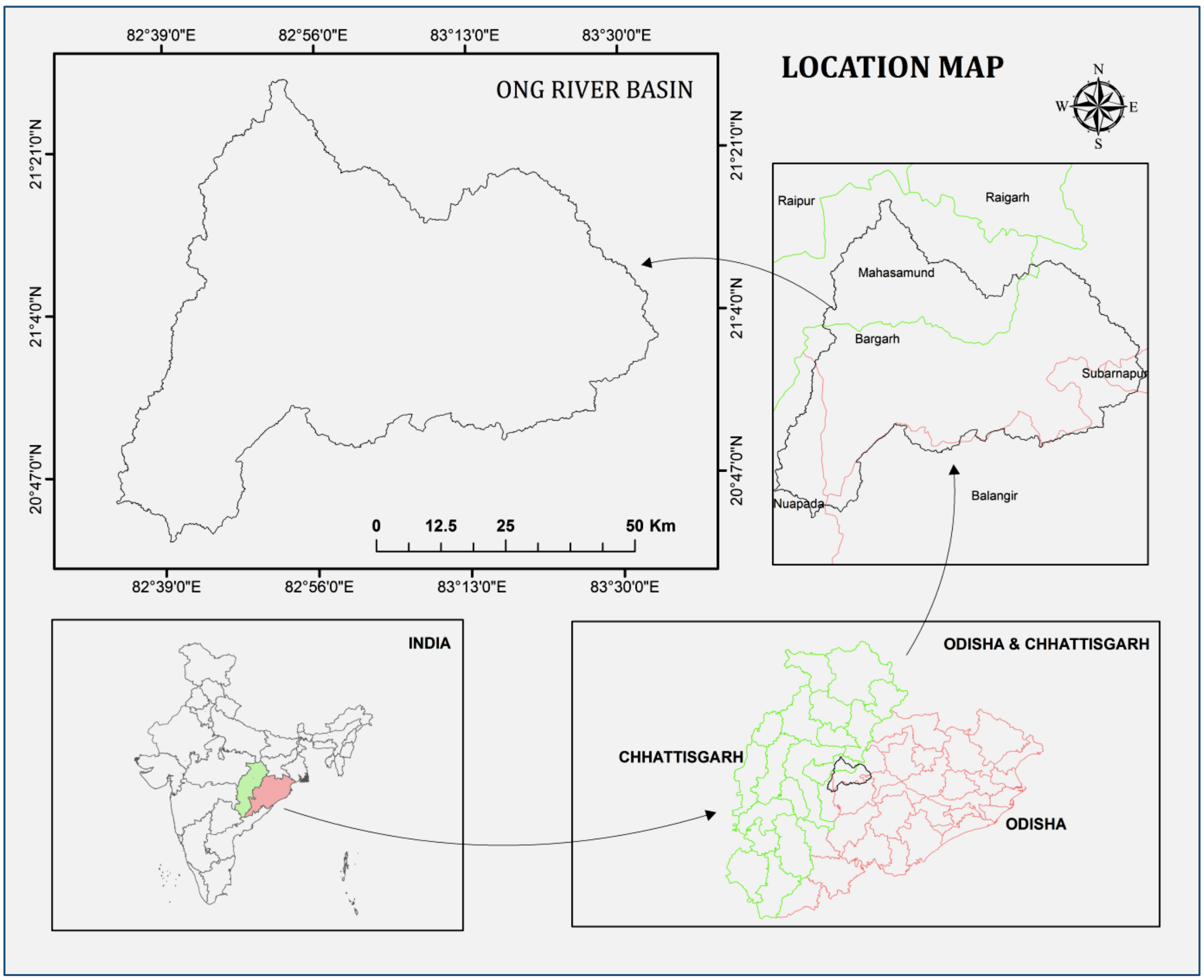

Figure No. 1 Location Map of Ong River Basin

Climate

The climate of the basin is dry sub-humid and designated as Aw i.e. tropical Savanna, hot and seasonally dry (usually winter) as per the IMD classification scheme. There are four distinct seasons in the year (i) The cold weather (ii) The Hot weather (iii) The SW Monsoon & (iv) The post monsoon. The mean minimum temperature ranges between 1° and 13.7°C whereas the mean maximum temperature ranges from 38°C over the hills to 43°C. In the plains South West Monsoon is the principal rainy season, during which most of the rainfall is received by the basin.

Soils & Geology

The General information about the soils of India indicates presence of mainly red and yellow soils. Mixed red and black soil occurs in parts of Bargarh district. The general geological sequences responsible from the present topography of the highland area are from the Archaean era to the Pleistocene age. The unclassified Crystalline, which include Granite gneisses and other magmatic rocks, are found in the Bargarh district of the region. Rocks of Gondwana system consisting of Shales, Sandstones and grit are fond in a narrow and elongated form.

1.5 Objectives of the study

1. To study and characterise the topography of the basin vis-a vis surface drainage and identify the challenges they pose to agriculture,
2. To analyse and identify the pattern of temporal variation of precipitation in the basin in relation to dominant crop(s) in the region,
3. To trace the evolution of geo-environmental innovations and examine their influence on paddy cultivation in the study region,
4. To study the institutional aspects of tank irrigations in the study area and to assess the efficacy of recent policy initiatives taken by the government for the revival of tank irrigation.

1.6 Research questions

- What is the relief characteristics and drainage characteristics of the basin?
- What is the pattern of temporal distribution of rainfall in the basin and its implication on the dominant crop in the region?

- What sorts of geo-environmental structural innovations have come up in response to the challenges posed by nature? Is there any significant difference in the way cropping is done across these structural innovations namely, *Aat, Maal, Berna and Bahal?*
- How do institutional arrangements determine the working of the irrigation systems?
- What are the recent initiatives by the Govt. for the revival of tank irrigation in the study region?
- Is there any change on equity among the farmers under different reaches in terms of access to irrigated water across sources of irrigation?
- What factors do the farmers think are behind varying equity in access to irrigation water and what are the factors that influence participation shifting away from tank irrigation to borewell irrigation?
- What factors determine the willingness to pay for community maintenance of tanks ?
- What impact have recent initiative of the government to revive tank irrigation made in the study region ?

1.7 Database

To achieve the objective of the study various secondary and primary data were collected and analysed. The various secondary data used for the study in pursuance of the first and second objectives are:

- Survey of India toposheets
- ALOS Palsar data
- Monthly Rainfall data collected from IMD Pune,
- Daily Rainfall data collected from Sub Collector's office, Padampur

Similarly in pursuance of third and fourth objectives a primary survey was conducted to collect data from 304 farms. The data so collected were analysed and relevant interpretation have been presented. Further to get the farmer's perspective on various issues related to irrigation and institutional dynamics pertaining to irrigation, ten focus Group discussions were conducted with the farmers, Pani Panchayat office bearers etc, The detailed methodologies used to process the data so collected have been presented in each chapters separately.

1.8 Organization of Material

The first chapter introduces the theme of the present study, including literature survey. Objectives are listed along with type and source of the data used and methodology used in the study.

Second chapter presents the analysis of the topography of the area expressing them in quantitative parameters through morphometric analysis of the river basin. The repercussion of the undulating nature of the basin has been highlighted, which has led to the geo-environmental innovations in the basin.

The third chapter deals with analysis of precipitation in the basin. Basically, the pattern of temporal variation of rainfall has been presented. An effort has also been made to understand the occurrences of dryspells during the dominant crop (rice) growing period.

In the fourth chapter, it has been attempted to understand the effect of geo-environmental innovations on the economic rice cultivation using the primary data collected from the farmers in the study area. The explanation uses the findings of statistical data analysis and those of the FGDs with the farmers.

The fifth chapter presents an analysis on the institutional aspects of tank irrigation. This has been done by critically evaluating the provisions of the prevalent act that decides the current institutional arrangement, namely Odisha Pani Panchayat Act. Further, it goes on to understand the efficacy of the act in improving or not in the irrigation water delivery to the farmers in the study area.

The final chapter summarises and concludes the present study.

Chapter II

MORPHOMETRIC CHARACTERISTICS OF THE BASIN

2.1 Introduction

Morphometry was first developed by Horton (1945) and was later modified by Strahler (1964). In geomorphology, the term morphometry is used to refer to the measurement and analysis of landform characteristics which influence the hydrological functioning of watershed (McCullaugh, 1978). "Quantitative analysis of drainage system is an important aspect of characterization" of drainage basin (Strahler, 1964). "Drainage pattern of a region provides information to understand slope, inequalities of rock hardness, structural controls, recent diastrophism, geological and geomorphic history of the drainage basin" (Thornbury, 1967). Interrelationships among topography, altitude, resistance to the constituent rocks, percentage of vegetative covers, presence of soil cover and their distribution over space and time, and govern the evolution and present state of the drainage basin (Zavoianu, 1985). Morisawa (1968) analysed the effect of different parameters and found a negative correlation with rainfall runoff ratio. The "drainage morphometry has been carried out in attempts to develop relationships among drainage basin parameters, viz. basin shape, sub-soil material, infiltration, relief characteristics" (Iqbaluddin, 1997) and runoff characteristics (Zernitt, 1932; Boulton, 1965). Mishra, Satyanarayana, and Mukherjee (1984) have studied the "effect of different topo-elements such as area, drainage density, form factor" etc. while trying to explain land forms (Biswas, 1999).

A growing demand for water resources from agricultural, environmental, industrial and domestic sectors, along with a rapidly urbanizing society necessitates a scientific approach to water resource management. Drainage basins are deemed to be the ideal hydrological units for the purpose of planning for conserving the land and water resources. With the increase in the opportunity costs of water, Rajagopal (2007) opines that "management of water resources and their allocation among competing demands assumes vital importance, and consequently demand management must indubitably receive preference over traditional supply management." Remote sensing, integrated with GIS, has proved to be the most effective approach in morphometric analysis of a watershed. Thiruvengadachari (1981) "discussed the importance and application of satellite remote sensing in the study of drainage patterns of the Indian sub-continent" (Srivastava, 1997). In an exhaustive study in the mountainous region of Dehradun district, strong relationship between various morphometric and hypsometric parameters on the one hand and the evolution, characteristics of underlying rocks and peak run-off on the other hand have been established (Nautiyal, 1964). Quantitative analysis of watershed geomorphology through the use of remote sensing products as inputs has been carried out in the arid region of Rajasthan (Singh, 1995), results suggest that the geomorphic variables are, by and large, significantly correlated to each other. Biswas, Sudhakar and Desai (1999) prioritized nine watersheds of Midnapur district based on morphometric parameters along with using sediment yield index model. Studies suggest that "morphometric analysis could be used for prioritization of watersheds even without the availability of reliable soil maps of the area under study" (Biswas et al., 1999) and further concluded that the top most priority of the sub watershed is the same. Debnath and Sitapathy (2001) studied *Gai* river sub "watersheds on the basis of morphometric parameters and land use" characteristics and further concluded that a sub watershed coming under priority one "based on land use and land cover" parameters and prioritization based on the morphometric parameters are the same (Akram, 2011). The morphometric analysis of the surface drainage was carried out for four micro watersheds of Bharatpur districts, Rajasthan. The morphochronology of landscape evolution has been described by Iqbaluddin, Saif, and Javed in 1997. The drainage pattern of Jharia region has been mapped and interpreted to relate it with "terrain and slope characteristics of the basin and sub basins" (Srivastava, 1997). Agrawal et al. (1993, 1997) reported that "geology and lithology play an important role in the development of drainage density and drainage frequency". Based on the drainage pattern from aerial data, the "scope for artificial recharge and deep ground water exploration" can be recommended (Agrawal, 1998). The "morphometric analysis of the river basin and its channel network play crucial role in understanding the geo-hydrological behavior of drainage basin and expresses the prevailing climate, underlying geology, associated geomorphology, structural aspects and other characteristic of the basin. The relationship between various drainage parameters and the aforesaid factors are well recognized" and widely studied (Horton, 1945; Strahler, 1957; Melton, 1958; Morisawa, 1959. Liaqat, 2015). Greater availability of remote sensing products alongside powerful Geographical Information System (GIS) platforms to handle such data quite efficiently and with faster speed has sort of revolutionized the study and understanding of the "morphometric properties of the river catchment area and surface drainage characteristics of many river basins" (Nayar and Natarajan, 2013) for the parts of the earth for which such data is available (Krishnamurthy et al., 1996; Nag, 1998; Agarwal, 1998; Pakhmode et al., 2003; Das and Mukherjee, 2005).

In an effort to describe the morphology of the Ong river basin and to understand the inherent relationships among them, morphometric characteristics of the basin has been analysed through various parameters and are described below. The objective of doing morphometric analysis is not to prove any hypothesis, rather to cater to the second objective of the study i.e. to undertake a study of the physiography of the basin, especially the topographical variation of the same, so as to assess the challenges topography pose to agriculture.

2.2 Morphometric Study of the Ong Basin

Morphometry in a generic sense refers to the "measurement of shape or geometry of any form, it may be a plant, animal or relief features" (Strahler, 1975).Morphometric analysis is preferred over other descriptive analysis as it provides a clear representation of the physiography of the area in a quickly verifiable quantified form. For segregating a region into certain homogeneous physiographic sub-regions morphometric analysis comes in as a handy tool. It's important to note that spatial variation of physiographic environment tend to influence the socio-economic activities like agricultural expansion, settlement pattern, development of transport network, urban development, industrial development and hence overall regional development of any region. In this backdrop, morphometric analysis has been undertaken for the Ong river basin.

2.3 Data and Methods

For the purpose of generating and analysing the surface Morphometry of the study area, GIS technique has been used. Satellite Imageries and Survey of India toposheets of the study area have been used as the data base for the study. ALOS-PALSAR data fortified with ground control points form toposheets and GPS waypoints have been used for generating the Digital Elevation Model (DEM) of the area. The DEM generated data have been verified and enhanced for accuracy with the Survey of India Toposheets. At 1: 2,50,000 scales, four toposheets viz. 64 K, 64 L, 64 O, 64 P covers the study area while at 1: 50,000 scale total fourteen toposheets viz. 64k/16, 64-L/9, L/10,L/14, 64-O/3, O/4,O/7,O/8, F44Q/12, F44W/13, F44-X/1,X/5,X/9 and X/13 cover the entire study area. The following methodology has been adopted for deriving various morphometric parameters of the Ong river basin:

- All topographic sheets were georeferenced, mosaicked and then a subset for the Ong river basin was prepared. The DEM derived from the satellite imageries was used for the delineation of the Ong river basin at Salebhata, where the only discharge Gauge site of Central Water Commission (CWC)is located in the study area.
- The entire basin was divided into 1147 number of 2kmX 2km square grids.
- Basic parameters like stream numbers, stream lengths, number of contour crossings, the highest and the lowest value of contours in each grid were counted and measured.
- Further, above base parameters were used to identify the basin parameters for the entire study area: linear aspects like stream numbers, stream order, stream lengths, bifurcation ratio and sinuosity index; areal aspects like basin shape, basin area, stream frequency, stream density and drainage textures; and relief properties like absolute relief, relative

relief, dissection index, ruggedness numbers etc. were computed for each grid.

- The point value of each grid was interpolated for the entire basin through Inverse Distance Weighted (IDW) method.
- Further, the entire basin was divided into suitable classes and area under each class was extracted from the interpolated raster maps. The outputs were presented as various morphometric maps and graphs.

2.4 Drainage Characteristics

A thorough study and evaluation of drainage network and their pattern is essential for understanding the landform, water resource potential and the environment. The drainage pattern of Ong river basin presents interesting characteristics. Dendritic pattern of drainage is the overwhelming feature of the basin. It is characterized by irregular branching of the tributaries joining with others mostly at angles less than 90 degrees. This indicates a notable lack of structural control and the rocks in the basin are mostly of uniform resistance. Such "…dendritic pattern is commonly found on nearly horizontal sedimentary rocks in areas of folded and complexly metamorphosed rocks, especially when imposed upon them by superimposition" (Thornbury, 1969).

Major tributaries of Ong River

Ong river initiates from the south eastern slope of the Gandhamardan hill trending south-west to North-east in the west central portion of the basin. The small river gets joined by other rivulets to gradually grow in size and volume. Many tributaries keep joining with it in its course by the time it joins with the master stream the Mahanadi river near *Jharpada*. One can see from the Figure 2.1 that, Ong is a fifth order stream. Two 4^{th} order streams namely Surangi and Ong join to form this stream. The *Surangi* river originates near *Basna*, Chhatisgarh and initially flows from the north-western part of the basin coming substantially in Chhatisgarh portion of the basin from west to south-east direction till *Kusmisarar* village and from where it takes a sharp southward turn to joins with Ong near upstream of *Pujharipali* and *Kulanti* village in Odisha.

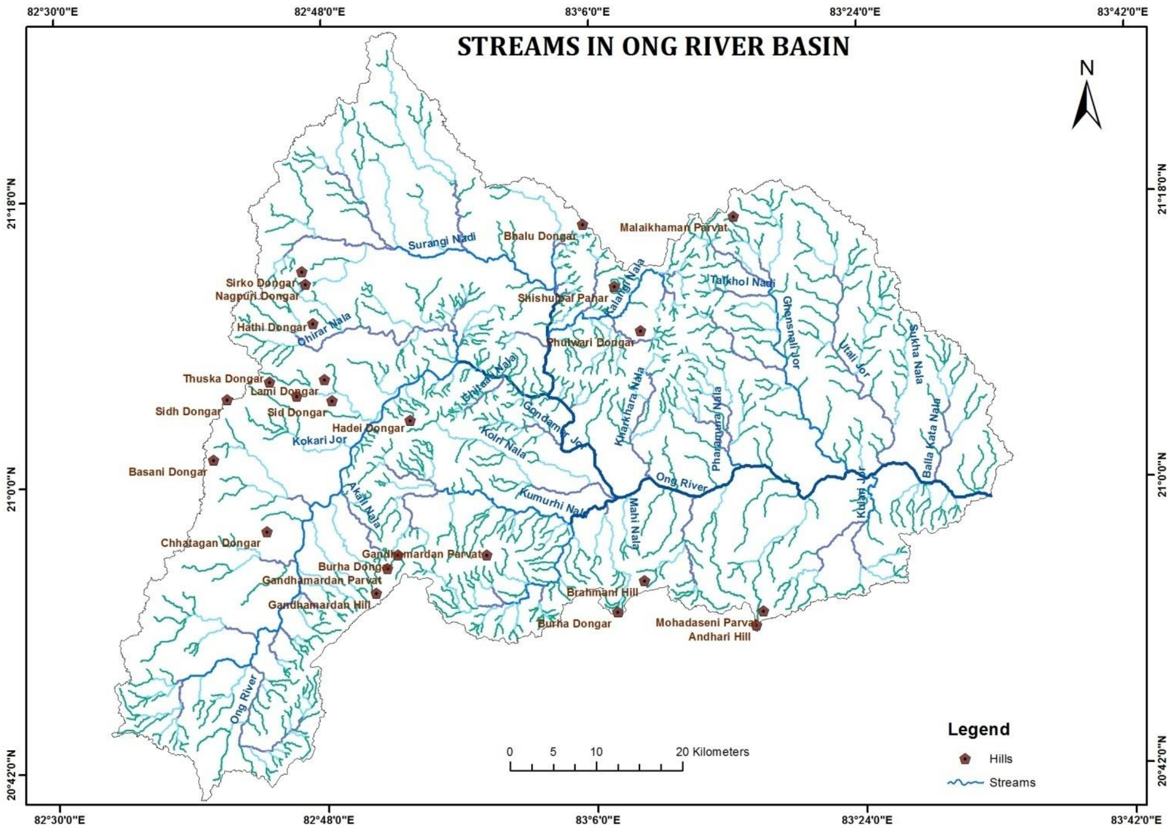

Figure 2.1 Streams in ONG River Basin

Another important river *Chirar Nadi*, a 3rd order stream joins Ong as a left bank tributary near the village *Badkanjari*, a little upstream of the confluence of *Ong and Surangi* river.

Among other major left bank tributaries joining the Ong river are Kharkharanadi (a 3rd order stream), *Dhangnasala* river, *Pheramura* river, *Ghensali nadi, Utali nadi* etc. All these rivers flow predominantly in a north to southward direction before joining the west to east flowing Ong river. *Dhangsala* river *and Pheramura* river join together to form *Mogragad r*iver which joins with Ong river near *Ganiapali* village, a village of great historical importance where many Buddhist relics have been discovered. Similarly, *Ghensalinadi* joins with Ong near the village *Banjipali*, after flowing in a north to slightly southeast ward direction.

Similar patterns has been seen with important right bank tributaries of Ong river viz. *Magranala, Kurmi river, Malkennala* and *Kurarinadi*. *Magranala* has its origin from the south-eastern flank of the Hadei dongar hill, flows in a west to east direction to join with the *K*umri nadi that flows from the south-eastern flank of the north-eastern portion of the Gandamardan hills near *Badimal* village. **B**oth *Magranalla and Kumrhi* river join together to form *Kumrhi* river which flow from south-west to north-east direction and joins with the Ong river near the village *Bandupali.* The *Kurari* nadi flows in a south to northward direction and joins Ong river near *Agalpur* village.

2.4.1 Linear Aspects

Under the linear aspects, stream order, stream number, stream length, stream length ratio, bifurcation ratio, main channel length, channel index and rho coefficient etc. have been computed and are presented below.

2.4.1.1 Stream Order

Horton introduced the method for assigning orders to streams in 1945 which was later on modified by Strahler (1952, 1964). Stream order classifies each stream reach in terms of its relation to other streams directly or indirectly. For the present study, Strahler's method has been adopted. In this method, the smallest unbranched stream is designated as the first order stream. Accordingly, these are streams which have no tributaries. As per Strahler's method, when streams of the same order join together, the next order stream is formed. Thus, the channel formed by joining of the two first order stream forms the second order and merging of two second order streams forms the third order stream and so on. In the present study, stream order has been computed using the flow accumulation and Flow direction raster derived from PALSAR DEM data. Ong River basin is witnessed to have a 5^{th} order as the highest order stream. Needless to say, this is the trunk stream through which all the water and discharge passes. It may be noted here that, the DEM derived streams indicated a very high number of first order streams in the basin. However, ground verification and cross verification through topographic base maps revealed that, many of the first order streams were actually pseudo streams. There are no real streams which existed in the course of many first order streams. They were found to be transitory channels of rainy season, which have been converted into cultivable low lying farms by the local farmers through ages of farm-scaping practices.

In fact, these low lying channel-converted-farms are the best quality of farms, largely coinciding with what is locally known as the *Bahal* land, the lowest lying farmland types classified on the basis of topo-terrain.

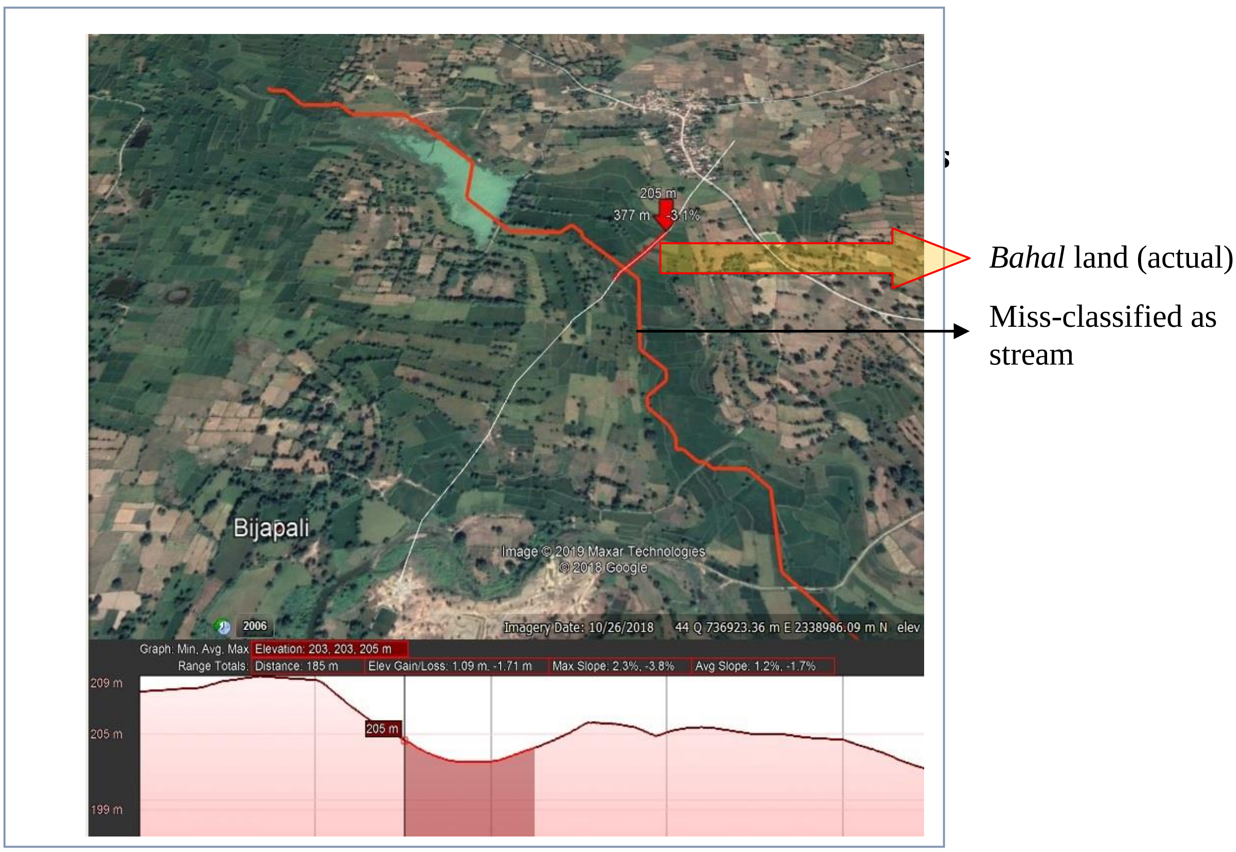

Figure 2.2 *Bahal* Land (actual) Miss-classified as stream

A ground verified miss-classified stream draped on Google Earth image is shown in figure 2.2, which as per DEM derived method is assigned as a stream, yet actually is the bed of a *Bahal* land. A detailed discussion on the topo-terrainic classification has been undertaken in the fourth chapter.

2.4.1.2 Stream numbers

Number of streams under each order was counted and is presented in the table 2.1. The number of streams decreases with an increase in the stream order which are clearly evident from the negative slope of the straight line (Figure: 2.3). The number of streams in Logarithmic scale was plotted against their order.. It can be seen that, the regression coefficient of the plot is -0.51 with the value of R square equal to 0.972.

Table 2.1 Stream Order in Ong River Basin

Stream Order(*u*)	**No of streams**(*Nu*)	**Length (km)**(*Lu*)
1	235	969.28
2	44	357.03
3	15	182.94
4	2	81.78
5	1	76.73
	$\sum Nu$ =297	**$\sum Lu$=1667.76**

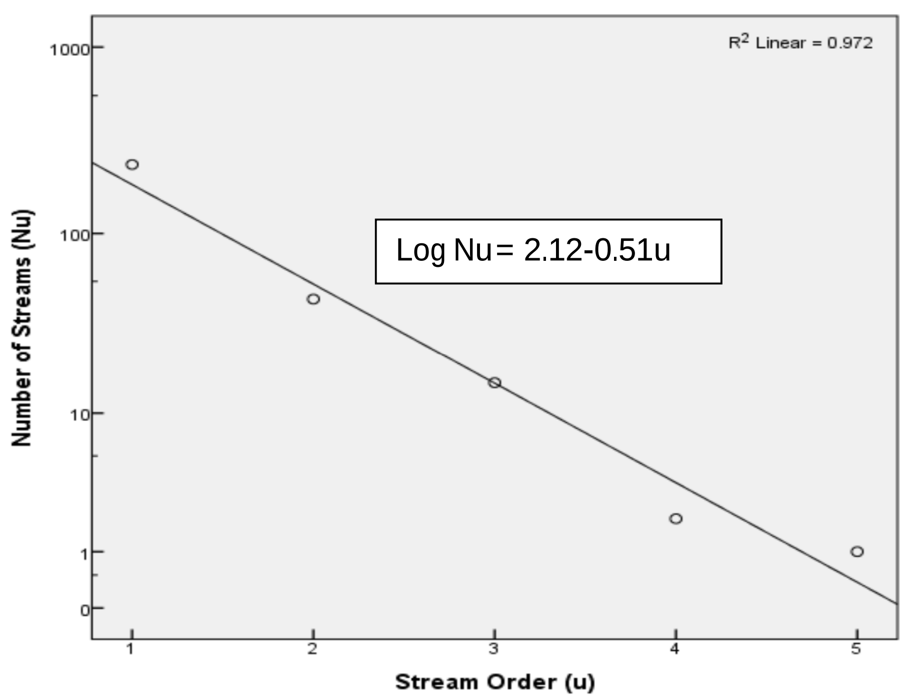

Figure No. 2.3 Stream Order versus Stream Number

2.4.1.3 Stream Length

Stream length of each order was calculated. Consequently, mean stream length was obtained by dividing the stream length (L_u) of a given order by the total stream number (N_u) of that order. Stream length ratio for each order was similarly obtained by dividing the length of a particular order (L_u) by the length of the previous order (L_{u-1}). Generally, this value of a given order is greater than that of the lower order and less than that of its next higher order. Changes in stream length ratio from one order to another is indicative of a "late youth to mature stage of the geomorphic development" (Singh and Singh, 1997). Finally, mean stream length ratios were calculated. The relationship between stream order and stream length has been plotted. The results are given in Table 2.2. One can see a linear relationship between mean stream length against stream order. It decreases as stream order increases. The coefficient of regression has been found to be -0.206 with the value of R square equal to 0.943. Further, it is quite evident that the mean stream length has positive relationship with the stream order in the Ong river basin (Figure: 2.4). Higher the value of mean stream length and also higher stream length ratio indicates that a particular order of stream is traversing relatively longer distance before merging with equal order stream to produce next higher order. Indirectly it indicates considerable proportion of the basin having nearly similar physiographical characteristics for streams to flow. A closer reference to the Table 2.2 shows a marked change of stream flow at the stream order level four.

Table 2.2 Mean Steam Length and Stream Length Ratio

Order *U*	**No of Streams** *Nu*	**Length (km)** *Lu*	**Mean Stream Length** *Lū*	**Stream Length Ratio** *Lūr=Lū+1/Lū*
1	235	969.28	4.12	--
2	44	357.03	8.11	1.97
3	15	182.94	12.20	1.50
4	2	81.78	40.89	3.35
5	1	76.73	76.73	1.88
Total	**297**	**1667.76**	--	--

Mean Length Ratio= 2.17

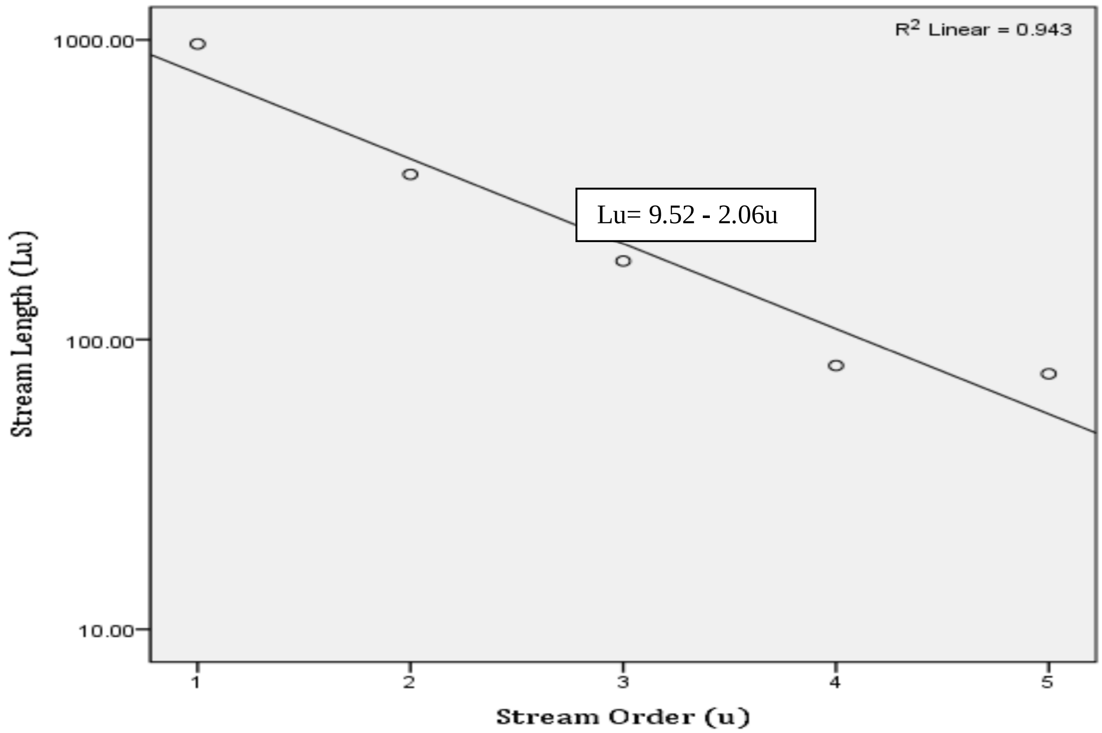

Figure 2.4 Stream Length versus stream order

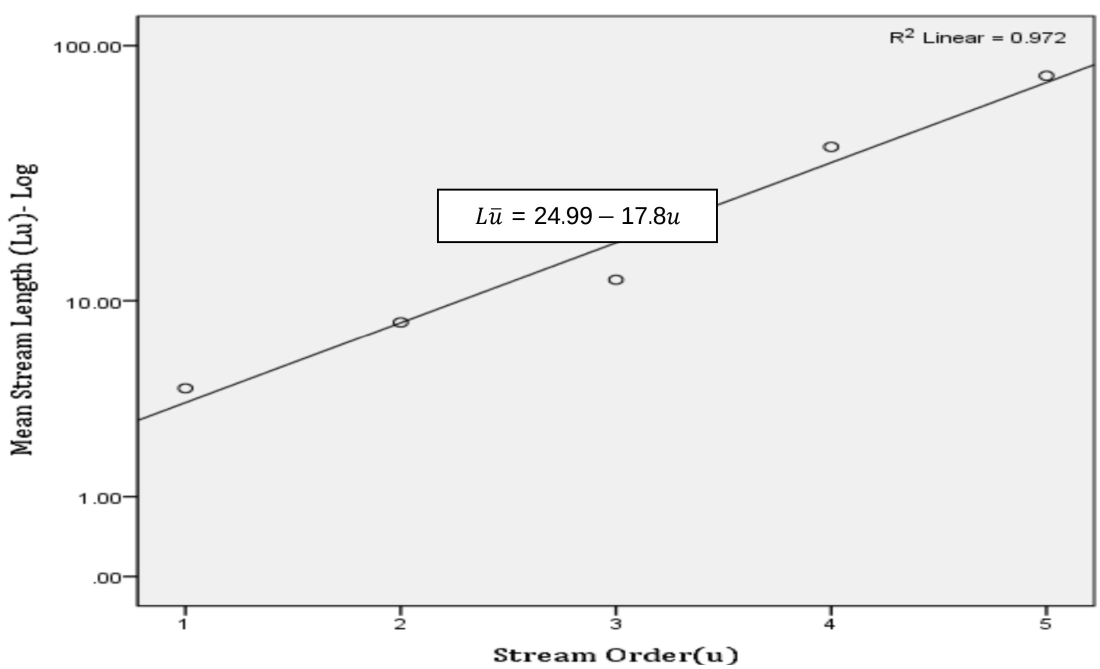

Figure No. 2.5 Mean stream Length versus Stream Order

2.4.1.4 Bifurcation Ratio

Bifurcation ratio indicates the average number of streams of a particular order which is required for the formation of the next higher order of stream. Stream bifurcation patterns or the branching pattern "vary depending upon the bedrock controls. Where uniform materials underlie the drainage basin, the streams usually branch randomly whereas the areas where folds or faults control weakness and stream development, the development of branches can be restricted to zones of fractures or weak sedimentary strata" (Nayar, 2013). High bifurcation ratios tend to signify "streams that have a higher than average flood potential" (Eash, 1996), because "numerous tributary segments drain into relatively few trunk transporting segments". The Bifurcation ratio for different order of streams in the Ong basin is given in Table 2.3. It has been observed that the bifurcation ratio characteristically ranges between 3 and 5 for river basins with somewhat homogenous geology and where the drainage basin has not been subjected to much structural disturbances, which seems to be the case for Ong river basin with a bifurcation ratio of 4.4. The Rho coefficients have also been computed for the streams by dividing the stream length ratio with the bifurcation ratios (Table 2.3). The rho coefficient (ρ) signifies the storage capacity of a drainage basin. It determines the relationship between the physiographic development of the basin and its drainage density. A high value of rho indicates risk proneness of being eroded by excessive discharge as is witnessed during flood. A close look at the Table 2.3 reveals that with the increasing stream order the rho coefficient increases indicating more susceptibility to flood in downstream region of the Ong basin. Further, the average value of the rho coefficient is also 0.57, by which it can be safely inferred that in general the Ong basin is susceptible to flood and flood based soil erosion.

Table 2.3 Bifurcation Ratio and Rho Coefficient

Order (*U*)	No. of Streams (*N*)	Bifurcation Ratio (RB)	Stream Length Ratio $L_{\bar{U}}R = L_{\bar{U}} + 1/L_{\bar{U}}$	Rho oefficient = $L_{\bar{U}}R/RB$
1	235			
2	44	5.34	1.97	0.37
3	15	2.93	1.50	0.51
4	2	7.5	3.35	0.45
5	1	2	1.88	0.94

Mean Bifurcation ratio = 4.44
Mean Rho Coefficient = 0.57

2.4.2 Basin Parameters

The basin geometry of the Ong river basin has been captured by various basin parameters viz. basin length, basin area, basin perimeter, form ratio, elongation ratio, circularity ratio, drainage texture, compactness coefficient, fitness ratio and wandering ratio etc. The results are given in Table 2.4.

Table 2.4 Basin Geometry Parameters

Parameters	Formulae	Result
Main channel length(C*l*)	$Re = 2/Lb * (A/\pi)^{0.5}$	172.95 Km
Basin area(A)	--	4571.63Km^2
Basin perimeter (P)	--	517.701 km
Basin length (Lb)	--	87.84km
Form factor(Ff)	$Ff = A/Lb^2$	0.59
Elongation ratio(Re)	$Re = 2/Lb * (A/\pi)^{0.5}$	0.84
Circularity ratio(Rc)	$Rc = 4\pi A/P^2$	0.21
Drainage texture(Dt)	Nu/P	0.57
Compactness coefficient(Cc)	$Cc = 0.2841 * P/A^{0.5}$	2.175
Fitness ratio(Rf)	$Rf = Cl/P$	0.33
Wandering ratio(Rw)	$Rw = Cl/Lb$	1.97

2.4.2.1 Form Factor

The form factor is defined as the ratio of the basin area (A) to the square of the basin length Lb. $Rf = A/Lb^2$. The value of form factor varies from 0 (in highly elongated shape) to 1(a perfect circular shape). Hence, higher the value of form factor, the more circular the shape of a basin. This value has important implication on the nature of peak flow in a river. The form factor for the basin was found to be 0.59.

2.4.2.2 Elongation Ratio

It is the ratio of the diameter of a circle of same area as that of the drainage basin to the maximum basin length. A higher value of elongation ratio indicates circularity of the basin shape and vice–versa. Strahler stated that this ratio ranges between 0.6 and 1.0, over a wide variety of climatic and geologic types. The varying shapes of a basin can be classified with the help of the value of elongation ratio. The following shapes and their ratio ranges are usually normatively associated viz. "less elongated (*<0.7*), oval (*0.9-0.8*) and circular (*>0.9*). Further, sub divisions like circular *(0.9-1.0),* oval (*0.8-0.9),* less elongated (*0.7-0.8*), elongated (*0.5- 0.7*), and more elongated (*< 0.5*)" are also used. These values are further segregated as. The Ong river basin has an elongation ratio of 0.84, thus its shape can be appropriately expressed as oval. Conversely, the circularity ration for the basin was found to be 0.21.

2.4.3 Areal Aspects of the Basin

The areal properties like stream frequency, stream density, drainage texture etc. were computed for the basin. These parameters have been computed after dividing the entire basin into 1147square grids. The results of these were then interpolated for the entire basin and were graphically presented.

2.4.3.1 Stream Frequency

Stream frequency provides important insight regarding the response of the basin to runoff process. It is defined as the number of stream segments per unit area. The occurrence of streams depends on the amount of rainfall received, the nature and structure of rock, the infiltration of rainfall through the rocks and vegetation cover in the basin. Stream frequency determines to a large extent the degree of relief fragmentation and thereby is reflective of the number of valley segments per unit area in the basin (Zavoianu, 1985). A high or low value of stream frequency in an area is the result of a complex interaction between the lithological characteristics and the quantum and distribution of precipitation in that area. Regions of highly resistant or highly permeable sub soil under vegetation cover favour development of lower drainage density (<1 km/sq.km) and low stream frequency (<1 stream/sq. km) (Strahler, 1964). The basin has an overall stream frequency of 0.065. Stream frequency has been computed grid wise using the following formula:

$$\text{Stream Frequency } (Sf) = \sum N / A$$

Where, $\sum N$ is the total number of stream segments in the grid

and A is the area of the grid.

Finally, the Sf for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

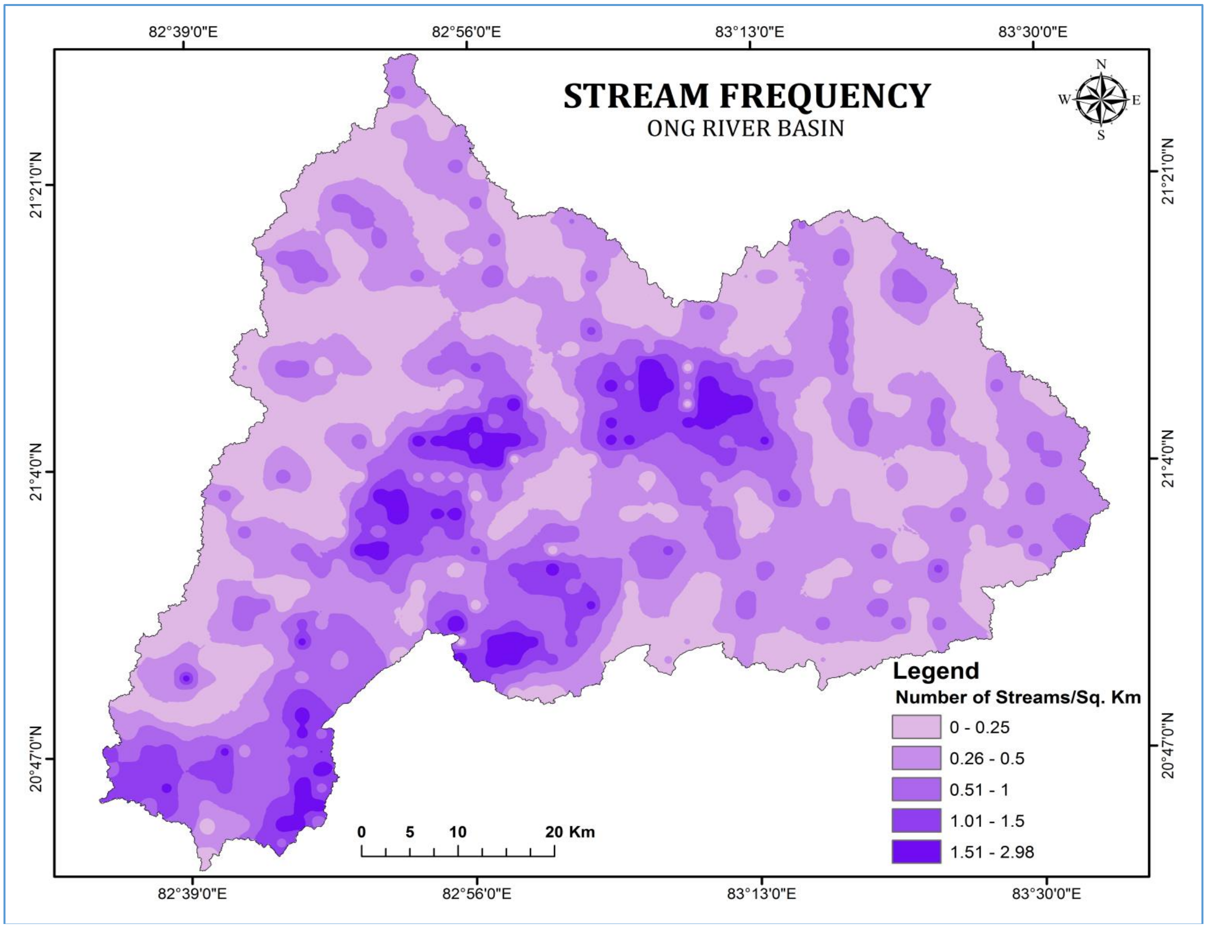

Figure No. 2.6a Stream Frequency

Table 2.5 Stream Frequency in Ong River Basin

Sl. No.	Classes	Frequency Range	% of area covred
1	Very Low	0- 0.25	33.89
2	Low	0.26- 0.5	37.31
3	Medium	0.51- 1	17.78
4	High	1.01- 1.5	8.23
5	Very High	1.51- 2.98	2.79
	Total		**100**

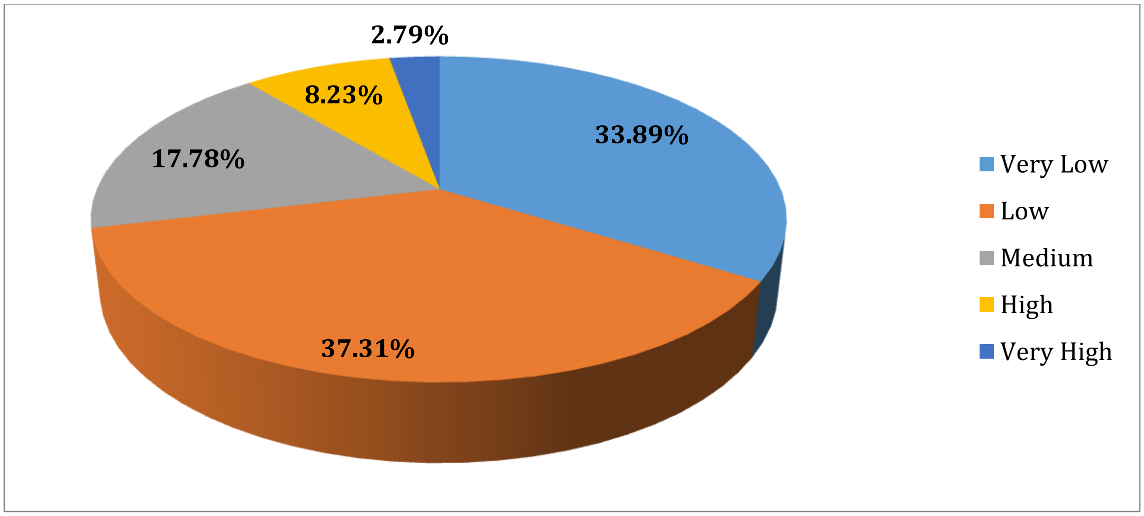

Figure No 2.6b Stream Frequency in Ong River Basin

2.4.3.2 Drainage Density

It is the ratio of total channel segments length to the basin area. "It is influenced by many factors like underlying geology, precipitation, the permeability" of the area etc. (Morisawa, 1968). "Drainage density is often regarded as one of the fundamental concept in hydrological analysis" (Yildiz, 2004). Melton (1957) established that, a higher "drainage density reflects a highly dissected drainage basin with a rapid hydrological response to rainfall events, whereas a lower value means a slower hydrological response". As per Horton (1932), "high precipitation indicates greater drainage density, while it decreases with increasing permeability" of the area concerned. Strahler (1975), "sums up all factors influencing drainage density like rock types, infiltration and vegetation cover", and suggested as rock hardens, infiltration and vegetation cover increase, drainage density tends to decline. Thus, it may be noted that, high drainage densities usually reduce the discharge in any single stream, while more evenly distributing run-off and speeding run-off into secondary and tertiary streams. Hence, it bears a very important implication in terms of determining the "time lag" between the rain fall events, especially storm events and the resultant peak flow formation. High drainage density represents a fine texture and a lower drainage density represents a coarser texture. Drainage density for each grid was computed by the following formula:

Drainage Density (DD)=$\sum L/A$,

Where, $\sum$ L is the total length of all the stream segments in a grid, in km,

and, A is the area of the grid in km^2

The basin is found to have a drainage density of 0.365 km/sq.km. Finally, the DD for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

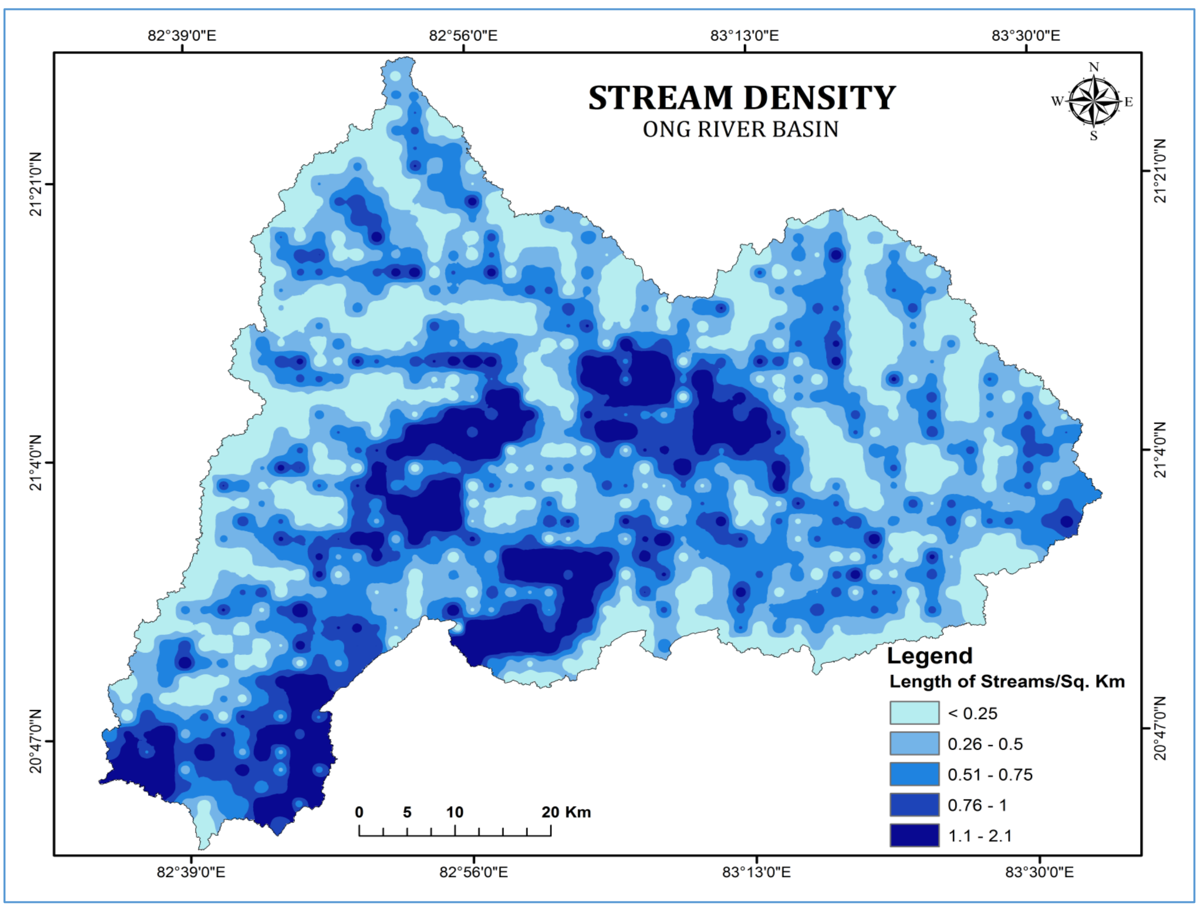

Figure No. 2.7a Stream Density

Table 2.6 Drainage Density in Ong River Basin

Sl. No.	Classes	Density	% of area covered
1	Very Low	< 0.25	25.47
2	Low	0.26 – 0.5	28.54
3	Medium	0.51 – 0.75	23.74
4	High	0.76 – 1	11.91
5	Very High	1.1 – 2.1	10.33
	Total		**100**

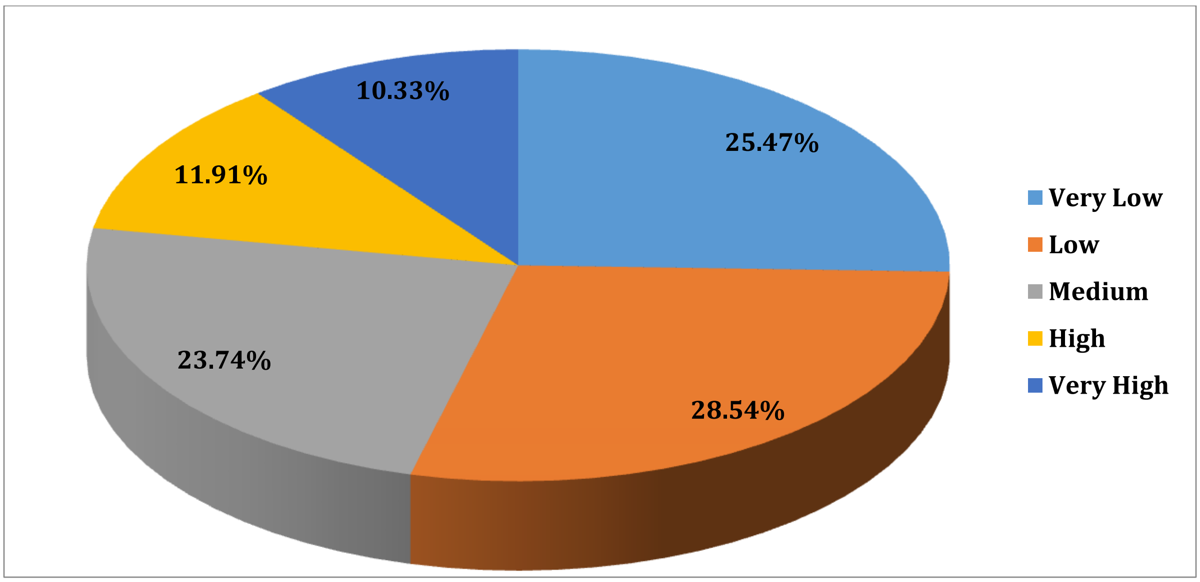

Figure No. 2.7b Drainage Density in Ong River Basin

2.4.3.3 Constant of Channel Maintenance

A morphometric index of great importance is constant of channel maintenance (CCM) which is the reciprocal of drainage density. CCM shows the area required to maintain each unit length of stream (McCullaugh, 1978). CCM for each grid was calculated by the formula:

CCM= Area of the Grid in km² / Length of stream segments in the grid, in km

The overall CCM for the basin was found to be 2.74 km^2 /km. Finally, the CCM for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

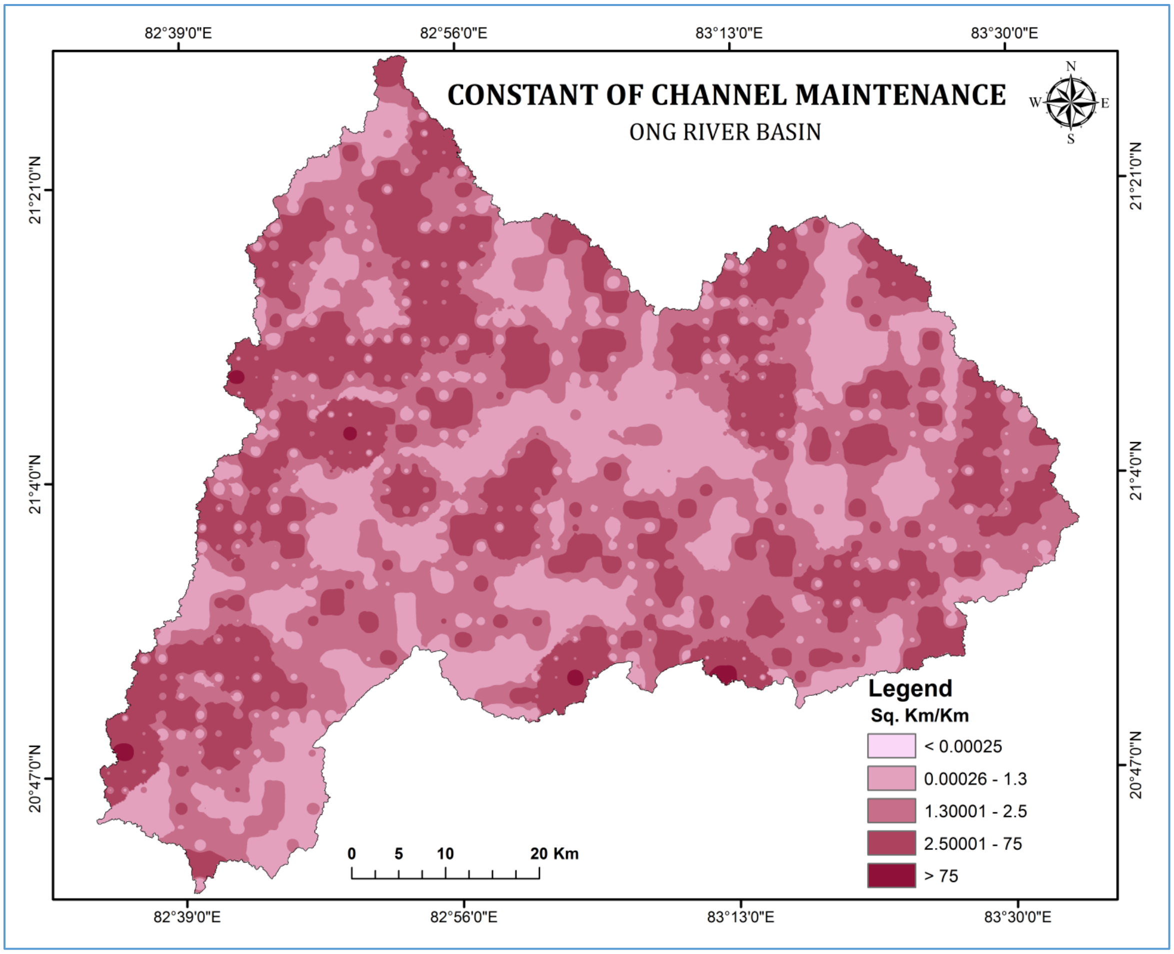

Figure 2.8a Constant of Channel Maintenance

Table 2.7 CCM in Ong River Basin

Sl. No.	Classes	CCM Range	% of area covered
1	Very Low	< 0.00025	0.00
2	Low	0.00026 – 1.3	29.26
3	Medium	1.30001 – 2.5	37.81
4	High	2.50001- 75	32.63
5	Very High	> 75	0.30
	Total		**100**

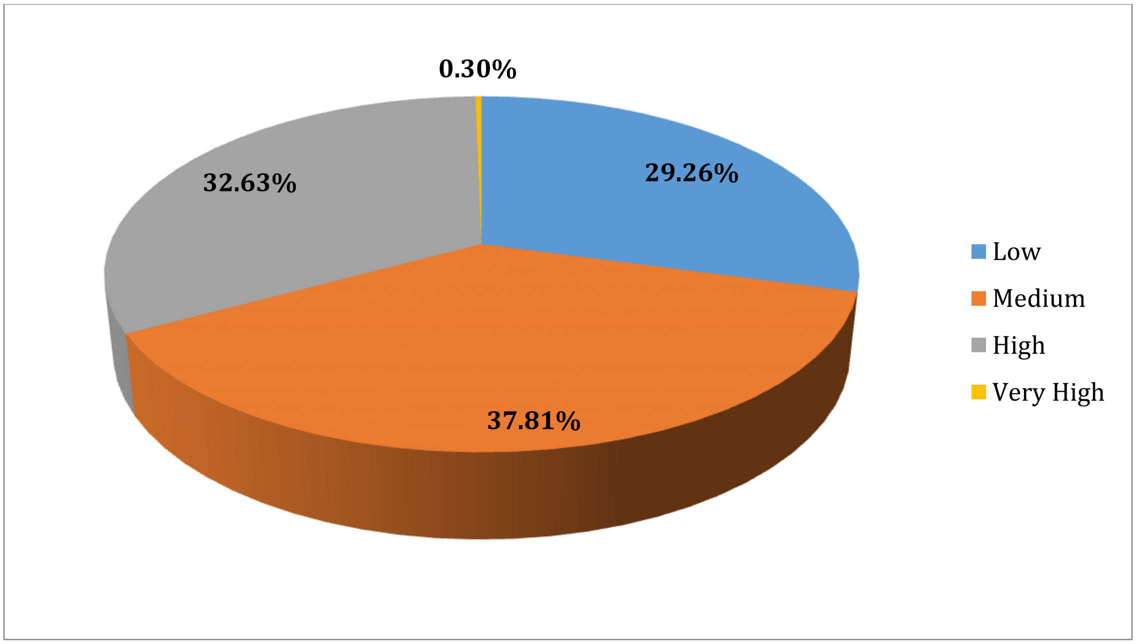

Figure No. 2.8b CCM in Ong River Basin

2.4.3.4 Length of Overland Flow

Another associated measure is the length of overland flow (OF). This term is used to refer to the length of the run of the rain before it gets into the channels. The length of overland flow is considered as a dominant hydrologic and morphometric factor and is the mean horizontal length of flow path from the water divide to the stream in a first order basin and is a measure of stream spacing and degree of dissection. Since this length of overland flow, on an average about half the distance between the stream channels, Horton (1945) defined "it to be roughly equal to half the reciprocal of the drainage density". The length of overland flow calculated thus for the Ong basin works out to be 1.37km. OF for each grid was calculated by the formula:

$$OF= 1/ 2*DD$$

The overall OF for the basin is 1.37. Finally, the OF for each grid has been interpolated over the entire basin, and the entire range divided into suitable classes, statistics generated and presented through tables and maps.

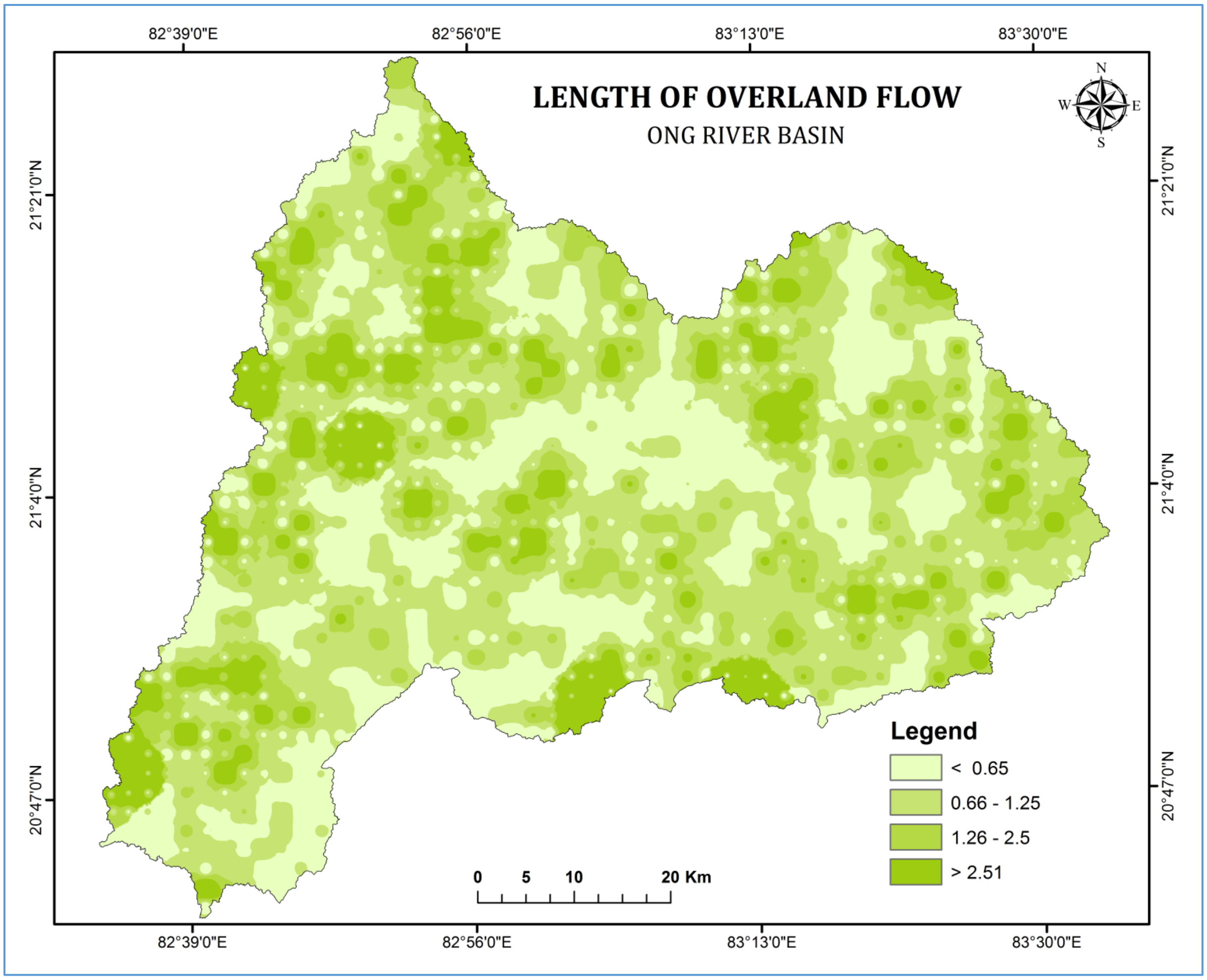

Figure 2.9a Length of Overland Flow

Table 2.8 LOLF in Ong River Basin

Sl. No.	Classes	OF Range	% of area covered
1	Low	< 0.65	37.51
2	Medium	0.66-1.25	21.64
3	High	1.26 – 2.5	21.97
4	Very High	> 2.51	18.87
	Total		**100**

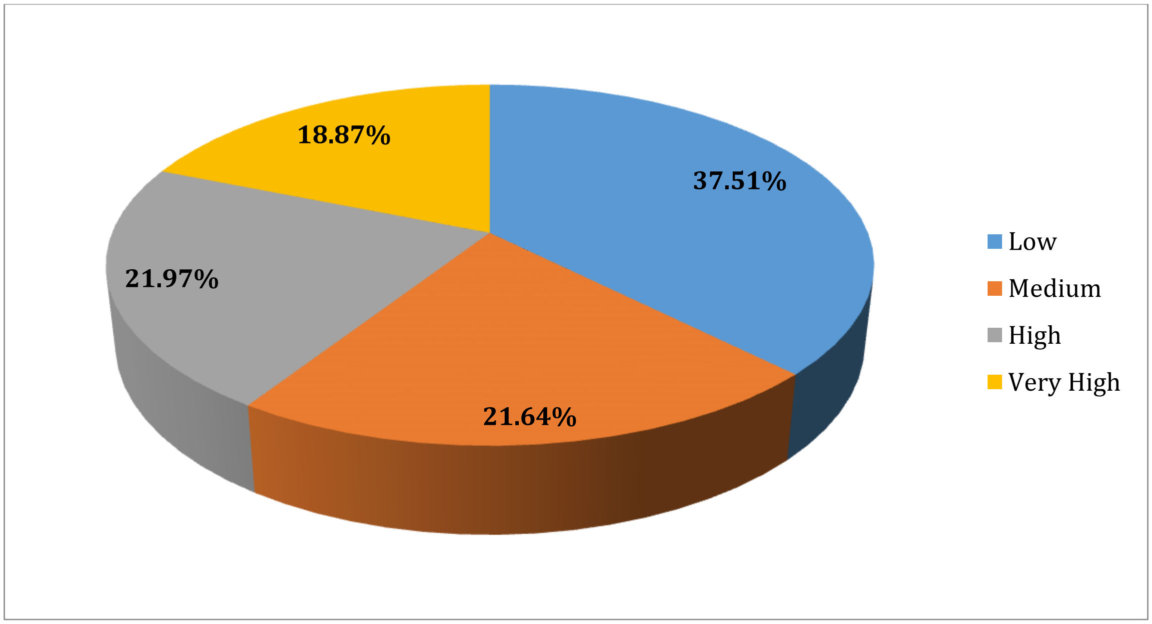

Figure No. 2.9b LOLF in Ong River Basin

2.4.3.5 Drainage Texture

Drainage texture is an important geomorphic concept and indicates relative spacing of stream segments in a unit area along a linear direction. Drainage texture was computed using the formula:

$$Dt = 1/ [(t+p)/2]$$

where, Dt is Drainage texture,

$t = [(t_1+t_2)/2]/ 2^{0.5}$

t_1, t_2= number of intersections between the stream network and diagonal 1, 2 of the grid square respectively,

and $p= (p_1+p_2+p_3+p_4)/ 4$

p_1 to p_4 = number of intersections between the stream network and the edges of the grid.

Smith (1939) classified drainage texture into five different textures i.e., very coarse (<2), coarse (2-4), fine (6-8), and very fine (>8). The drainage texture of the basin was found to be 0.57. Finally, the Dt for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

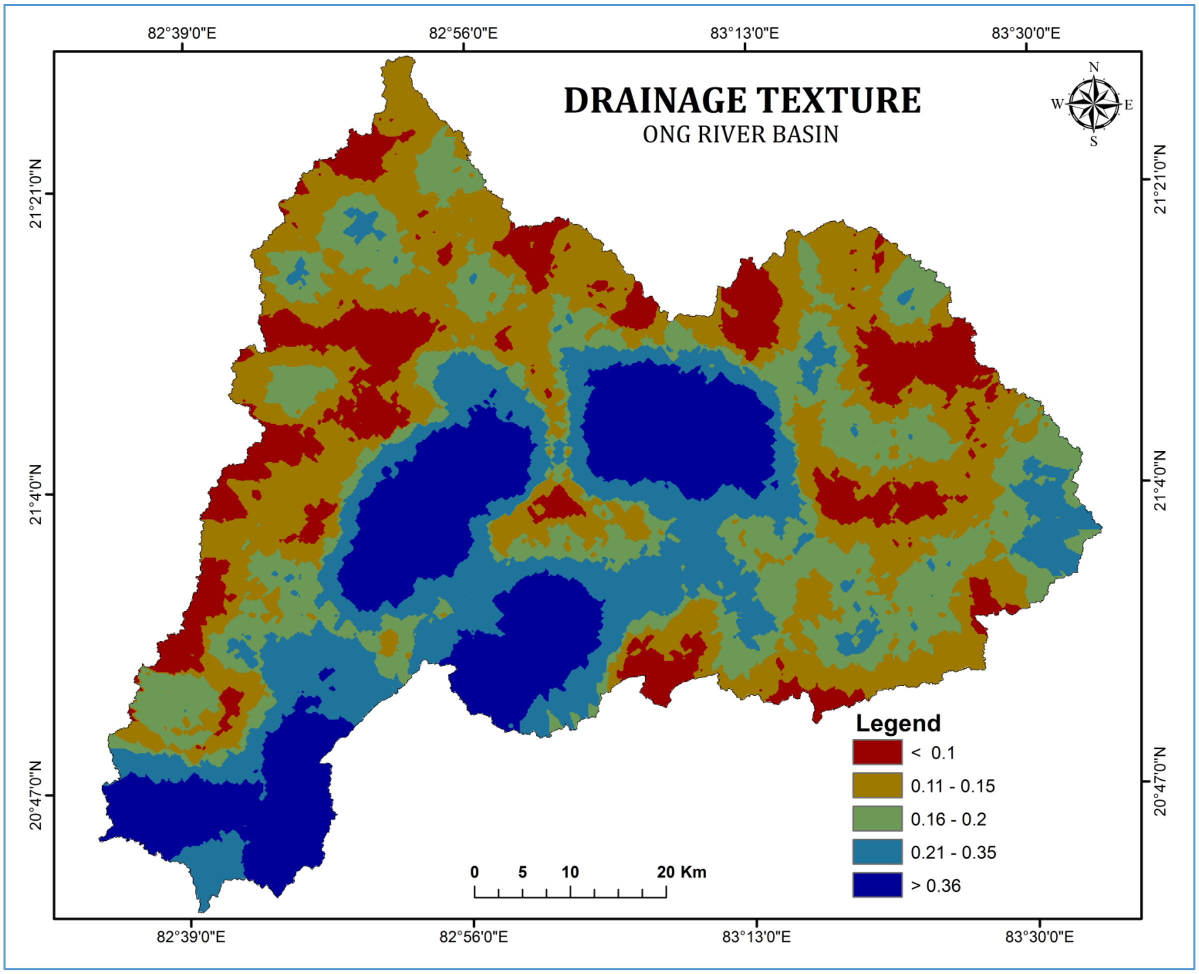

Figure 2.10a Drainage Texture

Table 2.9 Drainage Texture in Ong River Basin

Sl. No.	Classes	CCM Range	% of area covered
1	Very Low	< 0.1	12.23
2	Low	0.11 – 0.15	28.61
3	Medium	0.16 – 0.2	22.47
4	High	0.21 – 0.35	17.78
5	Very High	> 0.35	18.91
	Total		**100**

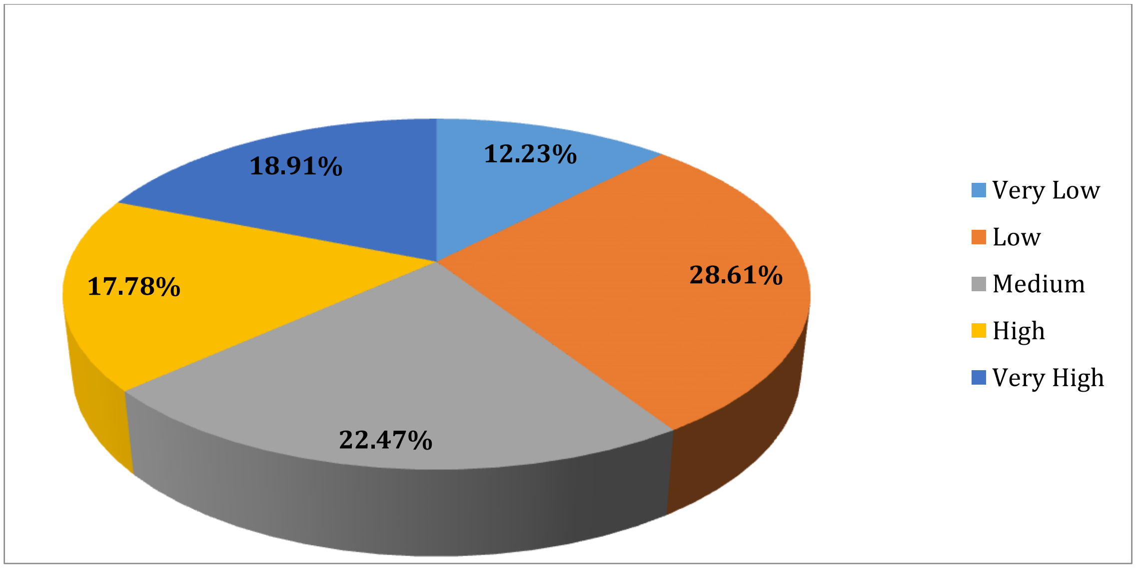

Figure No. 2.10b Drainage Texture in Ong River Basin

2.4.3.6 Infiltration Number

Infiltration number of a drainage basin is the product of drainage density and stream frequency. It provides an idea of the infiltration characteristics of the basin. The overall infiltration number for Ong river basin is found to be 0.42. The "higher the infiltration number, the lower will be the infiltration and higher will be the run-off" (Rao, Liaqat, 2011). Infiltration number was computed with the formula:

Infiltration Number = Drainage Density x Stream Frequency

Finally, the Dt for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

2.4.4 Relief Aspects

The origin of the term relief comes from latin- *relevare* meaning raise again, and from Old-French term- *relever* meaning raise up. In geography, the term thus connotes vertical inequality of land surface as a whole, or a terrain-unit wise variation of vertical dimension of the earth surface configuration. Smith(1935) states "relief is a concept intended to describe the vertical extent of landscape feature, without reference to absolute altitude or to slope. There seems to be no universally accepted unique definition of relief but its most common measure is the range in altitude of different sections in the area of interest. Durry (1951), for example, relates relief to depth of dissection, the difference between the summit surface and the stream-level surface. However, there lies considerable variation between these two surfaces as well. Thus, relief has to be expressed in terms encompassing these intermediate variations too.

Relief properties are important variables useful for mathematical expression of terrainic variation of a river basin. Under relief properties, the dynamics of vertical dimensions of the topography have been evaluated. Here, the relief aspects have been expressed through absolute relief, relative relief, dissection index, ruggedness index and average slopes etc.

2.4.4.1 Absolute Relief

Absolute relief reveals the elevation of any area above the sea level and is a function of the constructive and the de-constructive forces at work. It also indicates the potential energy available with the lithological materials in the area concerned. The analysis of absolute relief generally includes the identification of altitudinal zones. For the Ong river basin, the absolute relief (AR) within each grid was computed with the help of contours, spot heights and triangulated heights. Finally, the AR for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

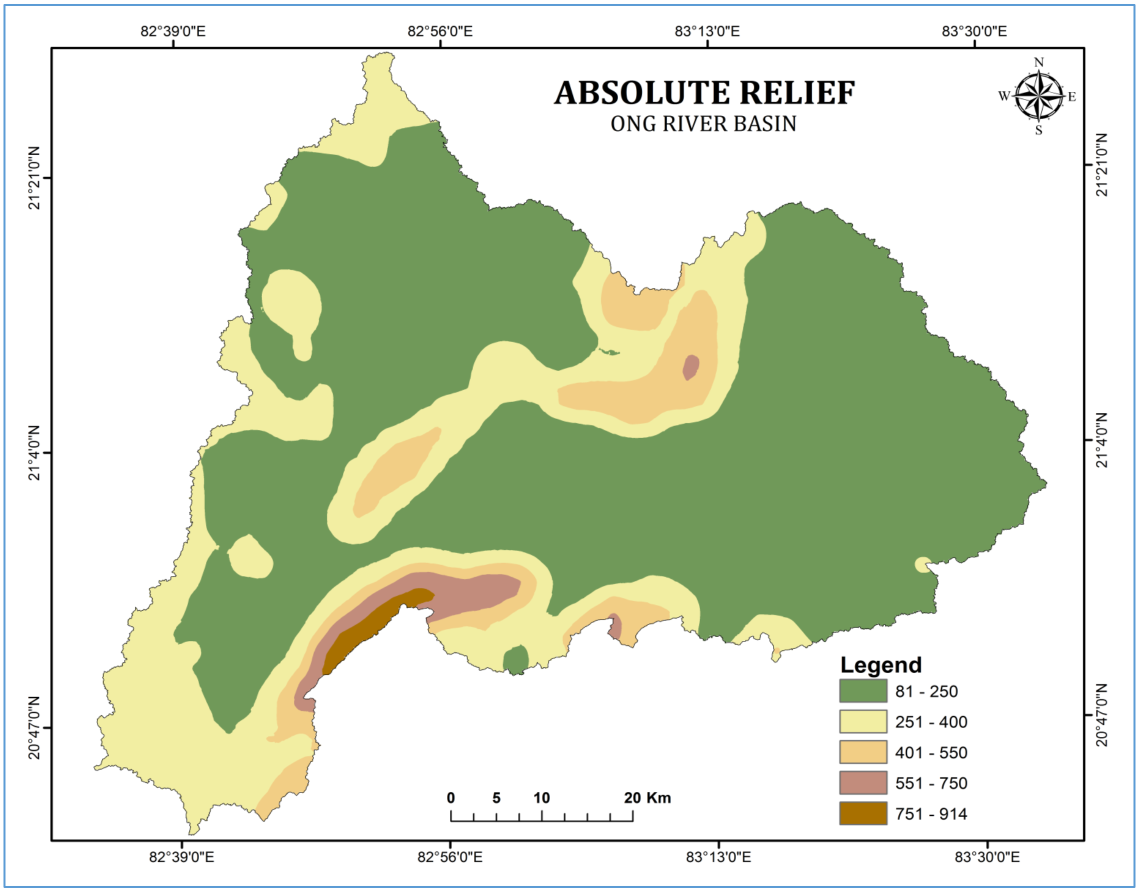

Figure No. 2.11a Absolute Relief in Ong River Basin

Table 2.10 Absolute Relief in Ong River Basin

Sl. No.	Classes	AR Range in Meters	% of area covered
1	Very Low	81 – 250	66.42
2	Low	251 – 400	24.43
3	Medium	401 – 550	6.77
4	High	551 – 750	1.76
5	Very High	751 - 914	0.62
	Total		**100**

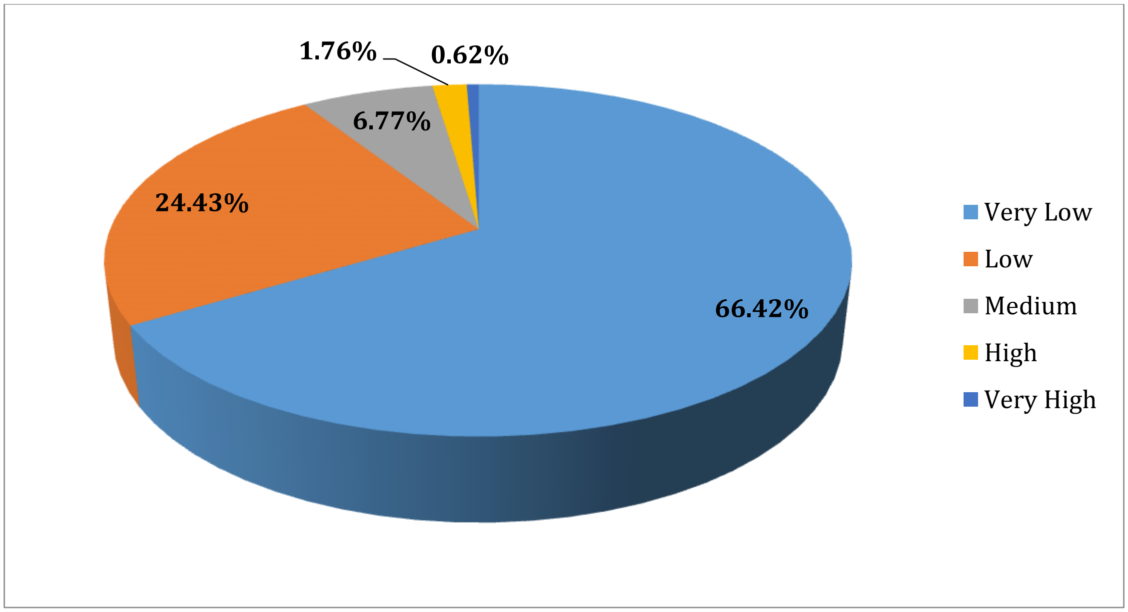

Figure No. 2.11b Absolute Relief in Ong River Basin

2.4.4.2 Relative Relief

Though absolute relief indicates the elevation of an area with respect to sea-level, it fails to capture the local roughness of the area that can be computed as the difference between the highest and the lowest elevation in the area (Smith, 1935). Further, though AR is indicative of the potential energy present in the area, it falls short in explaining the processes and potentialities of erosion. For these, a comparison with the local base level is essential, which achieved by relative relief that is defined by the difference in height between the highest and the lowest points in an area. In relative relief, topographical slopes are expressed in the degree of dissection. Higher the degree of dissection, greater will be the relative relief. Relative relief is calculated by the formula:

Relative Relief (RR)= Highest Contour value in the grid – the lowest contour value in the grid

The overall Relative relief of the Ong river basin was found to be 850 meters. Finally, the AR for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

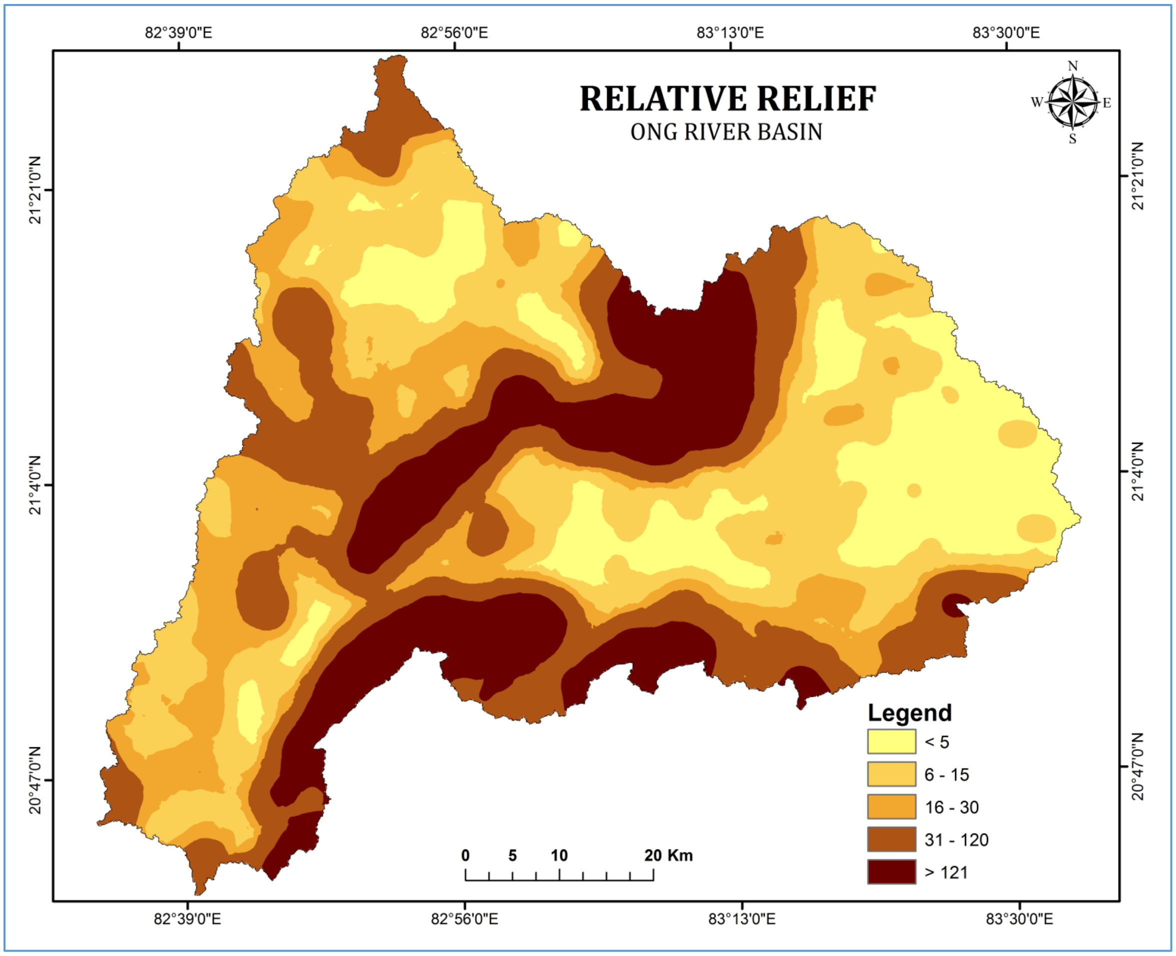

Figure No. 2.12a Relative Relief in Ong River Basin

Table 2.11 Relative Relief in Ong River Basin

Sl. No.	Classes	RR Range in Meters	% of area covered
1	Very Low	< 5	15.63
2	Low	6 – 15	26.62
3	Medium	16 – 30	18.05
4	High	31 – 120	23.13
5	Very High	> 120	16.56
	Total		**100**

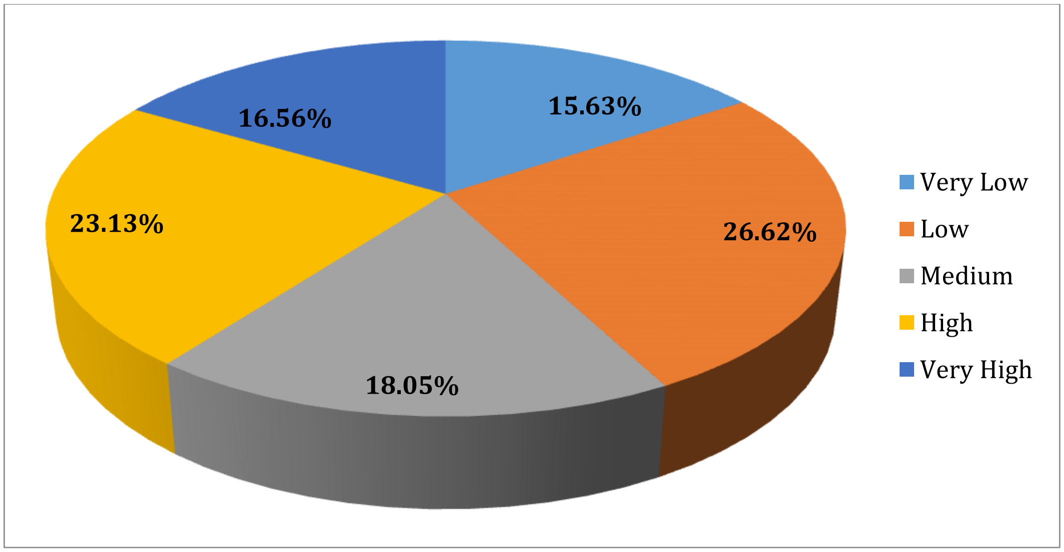

Figure No. 2.12b Relative Relief in Ong River Basin

2.4.4.3 Average Slope

Slope of a region is one of the most important morphometric parameters for the landscape. Any landscape can be seen as an open system with a highly varied input of energy and materials upon which slope is an important agent of landscaping operation (Pandey, 2005). Slope formation has many causative factors like geological structure, relative relief, drainage texture, dissection index, climate and vegetation, diverse denudational processes e.g., weathering, mass movement, rock wasting, erosion etc. and warrants essential study (Singh and Srivastava, 1975). Singh(2000), states that slope is the "most significant aspect of landscape assemblages displaying upward and downward inclination of surface between hills and valleys". Mathematically, the degree of inclination of a surface varies between 0^0 as in a completely flat surface to 90^0 as in case of a cliff. A higher slope angle is susceptible to slope failure. In places where overland flow is dominant, slope and drainage density are found to be positively related, whereas where there is mass wasting, they are negatively correlated (Tailing and Sowter, 1999). Howard (1997) posits that "drainage density and slope are negatively correlated in quickly eroding areas, whereas in slow eroding areas they are positively correlated". Slope largely determines the physical landscape of an area introducing variations and complexity in the topography. Slope represents the rate of change of vertical variation with respect to the horizontal distance. For the calculation of slope in the study area, Wentworth's (1930) formula has been used which is given as under:

$$\tan \Theta = N \times I / 636.6$$

Where, Θ is the slope angle in degrees

N = average number of contours crossing per unit length

I = contour interval

636.6 is a constant

Slope for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

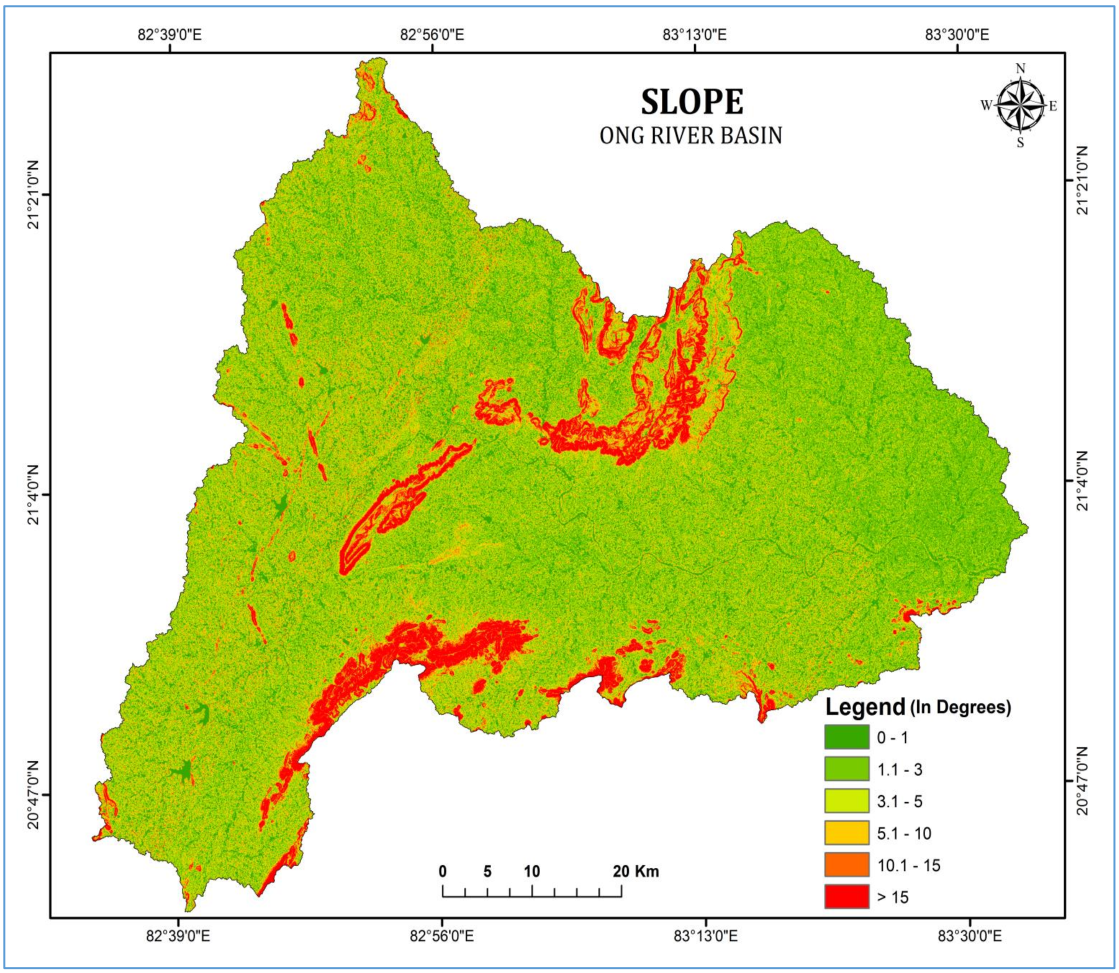

Figure No. 2.13a Slope in Ong River Basin

Table 2.12 Slope in Ong River Basin

Sl. No.	Classes	Slope Range in Degrees	% of area covered
1	Very Low	0-1	25.40
2	Low	1.1 - 3	24.92
3	Medium	3.1 – 5	22.20
4	High	5.1 - 10	18.56
5	Very High	10.1 - 15	3.23
6	Extreme	>15	5.70
	Total		**100**

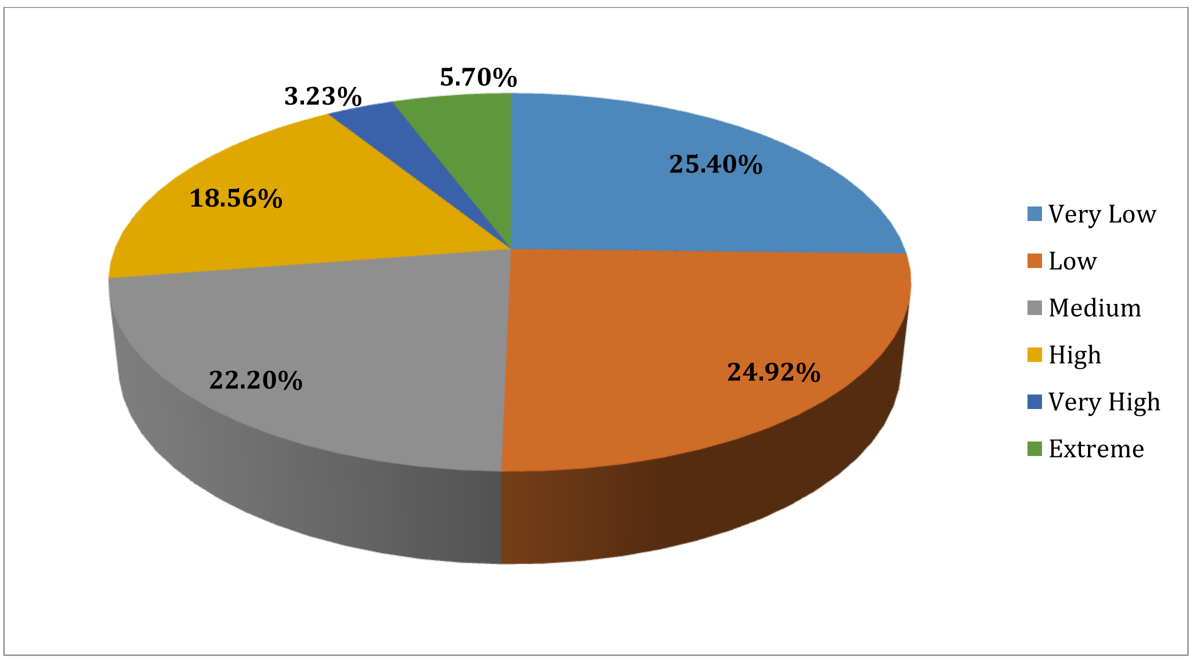

Figure No. 2.13b Slope in Ong River Basin

2.4.4.4 Dissection Index

Reflecting upon the utility of absolute relief and relative relief parameters separately, Nir (1957) stated that "as a criterion of relative energy, the concept of relative altitudes is not entirely satisfactory. Equal relative altitudes are not always of equal importance since their absolute altitude may differ. Therefore, the relative altitude is not only static, for it fails to take into account the vertical distance from the erosion base, i.e. the dynamic potential of the area studied." Based on this, he further "suggested the necessity of describing relief in terms of the ratio between absolute relief and the relative relief". Deen (1982), suggested that a high value of dissection index is indicative of youthful stage of landforms, whereas, low value of DI points towards old stage in the cycle of landform evolution. Dissection index was computed using the formula:

Dissection Index (DI) = Relative Relief (RR) / Absolute Relief (AR)

The value of DI ranges from 0 to 1. When RR equals 0, in case of a complete flat land, either near sea-level or at any level, DI approaches zero, there is no dissection at all. Conversely, when RR equals AR, when streams dissect (an area) to base level (sea level), while preserving interfluves at its original height, DI becomes 1, a case of complete and extreme dissection. The overall DI of the basin is 0.92. Finally, the DI for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

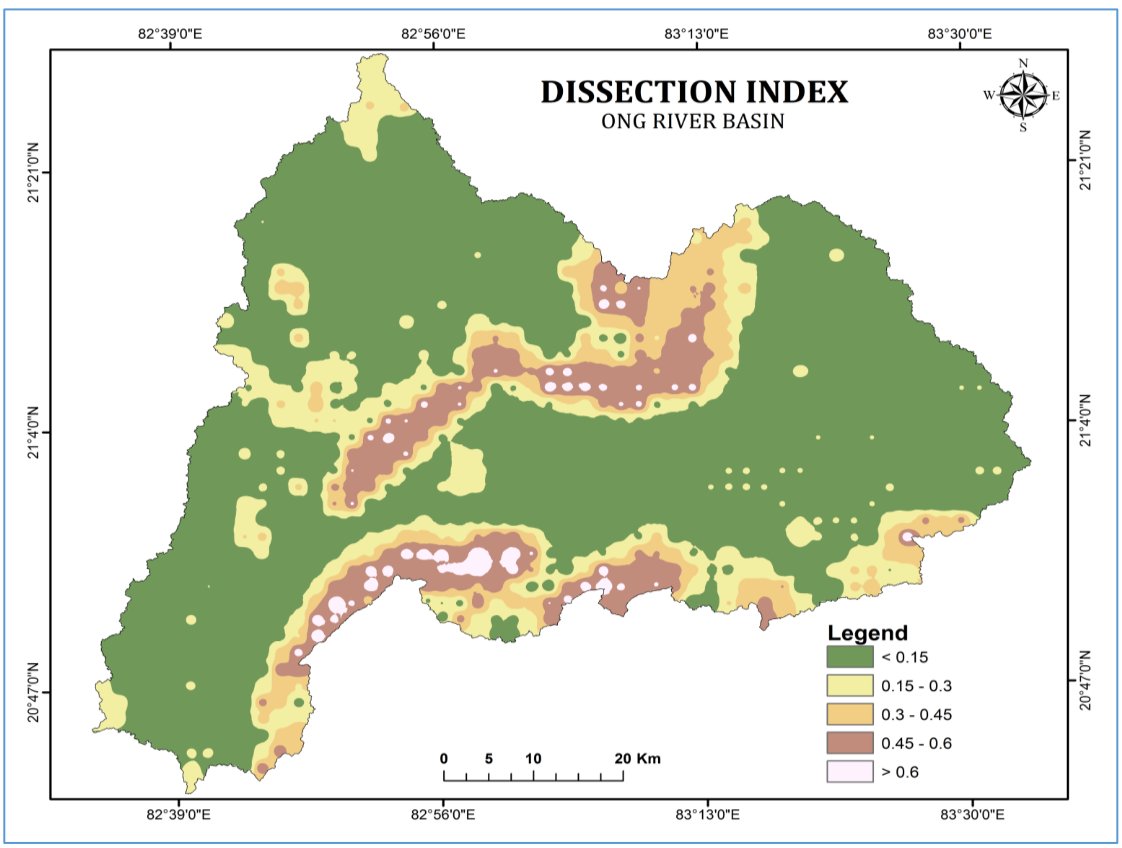

Figure No. 2.14a Dissection Index in Ong River Basin

Table 2.13 Dissection Index in Ong River Basin

Sl. No.	Classes	DI Range	% of area covered
1	Very low	< 0.15	66.95
2	Low	0.16 – 0.3	14.44
3	Medium	0.3 – 0.45	8.65
4	High	0.46 – 0.6	8.70
5	Very High	>0.6	1.26
	Total		**100**

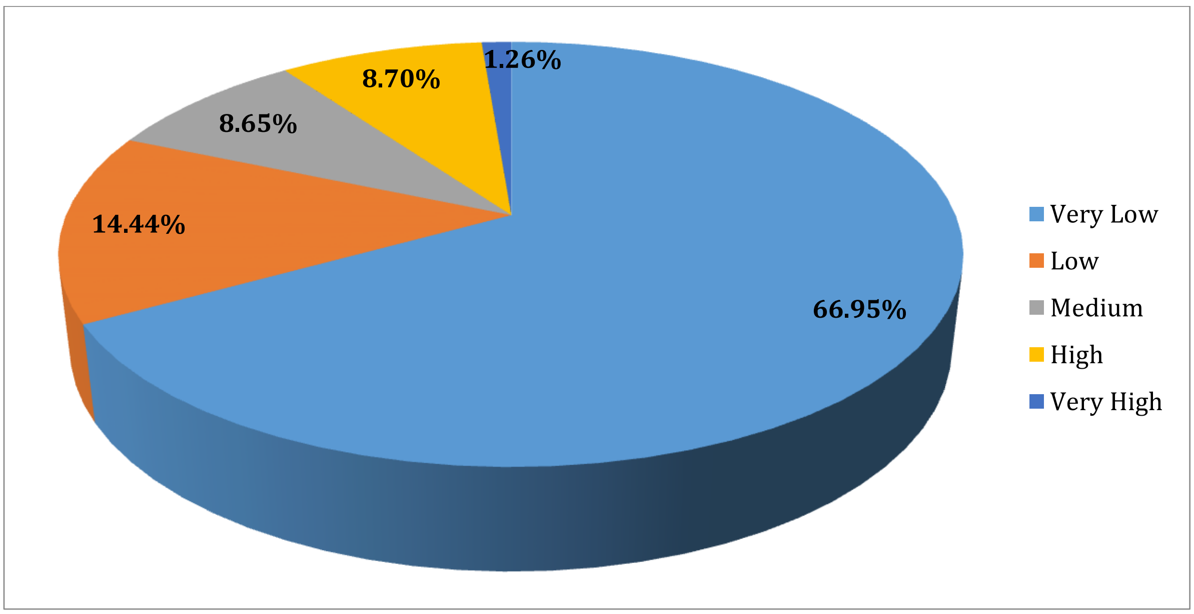

Figure No. 2.14b Dissection Index in Ong River Basin

2.4.4.5 Ruggedness Number

Ruggedness index is a measure of surface unevenness. Ruggedness number takes into account both relief and drainage density. It is a "derivative of long standing interaction between available sharpness of local relief and the amplitude of available drainage density along with other environmental parameters like precipitation, slope, weathering, soil texture and natural vegetation, etc". An extremely high ruggedness number value occurs when both drainage density and relief are large and it is associated with a long and steep slope. Generally the ruggedness number ranges from as low as 0.06 in subdued relief (plain areas) to over 1 in mountainous range or in bad land or in weak clays. It is calculated using the formula:

*Ruggedness Number = Relative Relief (RR) * Drainage Density/ 1000(constant)*

The overall RI of the Ong river basin was found to be 0.31. Finally, the ruggedness number for each grid has been interpolated over the entire basin, and the entire range was divided into suitable classes, statistics generated and presented through tables and maps.

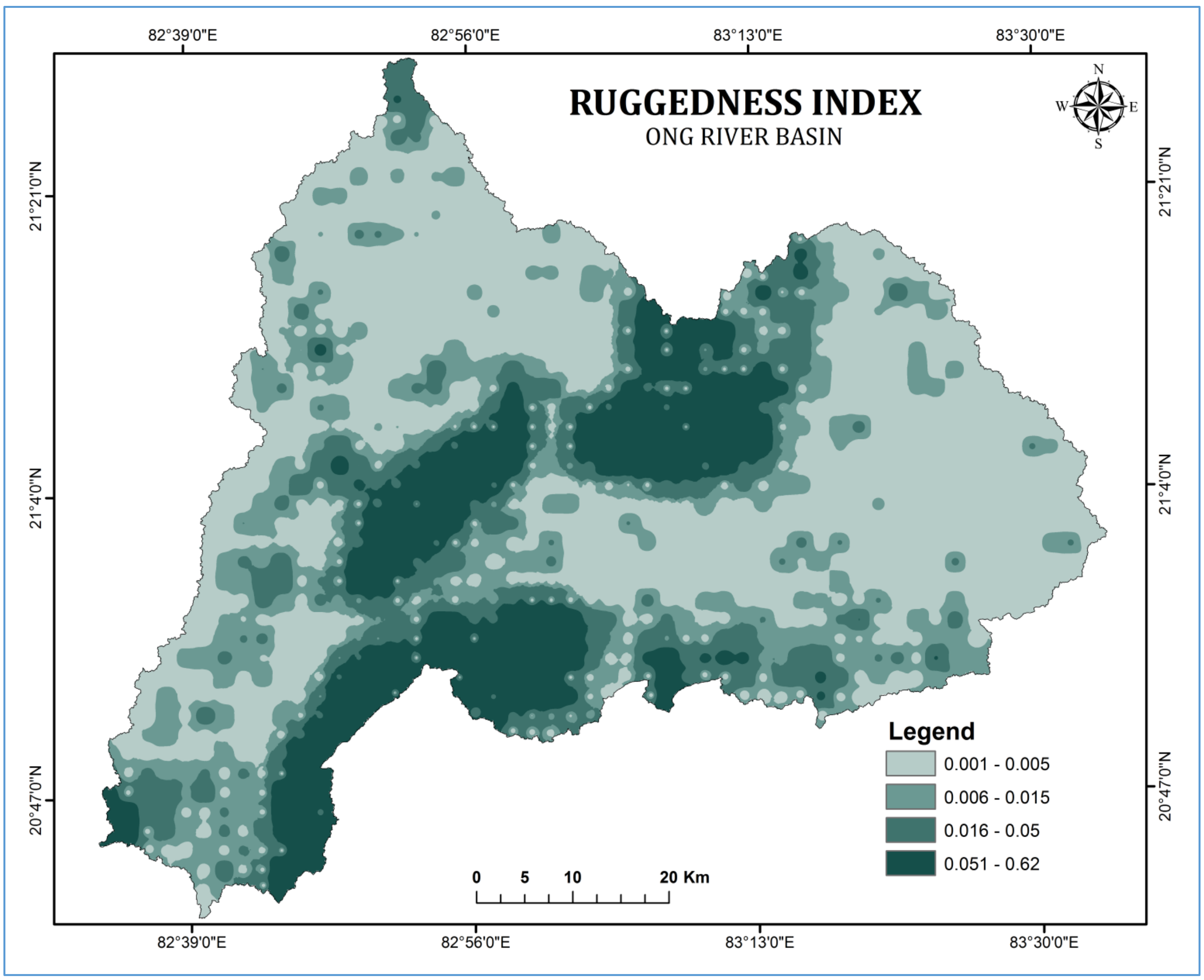

Figure 2.15a Ruggedness Index in Ong River Basin

Table 2.14 Ruggedness Index in Ong River Basin

Sl. No.	Classes	RI Range	% of area covered
1	Low	0.001 – 0.005	46.79
2	Medium	0.006 – 0.015	21.79
3	High	0.016 – 0.06	14.39
4	Very High	0.51 – 0.62	17.03
	Total		**100**

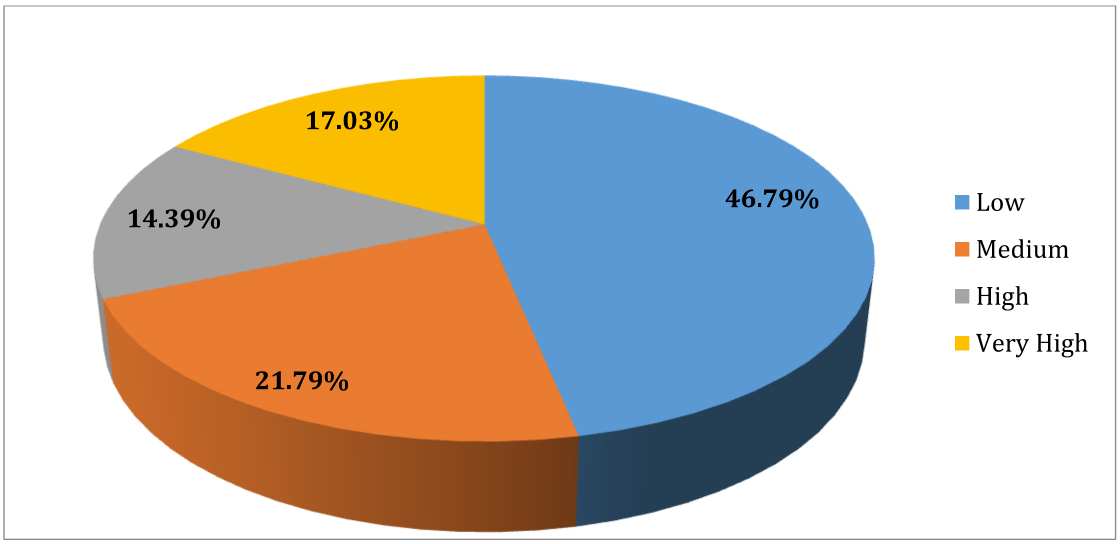

Figure No. 2.15b Ruggedness Index in Ong River Basin

2.5 Visualisation of the surface topography

Physiographically, the western part of Odisha, where most part of the Ong river basin lies, is described as rolling upland. We also saw from our analysis that considerable portion of the basin has an undulating topography. However except for the hills and the nearby surrounding areas, most part of the basin has been worked upon by human intervention to carve out terraces suitable for cultivation. In this section, an attempt has been made to visualize the general topography of the area by use of freely available Google Earth images. It's often seen that, within a distance of 300meters to 700 meters the general topography of the land transforms from a peak to valley bottom that repeats thereafter throughout the area.

These peaks-convex slopes-valley bottoms topography have been worked upon by the farmers over centuries to carve out terraces on the entire surface.

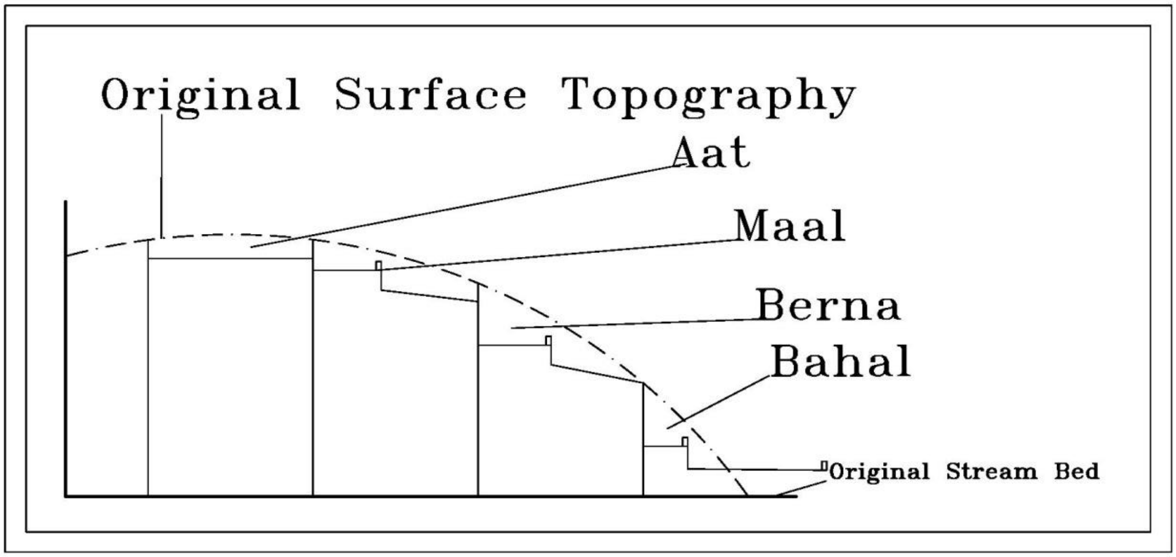

Figure 2.16 Schematic sketch diagrams of topoterrains

This has resulted in a fourfold topo-terrainic classification viz. *Aat* at the peaks or upland often elongated, followed by *Maal* lands surrounding the *Aat* uplands on both their sides, thereafter comes *Berna* lands at the end of *Maal* lands but before actually reaching the valley bottom, and lastly the *Bahal* land at the valley bottom (See figures 2.14 to 2.16). These topoterrains (also termed-toposequence or toposequentials) are of great significance from the viewpoint of agricultural use. They have been defined a bit differently in terms of their implications on cultivation and it is discussed accordingly in chapter IV later. Here in this section, they are represented visually to highlight their topographical aspects. Here one may note that, the faint white line in all the figures shows a transect line across the area in the central portion in the picture in a roughly north to south direction, the vertical profile of which is shown at the bottom of all the figures, which is mostly common. The section of this transect highlighted in red is also highlighted in the vertical profiles at the bottom. One should not miss that the *Bahal* land, located at the valley bottom (widened by human intervention for the purpose of cultivation) are rich in moisture condition and attract greener standing crops, clearly seen from the Google Earth images. On the contrary *Aat* lands are low in moisture conditions and usually are utilized for cultivation of low water demanding crops like pulses etc.

Figure 2.17 Google Earth Visualisation of Typical *Aat* Land

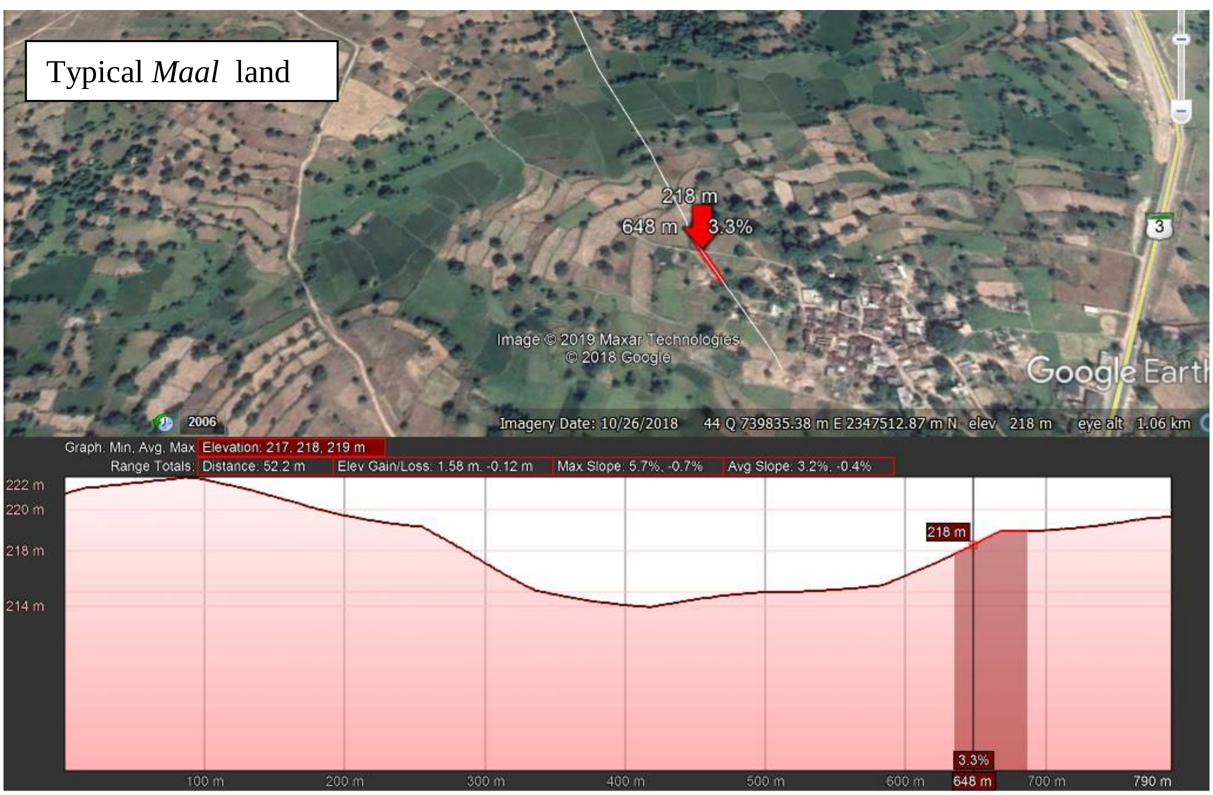

Figure 2.18 Google Earth Visualisation of Typical *Maal* Land

Figure 2.19 Google Earth Visualisation of Typical *Berna* Land

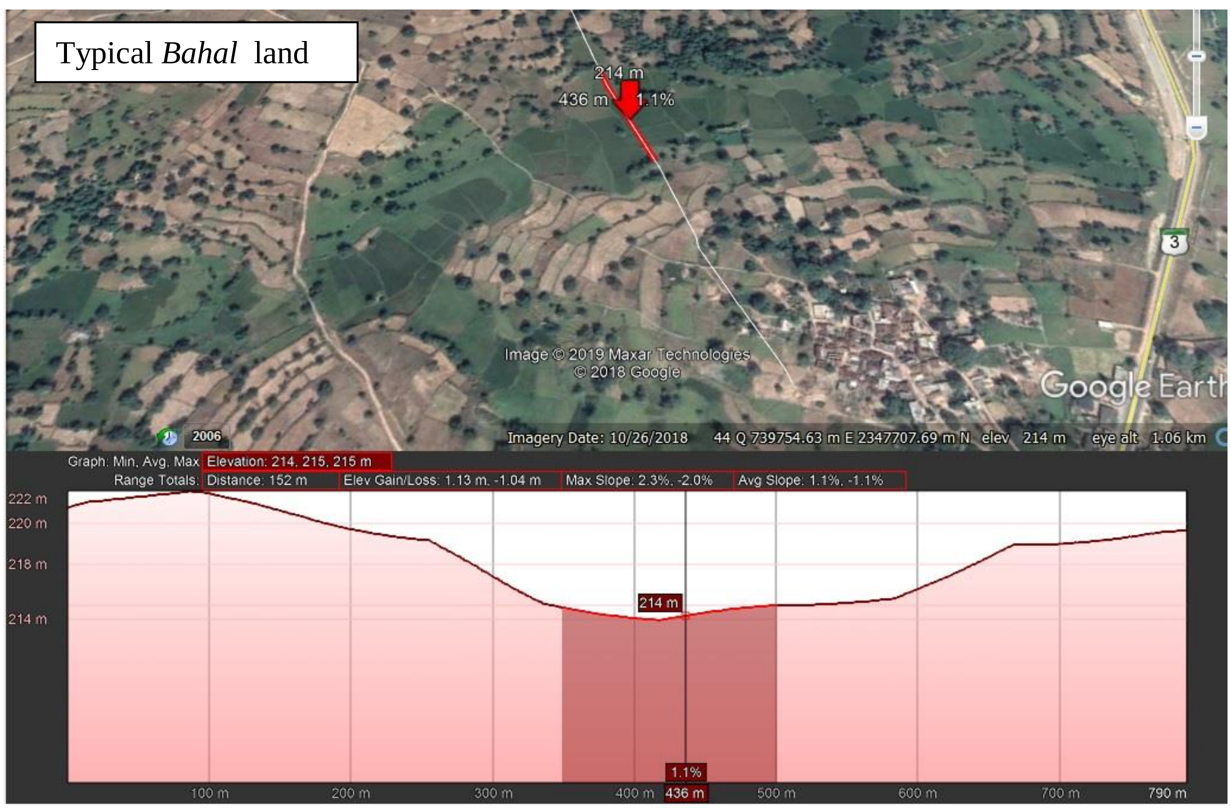

Figure 2.20 Google Earth Visualisation of Typical *Bahal* Land

2.5 Interrelationships among the Morphometric Parameters

In the table no. 2.16, the correlations among various morphometric parameters are presented. The exercise has been done to see how different parameters are correlated with each other. For the purpose of the analysis, correlation coefficient less than 0.4 has been considered *low*, whereas the same above 0.6 are interpreted as a *high* degree of correlation and the value in between these two value i.e, between 0.4 to 0.6 is considered as *medium*.

Table 2.15 Correlation Matrix of the Morphometric Parameters

	Relative Relief	**Absolute Relief**	**Dissection Index**	**Rug. Index**	**Drainage Texture**	**Stream Frequency**	**Drainage Density**	**CCM**	**LOLF**	**Drainage Intensity**	**Infiltration Number**
Relative Relief	**1**	.934**	.916**	.756**	.228**	.231**	.084**	-0.019	-0.019	-0.034	.170**
Absolute Relief	.934**	1	.826**	.702**	.229**	.237**	.081**	-0.001	-0.001	-0.024	.184**
Dissection Index	.916**	.826**	1	.695**	.221**	.222**	.073*	-0.021	-0.021	-0.033	.182**
Rug. Index	.756**	.702**	.695**	1	.528**	.530**	.420**	-0.056	-0.056	-0.049	.486**
Drainage Texture	.228**	.229**	.221**	.528**	1	.994**	.821**	-0.055	-0.055	0.001	.927**
Stream Frequency	.231**	.237**	.222**	.530**	.994**	1	.820**	-0.050	-0.050	0.007	.929**
Drainage Density	.084**	.081**	.073*	.420**	.821**	.820**	1	-.144**	-.144**	-.086**	.814**
CCM	-0.019	-0.001	-0.021	-0.056	-0.055	-0.050	-.144**	1	1.000**	.894**	-.091**
LOLF	-0.019	-0.001	-0.021	-0.056	-0.055	-0.050	-.144**	1.000**	1	.894**	-.091**
Drainage Intensity	-0.034	-0.024	-0.033	-0.049	0.001	0.007	-.086**	.894**	.894**	1	-0.036
Infiltration Number	.170**	.184**	.182**	.486**	.927**	.929**	.814**	-.091**	-.091**	-0.036	1

*** Correlation is significant at the 0.01 level*

**Correlation is significant at the 0.05 level*

The Table 2.15 presents the value of correlation among different parameters considered. Among different variables high, medium and low positive correlations can be seen while negative correlations are generally low to very low. From the table it is evident that relative relief has high degree of positive correlation with absolute relief, dissection index, ruggedness index, while it has low positive correlation with drainage texture, stream frequency, drainage density and infiltration number. Further, a very weak negative correlation has been observed between relative relief and constant of channel maintenance and length of overland flow. Like relative relief, absolute relief also found to have high degree of positive correlation with dissection index and ruggedness number while a weak positive correlation with drainage texture, stream frequency, drainage density and infiltration number. With other variables it has very weak negative correlations like relative relief. Dissection index also behaves in line with the relative relief and absolute relief to give high positive correlation with ruggedness number and low positive correlations with drainage texture, stream frequency, drainage density and infiltration number and very low negative correlations with remaining variables. In contrast to the relative relief, absolute relief and dissection index; ruggedness index show moderate positive correlation with drainage texture, stream frequency, drainage density and infiltration number but similar very low negative correlations with remaining variables. Further, contrasting the behavior of relative relief, absolute relief and dissection index; both drainage texture and stream frequency show high positive correlations (drainage texture show high positive correlation with stream frequency, drainage density, infiltration number and stream frequency show high positive correlation with drainage density and infiltration number). But with rest of the parameters they show similar very weak negative correlations as shown by relative relief, absolute relief and dissection index. Among others, drainage density has strong positive correlation with infiltration number; constant of channel maintenance and length of overland flow, both has shown perfect positive correlation with each other (which is quite obvious because one can be derived from the other), while high degree of positive correlation with drainage intensity and a very weak negative correlation with infiltration number. Finally, drainage intensity has shown very weak negative correlation with infiltration number. A comprehensive look over the entire table reveals that relative relief, absolute relief and dissection index are varying nearly in similar tone and can be grouped together within relief parameters while for similar reasons drainage texture, stream frequency and drainage density can be clubbed within stream parameters. Further, ruggedness number does not fit well to any of the category. Also the variations of drainage intensity and infiltration number are very weakly related with variations in variables of the other groupings.

2.6 Summary

ALOS-PALSAR data analysed through GIS techniques proved to be a simple yet powerful method that is simultaneously economical and time saving way to undertake a quantitative morphometric study of the Ong river basin with reasonable quality and accuracy. However, caution is warranted especially when deciding on the delineation of the first order streams, which in many occasions can be misleading. While the DEM derived first order reasonably matched with the reality in hilly and less intervened areas, in the low slope areas, most of the first order channel beds have been converted into cultivated lands and they coincided frequently with the *Bahal* land, the local terms for lowest topo-sequential land. Thus, ideally a DEM derived products should be verified with other secondary data and field observations before their uses. The distributions of steams as measured through the morphometry suggest that the underlying geology seems to be quite homogeneous without much structural disturbances. Further, the basin is oval in shape and hence will have a moderately accentuated peak of flow of medium duration with average in discharge efficiency. The basin has 'fine' drainage texture. Further, the drainage density and stream frequency of the basin indicate somewhat high permeable subsoil and moderate relief. This indicates relatively long overland flow of surface water; that is also found to be related with the surface roughness, runoff and climate of the region. This Ong basin has 'dendritic' drainage pattern composed of fairly homogeneous rock and indicating that the underlying geologic structure do not control surface drainage much.

On the basis of the analysis of the various parameters of the basin, it can be said that, the Horton's first law of stream numbers is applicable to the sub-basin. The average ratio is 4.424 which lies between 3.0 and 5.0. It indicates that the drainage pattern have not been distorted by the geologic structures of the basin. A higher value of bifurcation ratio indicates an extended peak flow, whereas the lower value of the same indicates a shorter peak. The Ong basin would yield flood hydrograph somewhere between these two extremes.

Low drainage density, low stream frequency and subdued drainage intensity indicate that the surface runoff is not quickly discharged from the basin, thereby enhancing its susceptibility to flash flooding and consequent soil erosion. The basin has relatively low infiltration number that indicates high rate of infiltration and reduced surface run-off. These are also confirmed from the length of overland flow. Though morphometric parameters pertaining to Ong river basin are somewhat favorable for infiltration and run-off, heavy rainfall events can occasionally result in flooding, which can be accentuated by inefficiency of surface storage structures like check dams, tanks, reservoirs and degeneration/ modification of streams and landuse changes due to increased human interventions on the natural landscape.

The above observations point to the fact that the Ong River basin displays all the potential to perform the drainage function more effectively. The analysis leads to the greater need to further increase the storage capacity of all the water bodies, rehabilitation and restoring of channels which will go a long way in enhancing the basin's water holding capacity. This in turn, will be of great use in meeting the growing demands for water for agriculture, urban as well as for industrial usages.

Further, the general undulating land in the basin has led into a fourfold topo-terrainic differentiation of the agricultural land, which is of great economic significance in terms of the way it challenges farming practices and also from the standpoint of costs of cultivation and productivity from these lands. Such repercussions have been discussed in details in chapter four of the study.

CHAPTER III

PRECIPITATION CHARACTERISTICS OF THE BASIN

3.1. Introduction

There are various manifestations of water. It occurs in various forms: precipitation (rain, snow, sleet), rivers, glaciers, surface water bodies, ground water aquifers, soil moistures, atmospheric moistures, etc. though all these forms constitute a unity, they have different connotations in terms of their characteristics, issues, uses, and the way they are all governed. Thus, water is highly variable in its occurrence in both the broader as well as any specific sense. Water is perceived differently by different people depending on their use of the same. So far as it sustains our basic necessities like drinking, sanitation etc, it is thought of as a “basic requirement”; so far as it supplements the irrigational need and industrial requirements, it can be viewed as an “input” in our economic activities, like wise it is also seen as a “social good”, source of “energy”, as well as “modes of transportation” depending on who uses it and in what manners. The way water is perceived by the people differs over time and space. This difference of perception is important because, different institutions evolve, regulations of use formulated based on how water is perceived. In turn, these institutions and regulations concerning water determine how the resource is used which has a huge implications on how people use it and are benefitted out of it. We will see this in the following chapters, how the nature of rainfall distribution and characteristic topography of the Ong river basin have led to the evolution of specific institutions and their diverse implications on their users.

The distribution of rainfall can have striking spatio-temporal diversity. So far as India is concerned, we can see that, there is wide spatial variation in the distribution of rainfall, ranging from less than a hundred millimeters in some parts of Rajasthan, to more than ten thousand millimeters in the northeastern part of the country. Apart from this marked spatial variation, the fact that India greatly relies on the tropical monsoon as its primary source of rainfall, it is predisposed to experience considerable temporal variation in terms of rainfall, which comes down in a very short period of the year what we call as the rainy season. Moreover, even within that period, the intensity is concentrated within a few weeks. This temporal variation assumes great importance, as we will see in our analysis, for the study region. Because agriculture is the mainstay of the population in the study area and the provision of irrigation is conspicuous in term of its inadequacy.

To meet the second objective of the study, we undertake a study on temporal variation of precipitation in the basin. It may be noted that, rice is the dominant crop in the basin. Rice being a water sensitive crop gets highly impacted by variation in rainfall distribution. Thus, after initial discussion on the overall temporal variation of precipitation in the basin, analysis on prevalence of dry spells and their implication on rice have been presented. The following section thus presents a discussion on the nature of occurrences of precipitation, their distribution and variation at annual, seasonal, monthly and weekly scales. The main aim of this chapter is not to investigate the causative factors behind rainfall variation; rather it is to identify the *pattern* of variation of itself and discuss its implication for the basin.

3.2 Data and Methods

For the analysis of rainfall, data were obtained from two secondary sources. There is one IMD station in the basin at Padampur, the annual and monthly data for which was obtained from IMD, Pune for the period 1970-2005. The data obtained from the IMD, Pune was in cents and were converted to millimeters. Beside this, there are six rain gauge stations located in the Ong river basin for which daily rainfall data were obtained from the Office of the sub-collector, Padampur, Odisha. The six rain gauge stations for which data have been obtained and analysed are Padampur, Paikmal, Gaisilet, Jharbandh, Bijepur and Sohela, which are located fairly spread out over the basin.

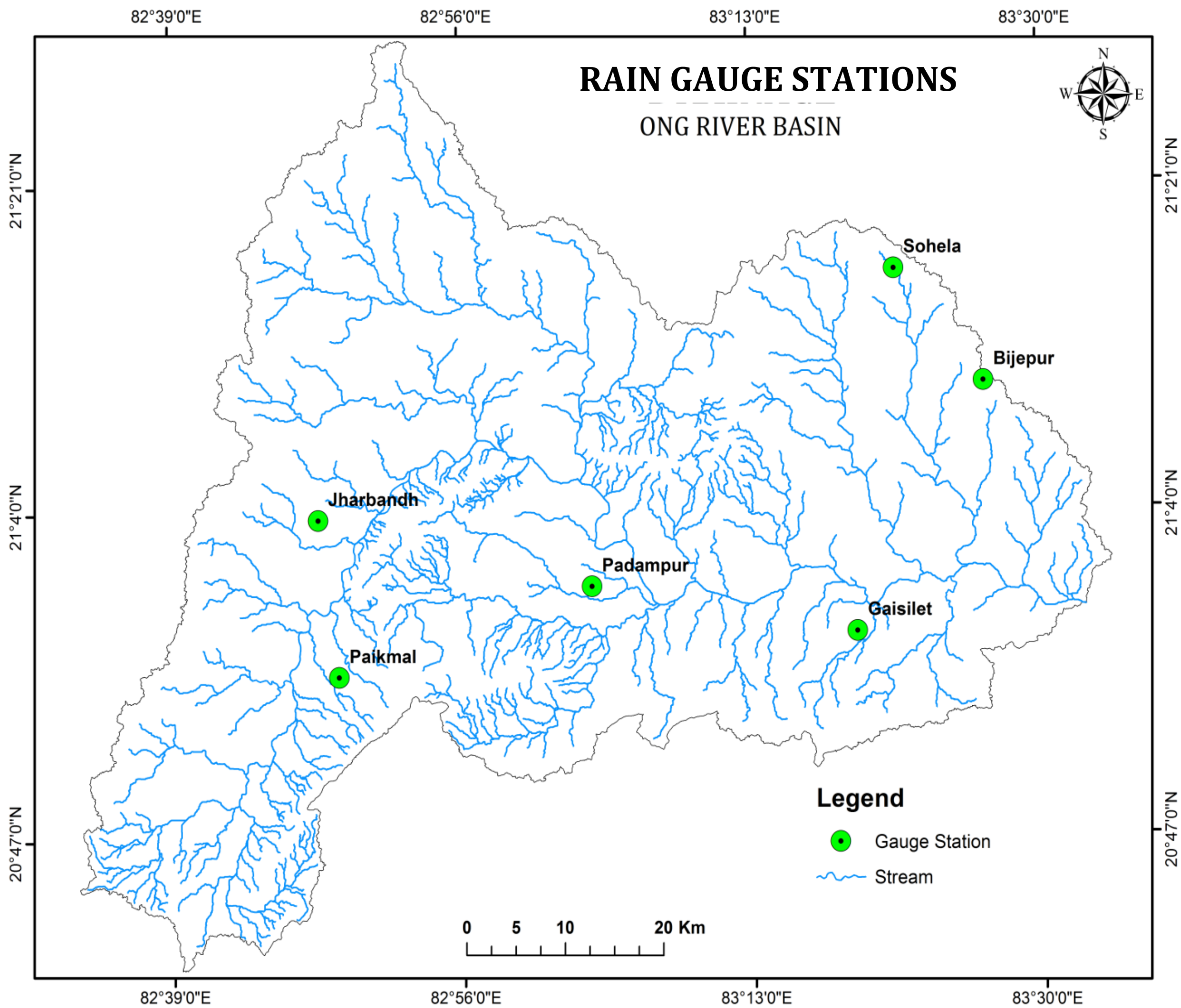

Figure No. 3.1 Rain gauge stations in Ong river basin

Various simple standard descriptive statistics like Mean, standard deviation, Coefficient of variation, skewness etc. have been used to study the annual, and seasonal variation characteristics of rainfall. The calculation of dry spells has been undertaken by Markov Chain analysis (steps presented below in sub-section 3.7 below). The discussion in this section covers broadly two aspects, viz. the temporal and spatial variation of rainfall and, the dry spell and wet spell studies that helped us assess the drought proneness of the region.

3.3. Precipitation in the basin

The nature of precipitation in a region is determined broadly by factors like location of the region, the general physiography, its altitude, its distance from the sea and the moving weather systems visiting the region. Owing to its location, the Ong river basin enjoys a tropical monsoonal climate. It is characterized by all the typical features of a monsoonal region like – highly imbalanced temporal distribution of rainfall, with most of the rainfall being highly concentrated during the monsoon season alone and the rest of the year is left with a little share of the rain. The Ong basin receives more than 80 % of the total annual rainfall during the rainy season alone. This, mixed with the fact that the share of dependable source of irrigation is quite less, suggests that cultivation during the rest of the year requires proper management in terms of crops selection as well as nature of water use.

3.4. The Rain Bearing Systems

The Ong river basin is influenced broadly by the weather system that affects the state of Odisha. Due to its location quite far from the west coast of India, the region is not directly influenced by the south-west branch of monsoon; rather its situation is such that it is parallel to it. But, the annual cyclones from the Bay of Bengal influences it and brings much of the rain with two seasonal peaks—July to August and October to November (Sinha, 1999).

The cyclonic storms during the monsoon originate in the Bay of Bengal and proceed in a north-west direction. During the course of their journey, they gradually weaken as they reach west Odisha. The study area lying in interior-west Odisha does not receive the high intensity yield from the cyclonic rain. There are two cyclonic peaks in the occurrence; one during May-July and the other during October to November, when maximum numbers of cyclones visit the state. However, most of them greatly weaken as they reach central–western part of the Ong river basin (300-350 km from Bay of Bengal). So far as the periodicity of occurrence of cyclonic storms are concerned, maximum number of cyclones come during the southwest monsoon, followed by post monsoon period during November –December, and pre- monsoon period. Besides these, however, the Ong basin receives some rainfall due to intensification of local lows during the hot weather season from March to May (Sinha, 1999).

3.5. Spatial and Temporal Variation of Annual Rainfall

The annual average rainfall of various stations points to the fact that most of the rain gauge stations in the Ong river Basin receive an annual average rain fall that is higher than 1180mm, the annual average rainfall of India. The annual average rainfall received by the region estimated through simple averaging the rain fall of all stations has been found to be 1211 mm (See Table 3.1). However, the average rainfall in the basin derived through *Theissen* polygonised averaging is 1199.36mm which just above the Indian average.

The broad temporal analysis of the average annual rain fall reveals that though the basin receives quite a good amount of total annual rain, its distribution over time is far from uniform (See the table below).

Table 3.1 Annual rain fall in different rain gauge stations in Ong river basin, 1970-2018

Stations	Mean	Std. Dev	CV	Minimum	Maximum	Skewness
Bijepur	1480.22	568.10	38.38	397	2552.00	0.134
Gaisilet	1042.41	331.84	31.83	232	1657.00	-0.314
Jharbandh	1114.78	353.48	31.71	252	2048.50	0.001
Padampur	1088.39	321.23	29.51	365	1917.33	0.262
Paikmal	1478.34	491.88	33.27	313	2558.00	-0.139
Sohela	1063.75	358.25	33.68	411	2599.12	1.673
Total	1211.32	453.28	37.42	232	2599.12	0.663

Looking at the table above, one can clearly see that the range is very high. The highest range (of 1986mm) in the annual average rainfall is found in the Sohela rain gauge station which lies in the North-eastern part of the basin and the lowest range has been reported in Gaisilet, about 1203 mm, which itself is quite high. Over the period of study, the fluctuation in the rain fall amount can be judged from the fact that it can go as low as 232mm (in Gaisilet, 2013) to as high as 2599mm (in Sohela, 1971). Thus, we find a very much skewed distribution of rainfall in the basin, skewness ranging from 0.001 in Jharbandh to 1.673 in Sohela.

To capture the variability of rain fall and express the same with a single value, the coefficient of variation of the annual average rain fall was computed and was found that it is quite high for the basin. The coefficient of variation of the annual rain fall ranges from 38.38% for Bijepur, to 29.51% in Padampur rain gauge station, which itself is a very significant variation. It becomes crucial, as the general level of dependable irrigation in the basin is low and rain fall is the dominant source of water for the predominantly agricultural economy of the region.

To show the trend in the variation of annual rain fall, three years moving average has been plotted and presented graphically below along with the 49 years average rainfall.

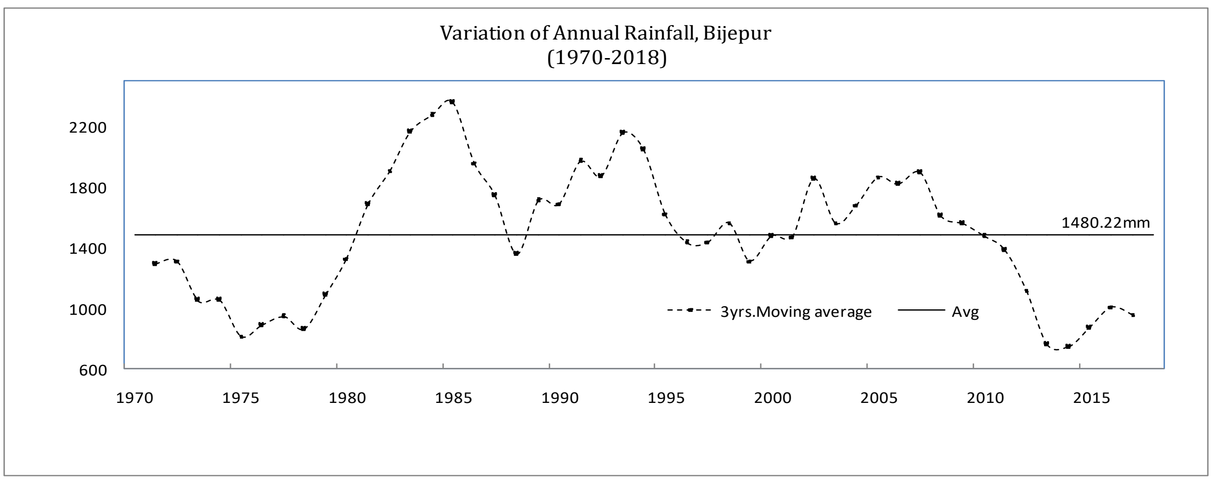

Figure 3.2. Variation of Annual Rainfall, Bijepur

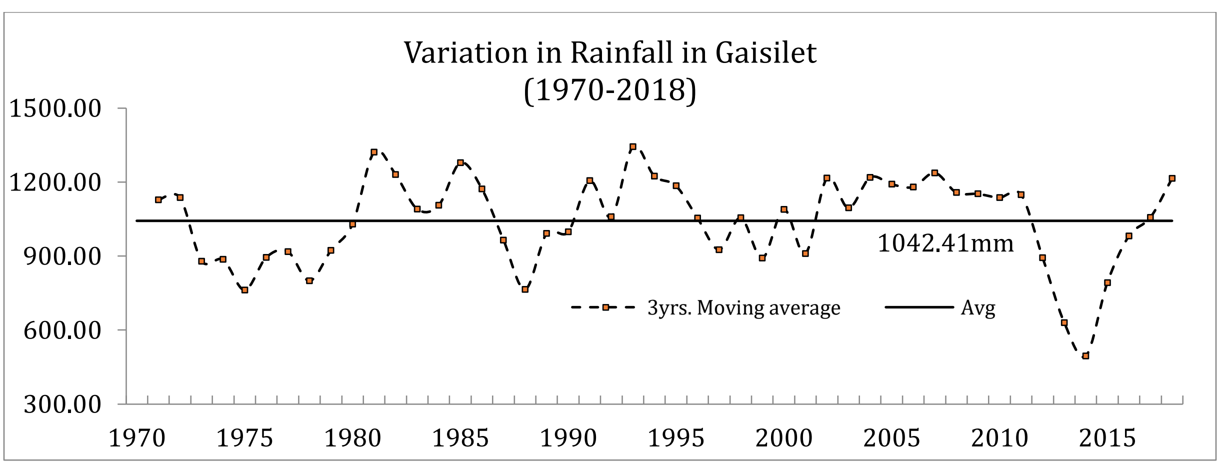

Figure 3.3. Variation of Annual Rainfall, Gaisilet

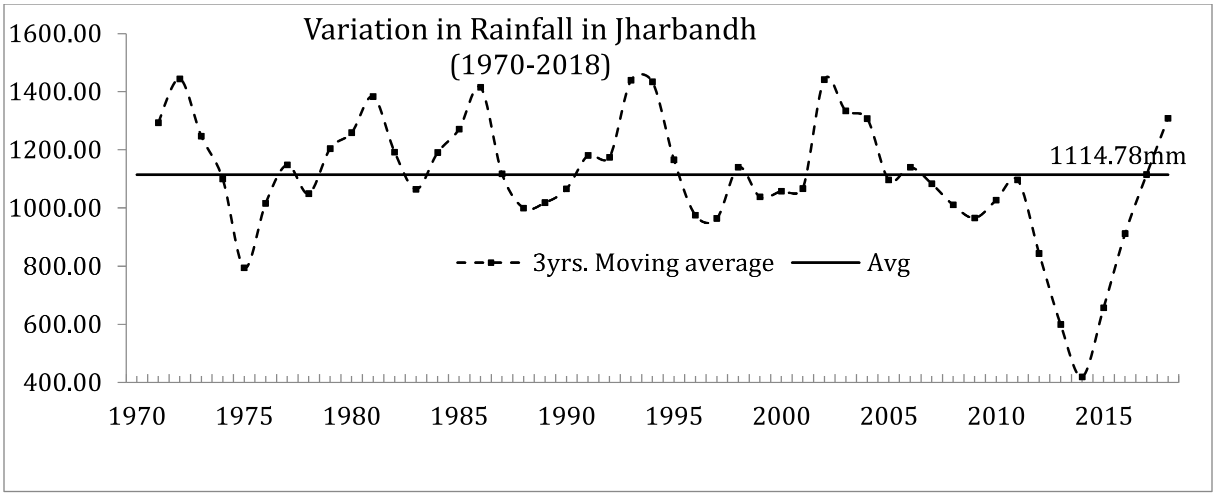

Figure 3.4. Variation of Annual Rainfall, Jharbandh

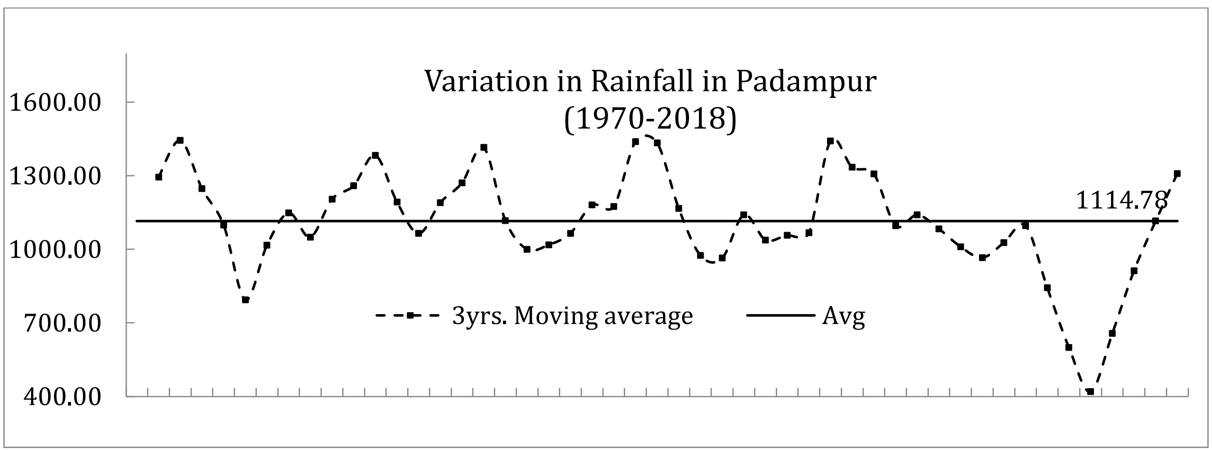

Figure 3.5. Variation of Annual Rainfall, Padampur

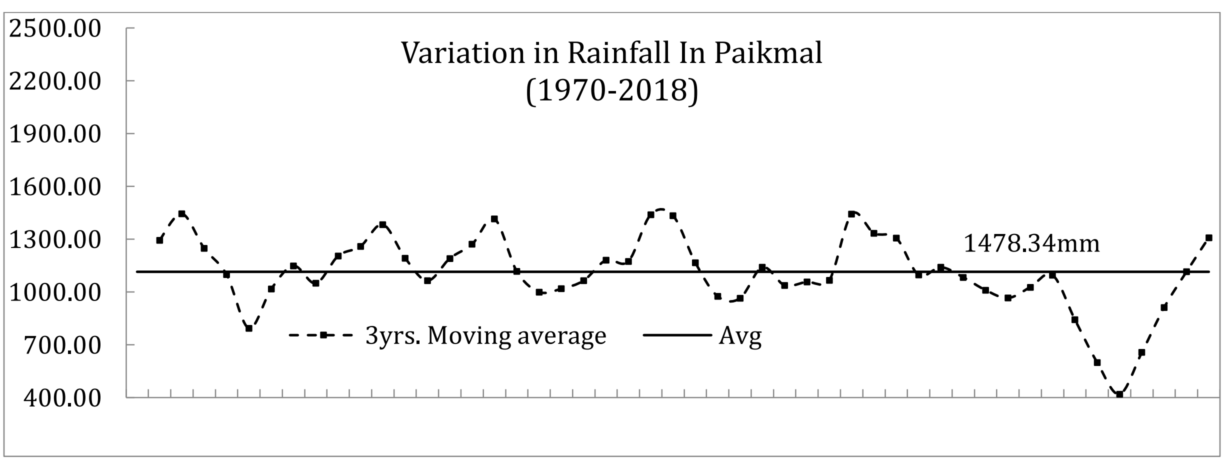

Figure 3.6. Variation of Annual Rainfall, Paikmal

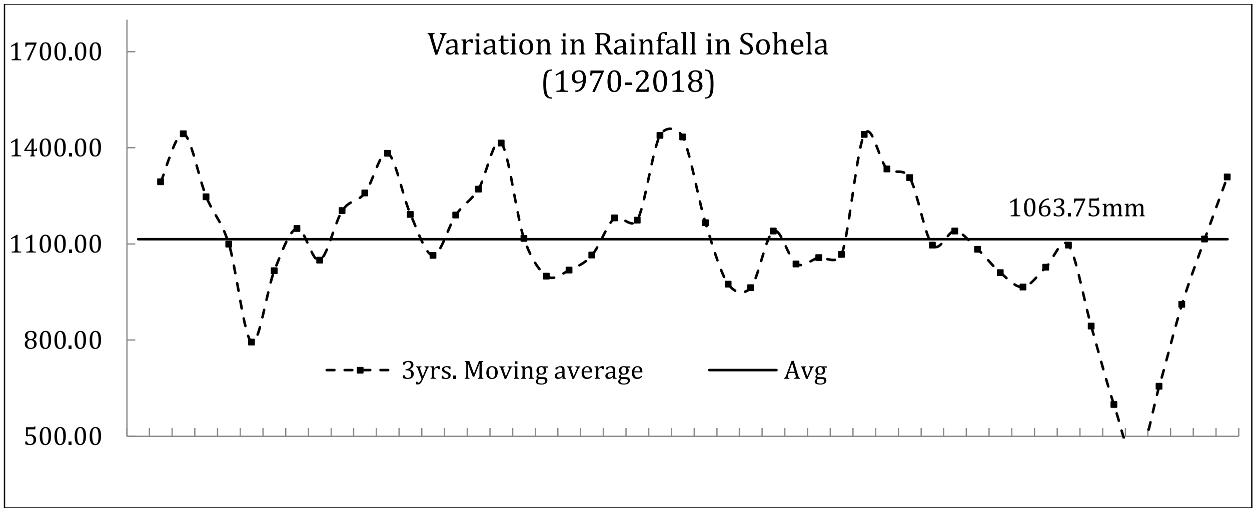

Figure 3.7. Variation of Annual Rainfall, Sohela

The moving average for different stations shows different trends, but they all point towards large variations over the study duration 1970-2018. Among all these stations, Jharbandh registers a consistently high variability throughout the period under study, followed by Gaisilet. There is seen a clear trend of increased rain fall during the mid seventies to late eighties in Bijepur rain gauge station. This station also marks the largest departure from the overall average of annual rainfall, followed by Sohela. However, it is worth noting that there is great variation in the trend and this indicates erraticity of rain fall in the study area. Thus, it also underscores the undependability of this single source of water and necessitates the augmentation of dependable irrigation and calls for the proper management of the water resource.

Finally, it may be noted that, like any average data, the annual average data can have a concealing effect on the actual minute variations therein, and it warrants an analysis at seasonal level, which is presented below.

3.6 Spatial and Temporal Variation of Seasonal Rainfall

In this section, we will look into the seasonal variation in rainfall distribution. After a brief description on the characteristics of different seasons, the data analysis is given and discussed. Though locally the study area has six seasons, for the present study, a year has been divided into four main seasons, viz.

1. The season of the North-East monsoon (January-February)
2. The Hot Weather Season (March -May)
3. The season of the South- west Monsoon (June -September)
4. The Season of Retreating Monsoon (October- December)

The beginning of the South west monsoon is marked by the appearance of stratocumulus type of cloud during early June, which changes to cumulonimbus type during the middle of June and ultimately to nimbostratus type during middle-late July. Here, it can be pointed out that the monsoon wind doesn't blow continuously to bring about continuous rain, rather it comes at intervals. Thus, the pulsatory characteristics of the monsoon wind are revealed. The arrival of the season of retreating monsoon (Oct- Dec) is marked by the change of the colour of the clouds from black to white grey. They again become strato-cumulous. During this season, at times, several depressions may occur. These cyclonic depressions cause harm to the mature paddy and vegetables as their timing coincides with the harvest of these crops. The season of North-east monsoon sets in the month of January. During this time, the amount of cloud cover in the sky is low and this helps in free radiation. In the evening stratus clouds appear in the horizon. Slight rain fall, however, in this season is a boon for the pulses. However, rain comes in the form of hail storms during late February. It may prove detrimental to rabi crops, which are by that time in their harvesting stage. Hot weather season follows it, when the mercury in the barometers fall and mercury in the thermometer rises. The cloud types of cirrostratus to cirrus during March changes to alto-cumulus during the end of May. The farmer keeps his farm fallow for a period in this season, before the sowing for the next season, especially in the unirrigated tracts of the Ong basin. The characteristics of rainfall received over different seasons is presented below.

Table 3.2 Variation of Seasonal Rainfall in Ong Basin, 1970-2018

Weather Stations	Seasons	ANNUAL	NE Monsoon	Hot Weather	SW Monsoon	Retreating Monsoon
Bijepur	Mean	1480.22	30.59	65.65	1319.74	64.24
	%	100.00	2.07	4.43	***89.16***	4.34
	Median	1454.87	8.50	47.00	1325.00	41.75
	Std. Deviation	568.10	55.36	70.83	517.36	90.16
	CV	38.38	181.00	107.90	39.20	140.35
	Minimum	397.00	0.00	0.00	386.00	0.00
	Maximum	2552.00	334.00	292.00	2418.00	527.00
	Skewness	0.13	3.81	1.33	0.27	3.18
Gaisilet	Mean	1042.41	14.42	44.39	937.64	45.96
	%	100.00	1.38	4.26	***89.95***	4.41
	Median	1022.02	0.00	27.00	941.00	32.00
	Std. Deviation	331.84	23.37	53.03	300.50	47.98
	CV	31.83	162.13	119.47	32.05	104.39
	Minimum	232.00	0.00	0.00	216.00	0.00
	Maximum	1657.00	90.00	224.00	1619.00	211.00
	Skewness	-0.31	1.82	1.59	-0.23	1.62
Jharbandh	Mean	1114.78	11.18	38.48	1001.37	63.76
	%	100.00	1.00	3.45	***89.83***	5.72
	Median	1116.20	4.00	30.00	1003.00	45.75
	Std. Deviation	353.48	16.44	40.97	315.10	82.08
	CV	31.71	147.07	106.47	31.47	128.74
	Minimum	252.00	0.00	0.00	191.00	0.00
	Maximum	2048.50	67.60	151.00	1630.75	399.00
	Skewness	0.00	1.75	1.12	-0.19	2.30
Padampur	Mean	1088.39	16.78	45.49	968.56	57.53
	%	100.00	1.54	4.18	***88.99***	5.29
	Median	1078.00	5.00	23.80	948.00	45.20
	Std. Deviation	321.23	26.97	49.01	292.76	53.35
	CV	29.51	160.68	107.74	30.23	92.72
	Minimum	365.00	0.00	0.00	178.00	0.00
	Maximum	1917.33	136.75	167.00	1752.50	189.00
	Skewness	0.26	2.63	1.13	0.09	1.00
Paikmal	Mean	1478.34	16.10	52.46	1333.84	75.95
	%	100.00	1.09	3.55	***90.22***	5.14
	Median	1460.00	4.00	32.00	1342.25	52.40

Weather Stations	Seasons	ANNUAL	NE Monsoon	Hot Weather	SW Monsoon	Retreating Monsoon
	Std. Deviation	491.88	24.82	53.86	460.54	86.94
	CV	33.27	154.16	102.67	34.53	114.47
	Minimum	313.00	0.00	0.00	143.00	0.00
	Maximum	2558.00	124.00	198.00	2264.00	443.00
	Skewness	-0.14	2.54	1.19	-0.09	2.11
Sohela	Mean	1063.75	17.73	37.70	961.93	46.39
	%	100.00	1.67	3.54	***90.43***	4.36
	Median	1001.00	11.00	31.00	899.80	38.00
	Std. Deviation	358.25	23.49	37.16	336.91	48.59
	CV	33.68	132.48	98.57	35.02	104.76
	Minimum	411.00	0.00	0.00	383.00	0.00
	Maximum	2599.12	95.00	151.00	2425.00	203.00
	Skewness	1.67	1.73	1.26	1.81	1.20
Total	Mean	1211.32	17.80	47.36	1087.18	58.97
	%	100.00	1.47	3.91	***89.75***	4.87
	Median	1152.14	5.00	30.00	1032.63	41.88
	Std. Deviation	453.28	31.36	52.38	414.08	70.82
	CV	37.42	176.20	110.60	38.09	120.10
	Minimum	232.00	0.00	0.00	143.00	0.00
	Maximum	2599.12	334.00	292.00	2425.00	527.00
	Skewness	0.66	4.60	1.52	0.72	2.62

Table 3.2 presents the descriptive statistics of amount of rainfall received in different seasons between 1970-2018 in six different stations in Ong River basin. The following sections present the summary of the findings.

Looking at the seasonal distribution of rain fall one can see that, overall 89.75% of the annual rainfall is received in the South West Monsoon season itself. It ranges from 88.99% in Padampur to 90.43% in Sohela. This indicates a very eccentric distribution of rainfall for the entire basin. It also points to the fact that for rest of the seasons, the water availability gets too scarce. However, the distribution of rain in SW monsoon season over the years in all the stations is approximately symmetrical as indicated by skewness value less than 0.5, except for Sohela, where it has reached upto 1.809.

In the non-monsoon seasons, the rainfall variation is too skewed, nowhere the skewness value is less than 1. Further, the low amount of rainfall in non-monsoon season curtails any chance of growing a second rainfed rice crop after monsoon season. Pulses, however, can be grown after rice is harvested utilizing the remnant moisture of the monsoonal and post monsoonal seasons. It may be noted that, even for good yield of pulses, the precipitation received in the NE monsoon season seems low. Nowhere, the median rainfall is more than mean rainfall for the non-monsoon seasons.

The coefficient of variation (CV) of annual rainfall in the basin over 49 years is 37.42%. CV for Monsoon season varies from 30.23% in Padampur to as high as 39.20% in Bijepur. Thus, for all the stations, it is quite high. For the non-monsoonal seasons, the CV is very high. The high CV for Hot weather season and the Retreating monsoon season is quite significant as this indicates that in some years the rain fails (or is extremely low) and in others it can go to some extremely high amount for the season. Despite the fact that these seasons account for a very little share of the annual rainfall, they are crucial, nonetheless, for the predominant crops of the study area i.e. rice. If rain fails in the late hot weather season, agricultural operation gets delayed, whereas if there is too high rainfall in the middle to late retreating monsoon season, harvested rice get rotted in the field. This leads to huge yield losses and impacts the farmers very adversely.

Finally, the discussion above necessitates that the variation of rainfall be analysed a bit deeper at a still shorter interval. The daily data collected for six rain gauge stations have been segregated into weekly aggregate data and analysis has been undertaken to identify dry weeks during the Kharif rice growing period. It is discussed in details in the next section.

3.7. Analysis of Accumulated Rain and Dry spells in the Basin

As was discussed in the previous section, in a sizable area in the study region, paddy is grown mostly under rainfed condition. As prudence demands, if one can't change, one must adapt. Further, until one is able to change the undesirable predisposition, one has to keep adapting to the same. Thus, rainfed farming also has similar lessons for the farmers, that instead of adapting the natural environments to specific crops, it is also possible to adapt the crop or cropping patterns to the prevailing environmental conditions. In the context of farming/cultivation, natural environments have traditionally been described through various agroclimatic variables like temperature, precipitation, potential evapotranspiration, soil type, crop potential productivity, moisture deficiency etc. Further, out of the various agroclimatic variables, while soil and physiographic characteristics change largely with locations, the climatic variables vary not only with *locations* but also with *time*. Under tropical conditions, seasonal fluctuations of the air temperature generally tend to have much less effect on cropping patterns, as much as they do in the temperate regions. However, year round cultivation largely depends on availability of water (Oldeman and Frere, 1982). In such a scenario, the distributional pattern and production potentiality of paddy crop is closely linked with the length of growing period and frequency of dry spells of different lengths. Further, in the area of erratic rainfall, or in areas where the growing season is interspersed with one or more weeks of dry period, having the knowledge of probability of such dry spells is of great importance. If the dry periods coincides with the critical crop growth stages, there may be irreversible damages to the crop resulting in reduced production. This warrants a comprehensive knowledge of the probability of adequate rainfall in the area concerned because of the economic implications on the precipitation sensitive rice crop operations.

Dry spell probabilities have been studied by many researchers (Basu, 1971; Khambhete and Biswas, 1984; Dabral, Purkayastha and Aram, 2014). In the study area, kharif paddy is the dominant crop grown that supports a sizable number of farmers. In the following section, a discussion on the length of growing period for kharif paddy based on the onset and termination of rainy season based on forward and backward accumulation method is presented.

The study area has six rain gauge sites, of which Jharbandh is on the north western part close to a local hill, Paikmal lies close by, Padampur and Gaisilet lie in the central portion of the basin, whereas Sohela and Bijepur are in the eastern most part of the basin. Daily Rainfall data for these stations were collected from the Sub-Collector Office, Padampur. The daily rain fall data were segregated into 52 IMD Standard Meteorological Weekly (SMW) rainfalls. The criterion suggested by Morris and Zandstra (1978) that an accumulated rainfall of 75mm for dry seeded rice and 200 mm of accumulated rainfall for transplanted rice for the onset of the growing season has been followed in the study. They also suggested that 300 m accumulated (backward) rainfall represents termination of wet season, after which sufficient/adequate rain can be expected to sustain a second crop assuming a fully recharged soil profile (Debnath, 2000). The variability of an accumulated rainfall amount viz. 75mm, 299 mm or 300 mm etc. for different stations, has been analysed as suggested by Oldeman and Frere (1982). Here, each rain fall record is assigned a ranking number, m to give the probability levels Fa(m) that is calculated as Fa(m)= 100[m/(n+1)]………………(1), where n is the number of years.

The frequency and probability of dry spells have been calculated following Markov Chain Model as described by Robertson (1976). In this study, a week is considered Dry when the weekly precipitation is less than the weekly potential evapotranspiration. The weekly potential evapotranspiration has been calculated from the ET values given by Lenka (1991) for different stations in Odisha.

The probabilities of dry weeks, as per Markov Chain Model, are calculated as:

P(D)=F(D)/N…………………………………………..(2)

P(DD)= F(DD)/F(D)…………………………………(3)

Where, P(D): the probability of a dry week,

F(D)= Frequency of a particular week being dry

P(DD)= Probability of a week being dry preceded by another dry week

F(DD)= Frequency of a week being dry preceded by a dry week.

N=Number of years

The onset and termination of the Rainy season has been determined by forward and backward accumulation of weekly rainfall. The result is presented in the figures (Fig no.3.7 to 3.12). The results have been discussed at 75% probability level. It can be noticed that, whereas for Bijepur and Paikmal, the accumulated 75mm Rainfall are received in the 24th week, for Gaisilet, Padampur, Jharbandh and Sohela, the same amount is received only in the 25th week. Similarly, the same graphs also show that, 200 mm of accumulated Rainfall is received in the 26th week in Bijepur and Paikmal and the same is received in the 28th week in rest of the stations. It can be noticed that, for Gaisilet, Padampur, Jharbandh and Sohela, not only the receipt of 75 mm is delayed by a week; it takes another 3weeks to accumulate 200 mm rainfall. In Bijepur, the receipt of 75mm is earlier and also the accumulation to 200 mm is one week shorter than the rest.

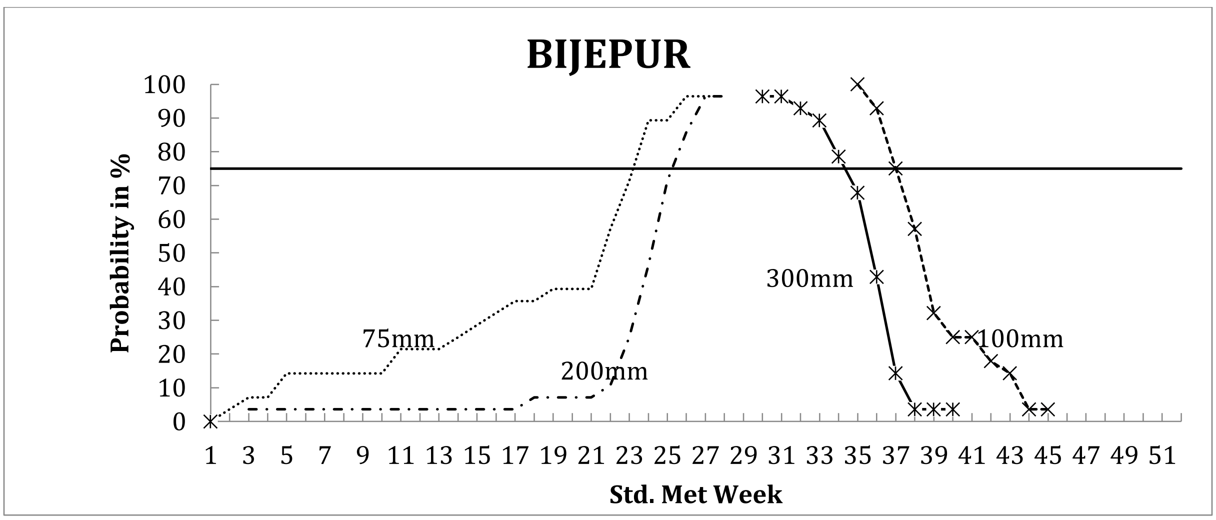

Figure No.3.8 Accumulated Rainfall Probability

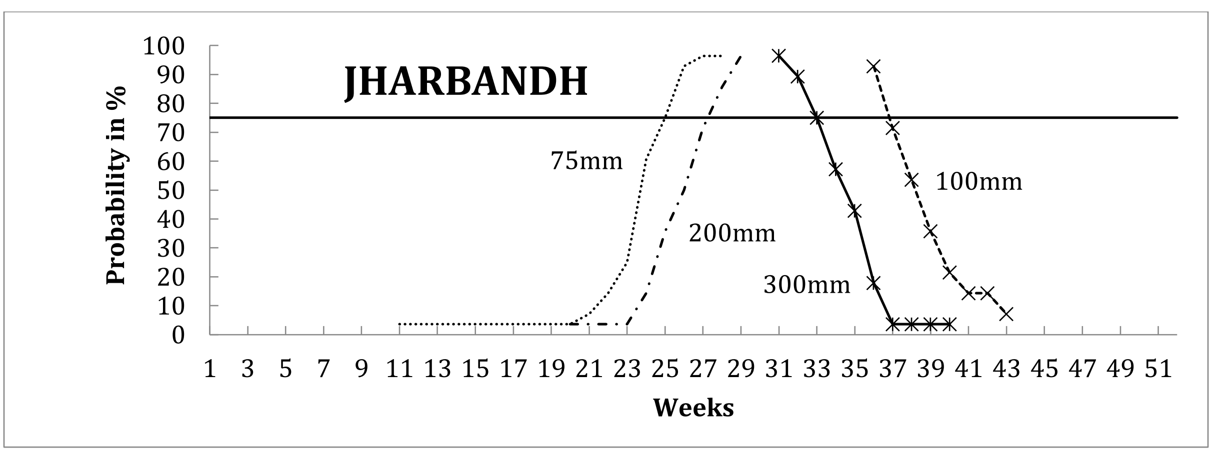

Figure No.3.9 Accumulated Rainfall Probability

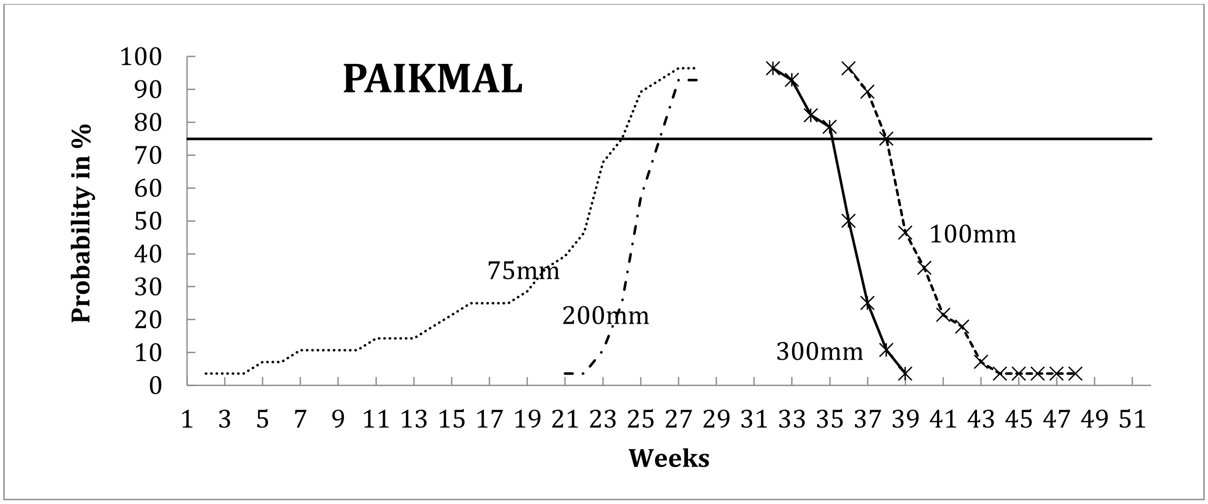

Figure No.3.10 Accumulated Rainfall Probability

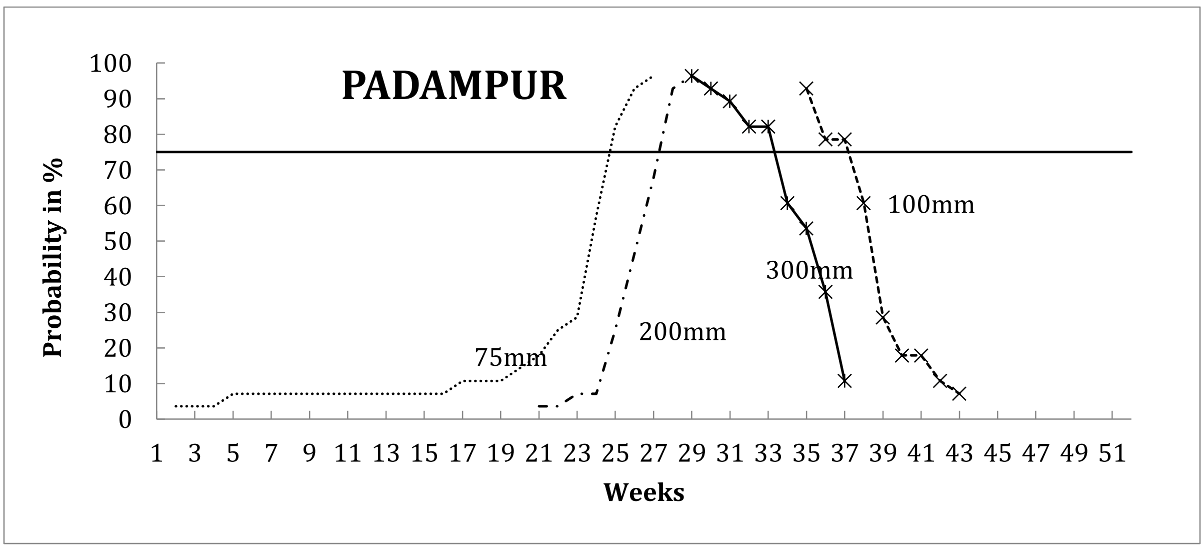

Figure No.3.11 Accumulated Rainfall Probability

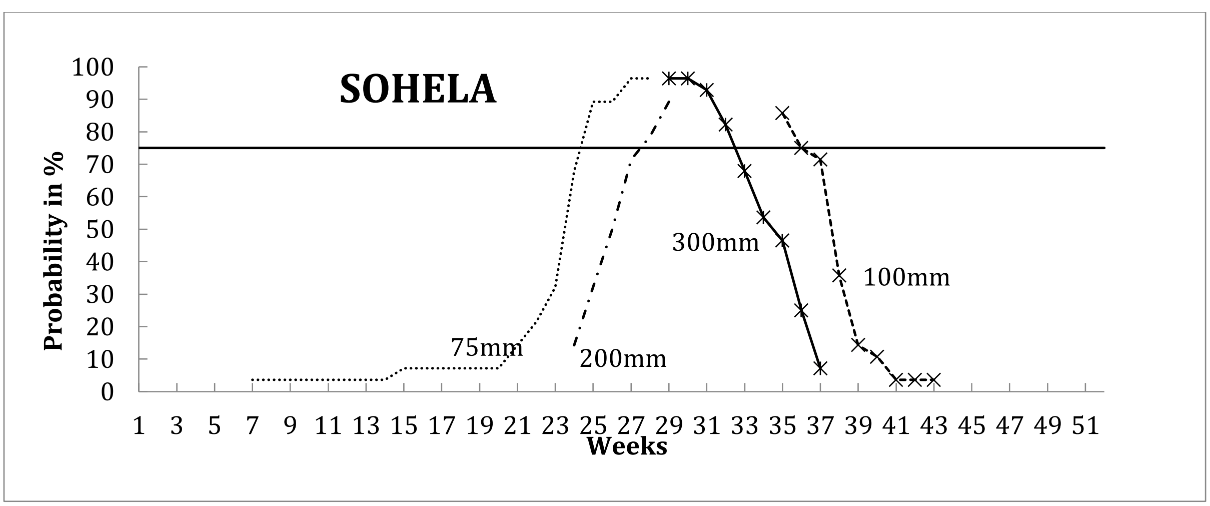

Figure No.3.12 Accumulated Rainfall Probability

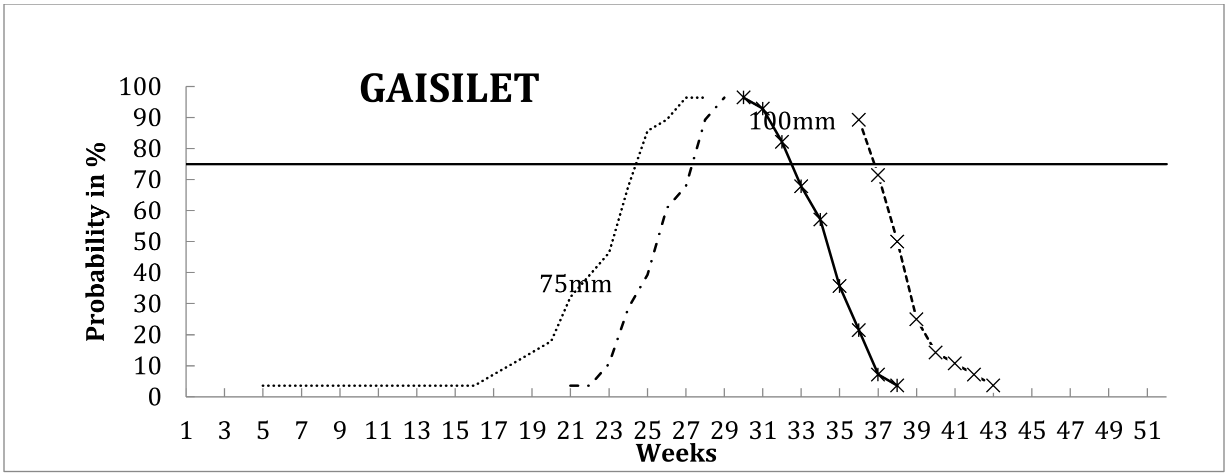

Figure No.3.13 Accumulated Rainfall Probability

The graphs also indicate that, in three out of six stations, namely, Gaisilet, Jharbandh and Sohela at least 100 mm rainfall can be expected only from the 36th week (the week ending on 9th of September). In the rest, it can be expected from 37th week. It may be noted that similar amount of rainfall can be expected up till the 39th week (end of September) in the coastal Odisha (Debnath, 2000). Similarly, 300 mm accumulated rainfall can be expected from as early as 32nd week (6th -12th August) at Sohela and Gaisilet. The corresponding weeks for 300 mm rainfall are 33rd for Jharbandh and Padampur, and 35th (27th August- 2nd September) week at Paikmal.

From the above discussion, it can be seen that, in case of dry seeding, growing season at the earliest can be started in the 24th week (ending on 17th June). For half of the stations in the basin, it takes 3 long weeks for accumulating 200mm rainfall from 75mm, the time when the transplanted rice growing season can be started. In case of backward accumulation, increase in accumulated rainfall from 100mm to 500mm, the cutoff date for all the stations is 32nd week.

3.8 Probability of Occurrence of Dry Weeks

In the previous section, we discussed the probable week when rainfall amount exceeds the normative amount of 75 mm and 200 mm required for initiation of cultivation activity for dry seeded rice and transplanted rice respectively. This is quite crucial in that, a few weeks delay of the initiation of rainfall sufficient to start the rice cultivation can lead to significant changes in the potential yield from rice. However, there is another important aspect which must be looked into- what happens thereafter? In other words, in what manner rainfall is distributed in the weeks that follow after the initial sufficient rain fall is received to start the cultivation of rice. This is important because rice as a crop, like many other crops, is quite sensitive to water requirements in their critical stages. Thus in this section, an analysis has been undertaken to see the probability of dryness of any particular week in the year. However, the discussion is restricted to the weeks coinciding with those of Rice cultivation which mostly spans from SMW 17 to SMW 45. The occurrence of a week being dry, its probability has been calculated through Markov chain model as discussed earlier and is presented in Table 3.3 and 3.4 .

It can be seen from the Table 3.3 and 3.4 that a week being dry in the initial 4-5 weeks ranges between 0.63 to 0.89 in Bijepur, 0.70 to 0.92 in Gaisilet, from 0.63 to 1 in Jharbandh, 0.59 to 0.93 in Paikmal, from 0.74 to 0.96 in Padampur, from 0.74 to 1 in Sohela. Less than 50 % probability of a week being dry ranges from SMW 27 to SMW 36 overall in all the stations in Ong river basin.

Table No. 3.3a Probability of Dry Weeks in Ong River Basin, July 1991 - Dec 2018

Week End Date		**BIJEPUR**					**SOHELA**					**GAISILET**				
	SMW	**F(D)**	**F(DD)**	**P(D)**	**P(DD)**	**PD2**	**F(D)**	**F(DD)**	**P(D)**	**P(DD)**	**PD2**	**F(D)**	**F(DD)**	**P(D)**	**P(DD)**	**PD2**
22-Apr	*16*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
29-Apr	*17*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
06-May	*18*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
13-May	*19*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
20 ay	*20*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
27-May	*21*	27	12	1.00	0.44	0.44	27	11	1.00	0.41	0.41	27	16	1.00	0.59	0.59
03-Jun	*22*	12	11	0.44	0.92	0.92	11	11	0.41	1.00	1.00	16	16	0.59	1.00	1.00
10-Jun	*23*	24	16	0.89	0.67	0.30	27	23	1.00	0.85	0.35	25	23	0.93	0.92	0.55
17-Jun	*24*	17	12	0.63	0.71	0.63	23	17	0.85	0.74	0.74	24	18	0.89	0.75	0.69
24-Jun	*25*	19	11	0.70	0.58	0.36	20	16	0.74	0.80	0.68	19	15	0.70	0.79	0.70
01-Jul	*26*	18	13	0.67	0.72	0.51	23	19	0.85	0.83	0.61	22	15	0.81	0.68	0.48
08-Jul	*27*	17	10	0.61	0.59	0.39	22	13	0.79	0.59	0.50	20	11	0.71	0.55	0.45
15-Jul	*28*	14	5	0.50	0.36	0.22	15	5	0.54	0.33	0.26	15	7	0.54	0.47	0.33
22-Jul	*29*	7	2	0.25	0.29	0.14	9	1	0.32	0.11	0.06	11	5	0.39	0.45	0.24
29-Jul	*30*	9	5	0.32	0.56	0.14	8	3	0.29	0.38	0.12	10	5	0.36	0.50	0.20
05-Aug	*31*	10	4	0.36	0.40	0.13	8	3	0.29	0.38	0.11	8	3	0.29	0.38	0.13
12-Aug	*32*	11	1	0.39	0.09	0.03	13	4	0.46	0.31	0.09	9	4	0.32	0.44	0.13
19-Aug	*33*	6	1	0.21	0.17	0.07	13	3	0.46	0.23	0.11	12	8	0.43	0.67	0.21
26-Aug	*34*	8	4	0.29	0.50	0.11	12	6	0.43	0.50	0.23	15	10	0.54	0.67	0.29
02-Sep	*35*	9	2	0.32	0.22	0.06	15	9	0.54	0.60	0.26	15	10	0.54	0.67	0.36
09-Sep	*36*	11	9	0.39	0.82	0.26	15	11	0.54	0.73	0.39	16	12	0.57	0.75	0.40
16-Sep	*37*	17	10	0.61	0.59	0.23	18	13	0.64	0.72	0.39	16	11	0.57	0.69	0.39
23-Sep	*38*	15	14	0.54	0.93	0.57	22	19	0.79	0.86	0.56	21	18	0.75	0.86	0.49
30-Sep	*39*	26	23	0.93	0.88	0.47	25	23	0.89	0.92	0.72	25	23	0.89	0.92	0.69
07-Oct	*40*	25	23	0.89	0.92	0.85	26	23	0.93	0.88	0.79	25	24	0.89	0.96	0.86
14-Oct	*41*	24	22	0.86	0.92	0.82	24	24	0.86	1.00	0.93	26	25	0.93	0.96	0.86
21-Oct	*42*	26	25	0.93	0.96	0.82	28	25	1.00	0.89	0.77	27	25	0.96	0.93	0.86
28-Oct	*43*	25	25	0.89	1.00	0.93	25	25	0.89	1.00	1.00	26	26	0.93	1.00	0.96
04-Nov	*44*	28	25	1.00	0.89	0.80	28	27	1.00	0.96	0.86	28	27	1.00	0.96	0.90
11-Nov	*45*	25	0	0.89	0.00	0.00	27	0	0.96	0.00	0.00	27	0	0.96	0.00	0.00

Table No. 3.3b Probability of Dry Weeks in Ong River Basin, July 1991 - Dec 2018

Week End Date		PADAMPUR					PAIKMAL					JHARBANDH				
	SMW	F(D)	F(DD)	P(D)	P(DD)	PD2	F(D)	F(DD)	P(D)	P(DD)	PD2	F(D)	F(DD)	P(D)	P(DD)	PD2
22-Apr	*16*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
29-Apr	*17*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
06-May	*18*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
13-May	*19*	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00	27	27	1.00	1.00	1.00
20 ay	*20*	27	26	1.00	0.96	0.96	27	26	1.00	0.96	0.96	27	26	1.00	0.96	0.96
27-May	*21*	26	14	0.96	0.54	0.54	26	16	0.96	0.62	0.62	26	14	0.96	0.54	0.54
03-Jun	*22*	15	15	0.56	1.00	0.96	17	15	0.63	0.88	0.85	15	15	0.56	1.00	0.96
10-Jun	*23*	26	20	0.96	0.77	0.43	25	20	0.93	0.80	0.50	27	22	1.00	0.81	0.45
17-Jun	*24*	21	16	0.78	0.76	0.73	21	14	0.78	0.67	0.62	22	16	0.81	0.73	0.73
24-Jun	*25*	20	15	0.74	0.75	0.58	17	11	0.63	0.65	0.50	20	11	0.74	0.55	0.45
01-Jul	*26*	22	17	0.81	0.77	0.57	16	8	0.59	0.50	0.31	17	14	0.63	0.82	0.61
08-Jul	*27*	20	7	0.71	0.35	0.29	12	4	0.43	0.33	0.20	19	9	0.68	0.47	0.30
15-Jul	*28*	12	5	0.43	0.42	0.30	7	1	0.25	0.14	0.06	12	3	0.43	0.25	0.17
22-Jul	*29*	10	5	0.36	0.50	0.21	8	3	0.29	0.38	0.09	10	2	0.36	0.20	0.09
29-Jul	*30*	15	7	0.54	0.47	0.17	9	4	0.32	0.44	0.13	11	5	0.39	0.45	0.16
05-Aug	*31*	11	4	0.39	0.36	0.19	11	3	0.39	0.27	0.09	8	2	0.29	0.25	0.10
12-Aug	*32*	10	2	0.36	0.20	0.08	9	2	0.32	0.22	0.09	9	4	0.32	0.44	0.13
19-Aug	*33*	11	5	0.39	0.45	0.16	11	4	0.39	0.36	0.12	13	9	0.46	0.69	0.22
26-Aug	*34*	14	5	0.50	0.36	0.14	11	2	0.39	0.18	0.07	16	7	0.57	0.44	0.20
02-Sep	*35*	12	7	0.43	0.58	0.29	6	3	0.21	0.50	0.20	12	6	0.43	0.50	0.29
09-Sep	*36*	15	10	0.54	0.67	0.29	8	5	0.29	0.63	0.13	15	8	0.54	0.53	0.23
16-Sep	*37*	16	11	0.57	0.69	0.37	14	7	0.50	0.50	0.14	16	10	0.57	0.63	0.33
23-Sep	*38*	20	15	0.71	0.75	0.43	18	14	0.64	0.78	0.39	18	16	0.64	0.89	0.51
30-Sep	*39*	23	21	0.82	0.91	0.65	22	19	0.79	0.86	0.56	24	19	0.86	0.79	0.51
07-Oct	*40*	25	24	0.89	0.96	0.79	22	20	0.79	0.91	0.71	23	21	0.82	0.91	0.78
14-Oct	*41*	26	25	0.93	0.96	0.86	24	21	0.86	0.88	0.69	25	24	0.89	0.96	0.79
21-Oct	*42*	27	25	0.96	0.93	0.86	25	24	0.89	0.96	0.82	27	22	0.96	0.81	0.73
28-Oct	*43*	25	24	0.89	0.96	0.93	27	27	0.96	1.00	0.89	22	22	0.79	1.00	0.96
04-Nov	*44*	27	26	0.96	0.96	0.86	28	26	1.00	0.93	0.90	28	26	1.00	0.93	0.73
11-Nov	*45*	27	0	0.96	0.00	0.00	26	0	0.93	0.00	0.00	26	0	0.93	0.00	0.00

The probability of a week being dry followed by another dry week is less than 50% from 28th to 35th week in Bijepur, from 28th to 32nd week in Gaisilet, from 27th to 32nd week in Jharbandh, 27th to 34th week in Paikmal, 30th to 34th week in Padampur, 28th to 33rd week in Sohela. So in all the stations in the basin, the trend is quite variable.

From the probability of accumulated Rainfall, it can be seen that, the season with heavy rainfall sufficient to grow paddy is from around 23rd week to 36th week, a total of around 13 weeks (91 days). Thus, short paddy cultivars which can mature in 90 days like "short height early and very early maturing high yielding varieties like *Parijat, Ghanteswari , Pathara, Khandagiri, , Sidhanta, Mandakini* from OUAT, *Heera, Shatabdi, Kalinga-III, Vandana, Vanaprava and Sahbhagi Dhan* from CRRI" (RKMP Portal, undated) offer reasonable choice to the farmers. However, some of these varieties "in general are less tolerant to drought and get easily smothered by weed growth. In drought years they even yield less than the traditional varieties like ***Kalakeri, Kulia, Dular*** etc. These traditional rice varieties despite their low yield potential can tolerate moisture stress" (Das, undated), can be the ones to fall back upon by farmers (Das, undated). Taking into consideration the graphs on weekly accumulated rainfall along with the probability of two consecutive dry weeks, it can be concluded that, though the paddy cultivation operation is possible to be started from the 24th-25th week, it is not risk free, because till around 25th -26th week, more than 50% probability of two consecutive weeks being dry still persists in some of the stations. Thus, even the cultivation of dry seeded rice has its own risk in the study area.

The discussions on the temporal variability of rainfall at the annual, seasonal and weekly level indicate that, growing rice under rainfed condition in Ong River basin is not without risk. This was realized by the farmers with years of experience on growing rice in the area, and they came up with innovative approaches of conserving water and making it available to the field, whenever rain failed. One such innovation was harnessing the topography of the land. We saw in the previous chapter the general topography is undulating that contributes to a quick surface flow of rainfall. Thus, traditionally farmers' endevours was to check the flowing water through bunds for short period of time so as to use it as and when rain failed. Subject to the local topography, topo-terrain of the field, size of such bunds, the farmers could insure their harvest against the vagaries of the erratic rainfall. The next chapter presents a discussion on these local topo-innovations.

CHAPTER IV

GEO-ENVIRONMENTAL INNOVATIONS BY THE FARMERS

4.1 Introduction

We saw in the previous chapters that there are two kinds of disadvantages imposed by nature related to uneven topography and erratic precipitation. There have been attempts to face these disadvantages through geo-environmental innovations by the farmers of the Ong river basin through sustained interventions. Firstly, the unevenness of the land has been worked upon by the farmers through ages by leveling the undulated surface topography and carving out cultivable lands out of them. Though the challenges posed by nature have not yet been completely overcome, years of negotiation with nature by ingenuous farmers have nonetheless resulted in a four-fold topo-sequential classification of farmlands based on water retention capacity of the soil viz, *Aat, Maal, Berna and Bahal*. No wonder, this diversity of topoterrain types have their inherent advantages and challenges. The uncertainty of rainfall distributions has been traditionally been worked upon by conserving water in the time of abundance for its utilization during scarcity. Such conservation efforts greatly utilized the undulating terrain to somehow check the gushing waters down the slope by bunding them. The resulting structures, once to be found in abundance throughout the landscape, were diversely named as *Kata, Munda, Bandh and chahala* etc. depending on their scales of operation. All such structures can be generically termed as tanks. Just as their structural diversity over *space*, their management has also witnessed tremendous diversity over *time*. In the absence of any major dams in the study regions, these small and numerous tanks have been the lifelines of agriculture since a remarkable period of time. After a brief discussion on the change in the nature of their management operations over time, across ownerships, their present roles have been evaluated from the stand points of their *inherent challenges*, and challenges emanating *from bore wells* as the alternative and preferred source of irrigation.

In this context, the present chapter seeks to see the impacts of irrigated agriculture vis-a-vis unirrigated agriculture in the study area with a particular focus to study the impacts of topo-terrains on agricultural intensification, expenditures, uses of modern inputs and productivity To be specific, the following questions have been addressed: is the difference in crop productivity significant, if the source of irrigation changes and if one moves across the various topoterrains? How costs of cultivation, productivity etc. differ across different sources of irrigation and on the basis of the reach of a canal where the farm is situated, for the same crop? It also answers the variation in costs of cultivation, productivity and profit across these four types of land for the same crop. The underlying basis for this comparisons being that how do the inherent advantages and disadvantages of the topoterrains affect cultivation practices and to what extent the challenges imposed by nature have been neutralized or negotiated upon by the local farmers. Rice being the dominant crop in the region, the analysis has been primarily done with respect to paddy cultivation. Thus the chapter caters to meet the third objective of the study i.e. to study and assess the effect of geo-environmental and institutional innovations on paddy cultivation.

The analysis is based on primary survey carried out in the year 2018-19 of farms under tank irrigation, bore well irrigation and under unirrigated condition. Specifically, the hypotheses to be tested in this chapter are as under:

- There is significant difference in productivity across different topoterrains, with increase in productivity as one goes from the upland to the low lands.
- The use of inputs is also different across topo-terrainic variation.
- There is higher productivity and input use in farms irrigated by borewells than those irrigated from tanks, which is more than those under unirrigated condition.
- There is significant difference in productivity and input use across farms located in different canal reaches like head, middle and tail reaches under tank irrigated conditions.

- Since the farms under Odisha Community tank management Project (OCTMP) have more equitable water distribution owing to their greater emphasis on effective functioning of pani panchayats, the difference in productivity and input use is more uniform across different canal reaches, (head, middle and tail) as compared to those not receiving OCTMP interventions.

4.2 Human negotiation against nature's imposition: Evolution of Tanks and topo-terrain land classification

As can be seen from the analysis in the third chapter on characteristics of precipitation in the river basin, the region is afflicted with non-uniform rainfall distribution, so much so that, many of the previous researchers, especially a few climatologists have opined that Paddy should *not* be grown in the region (Debnath, 2000). However, the region is having a long history of paddy cultivation. How was that possible? Historically, farmers in the region have depended on numerous tanks built by capitalising on the undulating topography of the region- a remarkable geo-environmental innovation exemplifying human negotiation against nature's imposition of uneven distribution of precipitation. Tanks, thus have acted to provide an insurance against rainfall erraticity. In the following sections, we will discuss the evolution, their management and the present governmental initiatives in place to sustain the tanks. Similarly, farmers have negotiated with the undulating topography of the land to carve out fourfold topoterrains to carry out cultivation. Both these innovations are presented below, starting with their evolutions and followed by the implications they have on paddy cultivation in the basin.

4.2.1 Topo-terrainic farm differentiation as recorded in Gazetteers

Making his observation on the topography of Sambalpur district, with which the a large portion of the basin overlaps, O S S Mailey (1990), writes "The district consists of an undulating upland plane broken by rugged ranges of hills and isolated peaks… The configuration of the country, however, is exceedingly well adapted for tank making and the number of village tanks is one of the most prominent features. The lowlands are generally cultivated with rice and are skillfully embanked, manured and irrigated. The uplands are much less carefully cultivated are not embanked and grow miscellaneous crops such as pulses, sesamum, coarse rice and cotton" (Mailey, 1909). Such topo terrain classification assumes importance, as Mailey later opines, the most usual classification of the soils of the district is based on their position or level. This is an important consideration to the cultivator, since the country is undulating except along the banks of larger rivers, and consists of ridges and slopes and of the depressions between them. The four main divisions are *Aat, Mal, Berna and Bahal*.

> "….. a. ***Aat*** land consists of high lying land on a watershed, i.e. the uplands which are dependent on rainfall for moistures. They are as a rule, sandy and are cultivated with oil-seeds, cotton and pulses. In recent time, these lands are being cultivated with dry seeding rice during monsoon season, though the productivity from them is noticeably low.
>
> b. The term ***Mal*** is used for the slopes which are terraced to catch the surface drainage coming down from the uplands. The lower terraces are wider and deeper than the upper and cultivators carefully recognize the great difference in fertility and in security of cropping between them. "The higher *Mal* lands are light and dry yielding light early crops which receive a little more attention than the chance crops on unembanked *Aat* lands". The lower Mal lands called *pita Mal* get excellent drainage and grow good varieties of rice.
>
> c. The term ***Berna*** denotes lands *towards the bottom* of a depression, which receives the drainage from the slopes on either side and also from the drainage line between them. *Berna* land vary considerably according to their steepness and the stage of their development. In the newly broken up land, they are liable to have sand and gravel washed into them, but where it is under close cultivation, the embankments of the terraced slopes prevent this.

d. ***Bahal*** is a term used for flat land *at the bottom* of a depression or drainage line; the chief distinction between *Berna* and *Bahal* being that the former is narrow and steep, and the latter wide and leveled. There is also considerable difference between a *wide-Bahal* lying between long slopes and receiving ample drainage from them and a *narrow-Bahal* lying between short steep slopes. Also the best *Bahal* lands are served by the widest and largest irrigation reservoirs, and so are secure from crop failures.

Bahal, *Berna*, *Mal* lands are, as a rule under rice, as they receive rain-washed detritus of fertile silt down to them while *Aat* lands are used for other crops which are less dependent on moisture or those varieties of dry seeded, early maturing rice breeds which thrive on limited rainfall. “Throughout the district there is more variation in the unembanked *Aat* land growing light miscellaneous crops than the rice land. It's soil in a closely cultivated tract is often little better than exhausted sand and gravel. In hilly wooded country it is more fertile, but it's crops suffer from the depredations of wild animals” (King, 1932).

4.2.2 Tanks: A local structural Innovation

It is evident from the analysis of precipitation that though the total annual rainfall is not very low, there is very high variability in its distribution over the year. There are spells of high rainfall followed by spells of dryness. After the Rains, water rapidly flows away due to the undulating terrain. “The design of the indigenous earthen tanks seems most appropriate for retaining surface water for use in dry months. Not surprisingly, every village in Western Orissa has a network of tanks” (Sengupta, 2000). Many of the focus group discussions by the researcher during field visit conducted in 2018-19 revealed that the tanks have an obscure origin, though there are some tanks which are recently built by some of the prosperous landowners. Whatever their origin, tanks have acted as reliable structures of protective irrigation for crops.

Historically, there are three kinds of tanks which are found in the region, viz. the *Kata*, *Munda* and *Bandh*. An ordinary irrigation tank which is known as *Kata* is constructed by "throwing a strong earthen embankment slightly curved at the ends across a drainage line so as to hold up an irregularly shaped sheet of water. The undulations of the locality usually determine its shape as that of a long isosceles triangle of which the dam forms the base" (Malley, 1909). It irrigates the *Bahal* land, a valley on its down streams. On the sides of Bahal, there are Maal terraces. "As a rule, there is a cutting high up the slope near one end of the embankment. From this, the water is led by a small channel or *tal* from field to field along the terraces down" (Malley, 1909) which it finds its way to the lowland. In normal rainfall years, irrigation may be entirely unnecessary and in that case the superfluous water is passed along until it falls into the *nullah* in which the small valley ends. In years of short rainfall, the centre of the tank is sometimes cut through, when the bottom lands need irrigation, but in ordinary years such an expedient would be dangerous for the water is deepest at the centre and no sluices are used. Such tanks supply water to at least 5 acres and usually to an area of 30 to 200 acres.

The *Munda* is an "embankment of smaller size across a drainage channel". Embankments of this sort are very common as they can easily be constructed by the *ryots* themselves for the benefit of their own holdings. These farmers have perhaps a few fields commanded by the main village tank, but have built *Munda*s to protect their outlying fields, more recently acquired from others or reclaimed from the wasteland. For its purpose, the *Munda* is useful for, if a failure of rain is not very serious, it may provide water enough in the later months of growth to save the crop. But it is necessarily shallow and cannot give a certain supply.

The *Bandh* is a four sided tank usuallay excavated just below the *Kata.* Usually a *bandh* stores water derived through percolation from the head *Kata and t*hey are invariably used mostly for drinking purpose, are properly regarded as suitable monuments of piety or charity and are invariably consecrated or married to a God. Apart from their obvious sanitary advantages, they add to the irrigated area by spreading percolation and by rendering it possible in years of drought to empty the irrigation tank completely without danger.

4.2.3 Promotion of Tank building

The construction of tanks was of such vital importance that concessions were given to encourage it. During the British rule under *Article 390 and 402* of the *Central Provinces Settlement Code,* a Gaontia or a ryot, who built a tank on his land, was entitled to remission of the revenue on the area submerged from the date on which the tank was completed. Similarly, in many instances the local rulers granted *Bhogra* lands (revenue tax exempted lands) to those engaged in the promotion and maintenance of tanks.

In the post-independent period, the distribution of water from the public tanks has hitherto been left in the hands of the panch, or village committee, and thus gives rise to much contention in a year of drought when no more Imperial and expert agency is available. Such an arrangement is necessary, for it is impossible to state definitely for every year what blocks of fields should first be irrigated from the public tanks. This is a question which depends largely on the various conditions of each year's rainfall, on the state of each tank, and on the state of the crops.

As regards the maintenance of tanks, the settlement officer writes as follows: "At last settlement, all the old tanks not constructed on the proprietary land of Gaontias were regarded as public property and were recorded as the property of the government. This step intended to prevent selfish or short sighted misuse and encroachment has probably been of real service. But encroachment on the beds of public tanks has been the rule rather than exception. Many cases have come to light in which part of the beds of the old tanks, temporarily cropped at last settlement, were then entered in private holdings. It has been found to be impossible to legally dispossess the encroachers and as they can now claim damages if their crops are submerged, many Gaontias who wish to restore old tanks to their former level are deterred from doing so. The abuse is a result of the imperfect system of repair adopted by the villagers. As they have pressing need for irrigation only once or twice in 8 or 10 years they do not annually repair embankments, but allow them to lose a few inches every year by the wash of rain until the water level has fallen two or three feet when a subscription is called for and the earth work made up. But in the intervening years, the falling water exposes round the upper edge of the tank, a strip of rich land into which the nearest cultivators are tempted to turn their ploughs, the Gaontia himself not infrequently a transgressor" (Malley, 1909). Thus, one can see tanks face a variety of challenges in terms of their maintenance since long back.

4.2.4 Proliferation of the Tanks

Though the origin of many of the tanks are not easily recalled by the people, certain important changes in the land revenue administration seem to have definitive impact on the proliferation of tank building in the region. Prior to the advent of the Maratha rulers in the early 18th century, most of the fertile land was held by tribal headman as hereditary 'Gountias'. The tribal *zamnidars* and kings commissioned irrigation structures; invariably embankments on the highest level of land to harvest rainwater which enabled the tribal communities some settled agriculture along with forest based subsistence. Cropping pattern of the time had an inbuilt mechanism of drought resistance. The *Aat* lands were sown with low moisture requiring short duration paddy that could be harvested within 40-60 days mostly bypassing the rainfall erraticism of late September and October months. Long Paddy of 120- 160 days occupied the secure *Bahal* land. The prevalence of dry land paddy along with pulses and oil seeds somewhat ensured optimal supply of food even when rain failed for a particular year.

With the advent of the Marathas, the strong tribal hereditary Gountiahi or tribal headman ship underwent through widespread change of hands a system of auctioning of villages was introduced. The lessee became the new headman. Between 1850-70, many tribal hereditary Gountias were dispossessed of their villages due the their failure to pay a fee called nazrana, that was needed to be paid now, each time the lease was to be renewed. The role and definition of the Gountia changed bringing along with it a fundamental change in the cultivation pattern in the village. The role of Gountia as a revenue collector became entrenched with the British land revenue system. Revenue maximisation was the major emphasis post the first settlement operation in 1870. Large tract of previously inaccessible land, wasteland and land held under various service grants were also brought under revenue assessment and the Gountia was responsible for payment of the revenue assessed from the village. For the non-tribal Gountias, growing and securing a good crop of wetland rice from *Bahal* land was important from the point of view of revenue maximisation. Thus, the aforesaid changes in the Gountiahi system accompanied by high revenue demands laid the foundation of intensive agriculture in the area. The unprecedented requirement for wetland rice which only could meet the higher demands for revenue warranted a proliferation of tanks in the region. The British administration provided a protected status to a Gountia, who otherwise was merely a thekedar with no absolute claims of renewal of his lease, if he spent largely on tanks. Secretariat letter number 44436-212 dated July 1889, issued by the Officiating Commissioner, Chhatishgarh division states among other things that: a protected status will be given to Gountias who have: (a) been 20 years or more in the possession of their villages, (b) been actual reclaimers of the village or (c) spent largely on tanks and settlement of raiyats (Das, 1946).

Rice cultivation already on the rise received another tremendous boost with the introduction of the branch line of Bengal-Nagpur railways to Sambalpur in 1896. There was new demand for the low cost tank irrigated rice. However, in the post independent era, when they became govt. property, Sengupta (2000) observes their decline started to appear, because under the panchayats, their maintenance suffered galore, as they lost the greater care previously available under the gaontias and zamindars who also had a selfish interest to take care of them to maximize revenue from the tank command areas. Years of improper attention and lack of technical expertise were perceived by the government to be the main reasons for the decline of numerous tanks.

4. 3 Tanks in the Post-Independent Period

In an effort to set things right and to provide the tanks with technical expertise, the Minor Irrigation Organization "(Erstwhile Rural Engineering Organization i.e. R.E.O) was created in the year 1962 under Rural Development Dept. After the abolition of the R. D, Dept. on 15.06.1980, Minor Irrigation (M.I) Organization was brought-over under Irrigation & Power Dept. Again it came under R. D. Dept. from 24.03.1990. Finally since 1996, it is under Water Resources (W.R.) Department" (DoWR, 2018). There are 19 numbers of territorial M.I.Divisions in the State of Odisha headed by Executive Engineers who are in charge of operation, repair/ maintenance of existing M.I.Projects and construction of new M.I.Projects. Majority of the area under the Ong river basin falls under the Padampur MI Division that is part of the Northern Minor Irrigation Circle in Sambalpur. "The Sub-Divisional Officers (A.E. & A.E.E.) assist the Executive Engineers in preparation of estimates, execution of work in field etc. The Junior Engineers work under different Sub-Divisions under the guidance of the Sub-Divisional officers. The Junior Engineers are responsible for survey, investigation, preparation of estimates, execution of work and preparation of bills for payments. They are also responsible for supply of irrigation water to the designated ayacut with the help of the field staff engaged in the projects. Minor Irrigation (Flow) organization takes care of construction, maintenance and management of Irrigation tanks of Culturable Command Area (CCA) between 40 Ha to 2000 Ha utilizing the surface flow, more commonly known as Minor Irrigation Projects (MIPs). Tanks with command area less than 40 Ha are still managed by the Panchayat bodies. Minor Irrigation projects are admired due to its lower cost, lower gestation period and very low rehabilitation & resettlement problem in construction. Efforts are also being made to complete new MIPs within a span of 2 to 3 years time to harvest immediate benefit. Initiatives have also been taken to renovate/ modernize the completed but not fully functional Projects, Partly Derelict (PD) and Completely Derelict (CD) Projects in phases under various schemes like RIDF, AIBP, External Assistance, Centrally sponsored scheme, RSVY, NFFW, FC, RR&R of Water bodies, ACA, FFW, BKVY, etc." (DoWR, 2018)

However, provision of technical expertise alone is not a guarantee for proper functioning of the tanks. The institutional aspect of governing a tank is equally important. Of late, emphasis is being given on farmers' participation in the maintenance and operation of the projects, mainly to have the equitable distribution of water (see details on current institutional aspects is covered in chapter V). For this objective, under the Pani Panchayat Act, 2002, Pani Panchayats (Water Users Associations) have been formed and some are in the process of formations who have taken the work of maintenance & operation of the MIPs. Finally, to give a boost to tanks, a world bank assisted programme called Orissa Community Tank Management Project (OCTMP) was launched in the year 2009, with greater emphasis on strengthening the institutional aspects of tank management in the state (discussed in details later in the chapter and in chapter V). Two of the Minor irrigation projects (MIPs) inside the Ong river basin, namely Batterma and Jhagadjhal were taken up under OCTMP.

4.4 Database and Methods

The data used for this chapter was collected through primary survey in 2018-19. Keeping in mind the objectives and hypotheses of the study, farm level data were collected for selected tanks. The topoterrains details of the farms were collected, along with the sources of any irrigation, or the lack of it (unirrigated farms). Similarly, care was taken to select farmers from all the different canal reaches like Head, Middle and Tail reaches were collected. Likewise, tanks have been selected so as to cover those under MIP, those under Panchayat unions and those receiving OCTMP interventions. Along with the primary survey through survey schedules (see annexure), focussed Group discussions were conducted with different farmers groups to understand their perceptions related to cultivation and irrigation facilities available to them. Though data for different crops were collected, since rice was the dominant crop, the analysis has been restricted to input cost and income from paddy alone.

The data collected were analysed with various simple statistical techniques and presented below. Various descriptive and inferential statistical tools were employed to understand the implications of the data and prove the hypotheses. In this chapter, an attempt has been made to understand how different (i) topoterrains, (ii) sources of irrigation and (iii) canal reaches of the farms affect the way farming of rice is done, so as to assess the extent to which the geo-environmental innovations like topoterrains and tanks impact cultivation practices. Basically, farms differing in these three aspects have been compared. Farms under these differing conditions are expected to differ in the way inputs are applied and income is received from those. Descriptive statistics like mean and standard deviations are presented in the tables. Mean (cost and income) values are presented in rupees term (decimals dropped intentionally) in each table. Further to check the hypotheses, inferential statistics like test of ANOVA has been conducted.

Formula for ANOVA

Since in most cases the group size differed, that is we are comparing different number of farms for some parameters (cost and income), Welch test values are given, which has been found out using formula, as under:

$$t^{'} = \frac{\mu_1 - \mu_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where,

$t^{'}$= Welch test statistic

μ_1, μ_2 are group means

s_1^2 is the variance of first group

s_2^2= the variance of the second group

n_1= size of group 1

n_2= size of group 2

The formula for the degrees of freedom is known as the Welch-Sattertwaite-equation and is calculated by:

$$d.f. = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{(s_1^2/n_1)^2/(n_1 - 1) + (s_1^2/n_2)^2/(n_2 - 1)}.$$

$$t = \frac{\mu_1 - \mu_2}{s_p^2\sqrt{\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

Where,

μ_1, μ_2 are the group means

S_p is the pooled Standard deviation and

s_p^2= pooled variance

n_1, n_2 are group sizes

And, where the pooled standard deviation is calculated by:

$$s_p^2 = \frac{(n_1\text{-}1)s_1^2 + (n_2\text{-}1)s_2^2}{n_1 + n_2\text{-}2}$$

Welch's *t*-test (t') does not pool the standard deviations(which is used in case of classic ANOVA), rather divides the variance in each group by the size of that group, as indicated above.

To see whether the assumption of homogeneity of variance is there, Levene statistics has been used that is calculated as under:

Levene's test is equivalent to a 1-way between-groups analysis of variance (ANOVA) with the dependent variable being the absolute value of the difference between a score and the mean of the group to which the score belongs (shown below $Z_{ij} = |Y_{ij} - Y_i$. The test statistic, W, is equivalent to the F-statistic that would be produced by such an ANOVA, and is defined as follows:

$$W = \frac{(N - k)}{(k - 1}.\frac{\sum_{i=1}^{k} N_i (Z_i - Z_{..})^2}{\sum_{i=1}^{k}\sum_{j=1}^{N_i}\left(Z_{ij} - Z_i\right)^2},$$

Where

- K is the number of different groups to which the sampled cases belong,
- N_i is the number of cases in the ith group,
- N is the total number of cases in all groups,
- Y_{ij} is the value of the measured variable for the jth case from the ith group,
- $Z_{ij} = \begin{cases} |Y_{ij} - \bar{Y}_{i.}| & \bar{Y}_i \text{ is a mean of the i-th group,} \\ |Y_{ij} - \bar{Y}_{i.}| & \bar{Y}_i \text{ is a median of the i-th group.} \end{cases}$

However, Welch test values give an overall omnibus difference among the groups and do not tell which specific groups differed and which do not. Thus, follow up tests were conducted to identify which of the pairs have significant difference and which have not. Depending on the value of Levene's statistics, suitable post hoc tests have been used. When there is homogeneity of variance among the group (Levene statistic is above *0.05*), Hochberg's post hoc tests has been used. However, if the assumption of homogeneity of variance is violated (Levene statistic < *0.05*), then Games Howell's post hoc test has been use using the formula:

The Games-Howell test is defined as $\bar{x}_i - \bar{x}_j > q\sigma, k, df$

Where σ is equal to standard error: $\sigma = \sqrt{\frac{1}{2}\left(\frac{s_i^2}{n_i} + \frac{s_j^2}{n_j}\right)}$

Degrees of freedom is calculated using Welch's correction: $\dfrac{\left(\frac{s_i^2}{n_i}+\frac{s_j^2}{n_j}\right)^2}{\frac{\left(\frac{s_i^2}{n_i}\right)^2}{n_i-1}+\frac{\left(\frac{s_j^2}{n_j}\right)^2}{n_j-1}}$

The t-value is found with Welch's t-test: $t = \dfrac{\bar{x}_i - \bar{x}_j}{\sqrt{\frac{s_i^2}{n_i}+\frac{s_j^2}{n_j}}}$

Thus, confidence intervals can be formed with: $\bar{x}_{i-}\bar{x}_j \pm t = \sqrt{\frac{1}{2}\left(\frac{s_i^2}{n_i}+\frac{s_j^2}{n_j}\right)}$

Lastly, p-values are calculated using Tukey's studentized range: $q_{t*}\sqrt{2, k, df}$

4.5 Expenditure on inputs and Income from Paddy in the study area

In this section, input costs and income analysis has been undertaken to see expense and earning status across topoterrains and sources of irrigation to see if there is significant differences in them.

4.5.1 Input use and Income under different topoterrains

The expenditure on inputs like seeds, chemical fertilizers, Organic manures, Pesticides, family labours, hired labours, Pumping costs, total inputs and total income at farm level has been found out and presented below.

4. 5.1.1 Expenditure on Paddy seeds

The table below presents the expenses on seeds by the farmers in the region. The cost is reflective of both their own seeds and purchased seeds. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the seeds. Whereas farmers in *Aat* lands spend on an average Rs. 637 per acre, its Rs 714, Rs. 746 and Rs. 943 per acre for the farmers in *Maal*, *Berna* and *Bahal* land respectively. One cannot miss the fact that, as one moves from the *Aat* to *Bahal* land, the expenses on seeds keeps increasing. It's because of the fact that in the upper reaches, farmers are forced to grow shorter paddy (early maturing varieties), which in a few cases are of traditional varieties and are less expensive. The low value of N for *Aat* farms is because of the fact that, *Aat*s are generally used for non-rice crops like pulses due to moisture constraints, and only in limited cases are under rice. In the lower reaches in *Berna* and certainly in *Bahal* lands, farmers are seen to be growing longer duration seeds, in many cases the HYV seeds which are higher in cost.

Table No 4.1 Expenditure on Paddy seeds across topoterrains

Topoterrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	943	375.15	F (3,278)=13.857 *P=0.000*	W(3, 278)=2.669 *P=0.048* Equal variance not assumed	F(3, 5.813)=11.287 *P=0.000*
Berna	47	746	248.90			
Maal	141	715	218.05			
Aat	18	637	130.65			
Total	282	777	288.54			

Further, test of ANOVA reveals that, the difference in costs of seeds across topoterrain is statistically significant (P value 0.000). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (P value 0.000) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (P value 0.000), Games Howell's post hoc test was computed. The result of the test is given as under:

Table No 4.1a Games-Howell Post hoc test on cost of seeds across topoterrains.

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	196.762*	56.302	.004
	Maal	228.604*	46.786	.000
	Aat	305.829*	52.915	.000
Berna	*Bahal*	-196.762*	56.302	.004
	Maal	31.842	40.686	.862
	Aat	109.067	47.607	.112
Maal	*Bahal*	-228.604*	46.786	.000
	Berna	-31.842	40.686	.862
	Aat	77.225	35.853	.159
Aat	*Bahal*	-305.829*	52.915	.000
	Berna	-109.067	47.607	.112
	Maal	-77.225	35.853	.159

** The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on seeds in *Bahal* land is significantly higher than those on other lands viz. *Berna*, *Maal* and *Aat* land. Further, the difference is significant between *Berna* and *Aat* land. No significant difference exists on expenditure on seeds between *Berna-Maal* and *Aat-Maal* lands. This is understandable as there is higher moisture availability in *Bahal* and *Berna* land owing to their geographical location in the bottom reaches within the local land ecosystem/topographic units, thereby being the bigger beneficiary of the available water and the nutrients flowing along with it, as compared to the higher reaches of *Maal* and *Aat* land, farmers are ready to spend more on farms located in the lower reaches.

4. 5.1.2 Expenditure on Chemical Fertilizer

The table below presents the expenses on chemical fertilizers by the farmers in the region. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on chemical fertilizers. Whereas farmers in Aat lands spend on an average Rs 1098 per acre, its Rs 2007, Rs 2585 and Rs 2700 per acre for the farmers in *Maal*, Berna and *Bahal* land respectively. There is a clear increasing pattern, as one moves from the Aat to *Bahal* land and the expenses on seeds keeps increasing. It's because of the fact that in the upper reaches there is short supply of moisture and its obvious that application of chemical fertilizers is thus curtailed. Only when there is provision of water through tanks, well etc.can fertilizers be applied. Under unirrigated conditions, its mostly manure that the farmers were seen to be applying on their fields. In the lower reaches in Berna and certainly in *Bahal* lands, farmers are seen to be growing longer duration seeds, in many cases the HYV seeds which also high in fertilizers consumption. As one of the seed-cum fertilizer shop owner put it during a discussion with the researcher, "… the longer a crop stays on the field, one needs to apply more rounds of fertilizer (and irrigation) on them. This simply requires the farmer to invest more on fertilizer as well as pesticides, insecticides etc. for such varieties". He was somewhat elated with the fact that, majority of the farmers are now opting for higher application of fertilizers, though their inaffordability doesn't allow them to do so. Simultaneously he submitted that, traditional varieties demanded less fertilizers but that is past now due to their lack of availability.

Table No 4.2 Expenditure on Chemical Fertilizer across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	2700	1574.42	F(3, 278)=8.299 P=0.000	W(3, 278)= 4.184 P=0.006 Equal Variance *not* assumed	F(3, 82.761)=17.896 P=0.000
Berna	47	2585	1331.05			
Maal	141	2007	1498.29			
Aat	18	1098	692.99			
Total	282	2232	1512.33			

Further, test of ANOVA reveals that, the difference in costs of chemical fertilizers across topoterrain is statistically significant (*P value 0.000*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. A follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.000*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table No 4.2a Games-Howell Post hoc test on expenditure on chemical fertilizers across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	115.327	265.163	.972
	Maal	693.398*	220.311	.011
	Aat	1602.652*	243.506	.000
Berna	*Bahal*	-115.327	265.163	.972
	Maal	578.071	231.553	.067
	Aat	1487.325*	253.723	.000
Maal	*Bahal*	-693.398*	220.311	.011
	Berna	-578.071	231.553	.067
	Aat	909.254*	206.399	.000
Aat	*Bahal*	-1602.652*	243.506	.000
	Berna	-1487.325*	253.723	.000
	Maal	-909.254*	206.399	.000

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on chemical fertilizers in *Aat* land is significantly lower than on all other lands viz. *Bahal*, Berrna and *Maal* land. Also there is significantly lower application of fertilizers in *Maal* land as compared to *Bahal* land. No significant difference, however, could be seen on expenditure on chemical fertilizers between *Bahal*-*Berna*, and *Berna*-*Maal* lands. Thus, we can say that, barring *Aat* land, rest of the topoterrains, showed no significant difference in fertilizers application with their immediate neighbouring topo sequentials. Thus the propensity of topoterrains in terms of their fertilizers application was found to less staggered among *Maal*, *Berna* and *Bahal* lands.

4. 5.1.3 Expenditure on Organic Manures

The table above presents the expenses on organic manures by the farmers in the region. The cost is reflective of both their own organic manures and purchased Organic Manures. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the organic manures. Whereas farmers in Aat lands spend on an average Rs. 674 per acre, its Rs. 1070, Rs. 1355 and Rs. 1541 per acre for the farmers in *Maal*, Berna and *Bahal* land respectively. One can see that, as one moves from the Aat to *Bahal* land, the expenses on organic manures keeps increasing. It may have to do with the variety of crops and the affordability of the farmers of these lands. Short duration paddy require less number of manuring which are predominantly on Aat land as compared to longer duration paddy that mostly adorn the low lands. The best varieties of low lands are usually owned by farmers with comparatively better economic background than the Aat owners. Further the expectancy of higher assured returns may also necessitate farmers to apply more manures on lands of more fertile variety. Lower returns from Aat also keeps farmers not to heavily invest in them. During the Focus Group Discussions (FGDs) by the researcher with the farmers in many villages, many farmers lamented that manure is getting less and less available lately and is out of reach by the poor farmers.

Table No 4.3 Expenditure on Organic Manures across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	1541	941.88	F(3, 278)=4.322	W(3, 278)= 1.385	F(3,74.069)=6.823
Berna	47	1355	982.04			
Maal	141	1070	1332.65	*P=0.005*	P= 0.248	*P=0.000*
Aat	18	674	753.76		Equal variance assumed.	
Total	282	1219	1172.65			

Further, test of ANOVA reveals that, the difference in expense on organic manures across topoterrain is statistically significant (P value 0.000). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (P value 0.000) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus a follow up test was conducted to identify which of the pairs have significant difference and which have not. However, equal variance was confirmed by Levene's statistic (P value 0.248), and Hochberg's post hoc test was computed that is suitable for unequal group size and equal variance. The result of the test is given as under:

Table No 4.3a Hochberg Post hoc test on expenditure on Organic Manures across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	186.010	213.845	.945
	Maal	470.939*	163.989	.026
	Aat	866.716*	302.081	.026
Berna	*Bahal*	-186.010	213.845	.945
	Maal	284.929	194.099	.602
	Aat	680.707	319.429	.186
Maal	*Bahal*	-470.939*	163.989	.026
	Berna	-284.929	194.099	.602
	Aat	395.778	288.440	.673
Aat	*Bahal*	-866.716*	302.081	.026
	Berna	-680.707	319.429	.186
	Maal	-395.778	288.440	.673

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on organic manures in *Bahal* land is significantly higher than those on *Maal* and *Aat* land. The difference in the use of organic manures is not statistically significant in other types of topo-terrains. One can note that, farmers use about 2.5 times more manures in *Bahal* over *Aat* lands, and 1.5 times more than on *Maal* lands. Expenditure on Manures in *Berna* and *Bahal* land is somewhat comparable. Further, one realizes that in the study villages, farmers were found to be spending almost twice as much on fertilizers over what they spent on organic manures. Their preference for chemical fertilizers is clearly visible, though its for further research what actually the dominant reason for this is; whether it's the imminent dearth of organic manures lately and especially at affordable prices, or the immediate visible results that chemical fertilizers can bring in terms of rise in yield. However, during informal discussions of the researcher, the Agricultural Extension Officers in Padampur confided that, many a times the farmers don't apply the appropriate doses of chemical fertilizers in their field and its mostly urea that they tend to use, whatever be the requirement of the field concerned. In effect, the higher expenditure on chemical fertilizers does not necessarily warrant higher yield from the field in commensurate with their expenses.

4. 5.1.4 Expenditure on Pesticides

The table below presents the expenses on Pesticides by the farmers in the region. The cost represents expenses on pesticides, weedicides and insecticides on paddy cultivation by the farmers. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the Pesticides. Whereas farmers in Aat lands spend on an average Rs. 530 per acre, its Rs. 905, Rs. 1127 and Rs. 1227 per acre for the farmers in *Maal*, Berna and *Bahal* land respectively. One can see that, as one moves from the Aat to *Bahal* land, the expenses on Pesticides keeps increasing. It may have to do with the variety of crops and the microclimate that these topoterrains offer. As was observed by the farmers during the researcher's FGD, pests and insects reportedly attack those farms more which are relatively swampy. *Bahal* lands are thus susceptible to pest and insect attack followed by Berna lands which are relatively moisture rich. This is not to say, in any manner that

Maal and Aat lands are free from pest attack, its just a matter of degree of preference for the pests. Anyway, it should also be noted that standing water in *Bahal* lands are also believed to be having a dispelling effect on weeds and pests. Conversely, lack of it makes *Bahal* and Berna the most preferred grounds for weed and pest attack. Short duration paddy requires less application of Pesticides due to their lower duration of standing on the land which are predominantly on Aat land as compared to longer duration paddy that mostly adorn the low lands. Farmers narrated their encounters with the widespread pest attack by locusts/grasshoppers, what they termed as "*Chakda Pok*" attack the previous year (2017), quite exasperatingly, when many farmers completely lost their harvests to *Chakda* and they could do nothing to save their crops. No pesticide would work against them.

Table No 4.4 Expenditure on Pesticides across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	1227	846.20	F(3, 278)=5.502	W(3, 278)= 3.027	F(3,76.647)=9.244
Berna	47	1127	801.93			
Maal	141	905	758.28	*P=0.001*	P= 0.030	*P=0.000*
Aat	18	530	425.92		Equal variance Not assumed.	
Total	282	1005	793.158			

Further, test of ANOVA reveals that, the difference in costs of pesticides across topoterrain is statistically significant (P value 0.001). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (P value 0.000) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. However, equal variance was not confirmed by Levene's statistic (P value 0.030), and Games-Howell's post hoc test was computed that is suitable for unequal group size and equal variance. The result of the test is given as under:

Table No 4.4a Games-Howell's Post hoc test on expenditure on Pesticides across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	99.997	152.001	.913
	Maal	321.792*	116.188	.032
	Aat	696.874*	139.642	.000
Berna	*Bahal*	-99.997	152.001	.913
	Maal	221.794	133.269	.350
	Aat	596.877*	154.146	.002
Maal	*Bahal*	-321.792*	116.188	.032
	Berna	-221.794	133.269	.350
	Aat	375.083*	118.980	.017
Aat	*Bahal*	-696.874*	139.642	.000
	Berna	-596.877*	154.146	.002
	Maal	-375.083*	118.980	.017

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on Pesticides in *Bahal* land is significantly higher than those on *Maal* and Aat land but not than Berna lands. Similarly, an expense on Pesticides was significantly lower in Aat land as compared to rest all types of topo-terrains. The difference in the use of Pesticides is not statistically significant between *Bahal*-Berna and Berna-*Maal* lands. One can see that, farmers use about 2.5 times more Pesticides in *Bahal* over Aat lands, and twice as much on Berna and *Maal* lands over Aat lands.

4. 5.1.5 Expenditure on Farm Machinery

The table below presents the expenses on farm machinery by the farmers in the region. The cost represents expenses on tractors, ploughs, threshers and harvesters etc. on paddy cultivation by the farmers. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the farm machinery. Whereas farmers in *Aat* lands spend on an average Rs. 1618 per acre, its Rs. 1796, Rs. 2902 and Rs. 2796 per acre for the farmers in *Maal*, *Berna* and *Bahal* land respectively. One can see that, as one moves from the *Aat* to *Berna* land, the expenses on farm machinery keeps increasing. Interestingly, *Berna* lands have attracted a slightly higher investment in farm machinery than the *Bahal* land. This may be due to the fact that, *Berna* land being located on the land between upper *Maal* land and the flat bottomed *Bahal* land, are characterized by slow but continuous farm bed steepening, albeit very gentlely. This requires a bit more leveling as compared to the flatter bedded *Bahal* land. Rest of the agricultural operations are same for both the lands. Though some farmers use ploughs to till their lands, most prefer mechanized tilling of the farms. The economically better off farmers go for one or two more rounds of tilling than the others for land preparation and in between the cultivation. One witnesses the expenses on machinery to be somewhat similar between *Aat* and *Maal* land and those between *Berna* and *Bahal* lands.

Table No 4.5 Expenditure on Farm Machinery across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	2796	2375.55	F(3, 278)=6.838	W(3, 278)= 11.136	F(3,68.504)=6.864
Berna	47	2902	1877.97			
Maal	141	1796	1784.21	*P=0.001*	P= 0.000	*P=0.000*
Aat	18	1618	1488.54		Equal variance Not assumed.	
Total	282	2238	2020.97			

Further, test of ANOVA reveals that, the difference in costs of farm machineries across topoterrain is statistically significant (*P value 0.000)*. However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus a follow up test was conducted to identify which of the pairs have significant difference and which have not. However, equal variance was not confirmed by Levene's statistic (*P value 0.000*), and Games-Howell's post hoc test was computed that is suitable for unequal group size and equal variance. The result of the test is given as under:

Table No 4.5a Games-Howell Post hoc test on expenditure on farm machineries across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	-106.363	386.381	.993
	Maal	1000.005*	311.176	.009
	Aat	1177.880	444.241	.053
Berna	*Bahal*	106.363	386.381	.993
	Maal	1106.369*	312.433	.004
	Aat	1284.243*	445.123	.031
Maal	*Bahal*	-1000.005*	311.176	.009
	Berna	-1106.369*	312.433	.004
	Aat	177.875	381.673	.966
Aat	*Bahal*	-1177.880	444.241	. 053
	Berna	-1284.243*	445.123	. 031
	Maal	-177.875	381.673	. 966

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on farm machineries in *Berna* and *Bahal* land is significantly higher than those on *Maal* land statistically. Similarly, an expense on farm machineries was significantly lower in *Aat* land as compared to *Maal* and *Berna* lands. The difference in the use of farm machineries is *not* statistically significant in between *Bahal-Berna* and *Bahal-Aat* lands.

4. 5.1. 6 Expenditure on Family Labour

The table below presents the expenses on family labour by the farmers in the region. The cost represents the *imputed* cost on family labour, which is actually unpaid by the farmers. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the *imputed* cost on family labour. Whereas farmers in *Aat* lands spend on an average Rs. 2444 per acre, its Rs. 3271, Rs. 3700 and Rs. 4548 per acre for the farmers in *Maal*, *Berna* and *Bahal* land respectively. One can see that, as one moves from the *Aat* to *Bahal* land, the expenses on Family Labour keeps increasing. The short duration paddy requires relatively less intensive agricultural operation as compared to the long duration varieties and this can be an explanation for lower expenses on family labours on *Aat* lands having mostly short duration paddy. Further, higher expectancy of return may encourage farmers to devote more man days in the lower topoterrains and hence the imputed family labour expenses are more in *Bahal* and *Berna* lands.

Table No 4.6 Expenditure on Family Labour across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	4548	2808.51	F(3, 278)=4.367	W(3, 278)= 1.761	F(3,66.916)=4.645
Berna	47	3700	3120.22			
Maal	141	3271	2848.33	*P=0.005*	P= 0.155 Equal variance assumed.	*P=0.005*
Aat	18	2444	2572.53			
Total	282	3634	2919.77			

Further, test of ANOVA reveals that, the difference in imputed costs on family Labour across topoterrain is statistically significant (*P value 0.000)*. However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus a follow up test was conducted to identify which of the pairs have significant difference and which have not. However, equal variance was confirmed by Levene's statistic (*P value 0.155*), and Hochberg's post hoc test was computed that is suitable for unequal group size and equal variance. The result of the test is given as under:

Table No 4.6a Hochberg Post hoc test on expenditure on Family Labour across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	848.847	532.327	.507
	Maal	1277.414*	408.221	.012
	Aat	2103.977*	751.974	.033
Berna	*Bahal*	-848.847	532.327	.507
	Maal	428.567	483.172	.940
	Aat	1255.130	795.158	.519
Maal	*Bahal*	-1277.414*	408.221	.012
	Berna	-428.567	483.172	.940
	Aat	826.563	718.017	.821
Aat	*Bahal*	-2103.977*	751.974	.033
	Berna	-1255.130	795.158	.519
	Maal	-826.563	718.017	.821

* *The mean difference is significant at the 0.05 level.*

One can see that, the difference in farmer's imputed cost on family Labour to be statistically significant between *Bahal* –*Aat* and *Maal-Bahal* lands. For the rest, it was not found to be statistically significant. Its quite interesting to see this, family members across types of lands they cultivate work substantially on their farms. It is also to be noted that, even the *Bahal* land owners, who usually are a bit better off financially than the others, are working in their field. During FGD with the researcher, upon being asked, do the *Bahal* owners also do farming works, many farmers replied in the affirmative. A few of them also pointed out that, at times it becomes essential for them to work due to the unavailability of hired labours during crucial cultivation stages and not all *Bahal* owners can be assumed to be rich.

4. 5.1. 7 Expenditure on Hired Labour

The table below presents the expenses on hired Labour by the farmers in the region. The cost represents the *the expenses incurred on hiring* labour, to undertake various agricultural operation related to paddy cultivation like tilling, ploughing, transplanting, harvesting etc. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the hired Labour. Whereas farmers in *Aat* lands spend on an average Rs. 1428 per acre, its Rs. 1838, Rs. 3203 and Rs. 3739 per acre for the farmers in *Maal*, *Berna* and *Bahal* land respectively. One can see that, as one moves from the *Aat* to *Bahal* land, the expenses on hired Labour keeps increasing. The short duration paddy requires relatively less intensive agricultural operation as compared to the long duration varieties and this can be an explanation for lower expenses on hired Labour as well as family labours on *Aat* lands having mostly short duration paddy. Further, higher expectancy of return may encourage farmers to devote more mandays in the lower topoterrains and hence the hired Labour expenses are more in *Bahal* and *Berna* lands.

Table No 4.7 Expenditure on Hired Labour across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	3739	2510.09	F(3, 278)=17.741 *P=0.000*	W(3, 278)= 23.382 P= 0.000 Equal variance not assumed.	F(3,65.294)=15.892 *P=0.000*
Berna	47	3203	2719.14			
Maal	141	1838	1494.55			
Aat	18	1428	1366.75			
Total	282	2552	2215.00			

Further, test of ANOVA reveals that, the difference in expenses on hired Labour across topoterrain is statistically significant (*P value 0.000)*. However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus a follow up test was conducted to identify which of the pairs have significant difference and which have not. However, unequal variance was confirmed by Levene's statistic (*P value 0.000*), and Games Howell's post hoc test was computed that is suitable for unequal group size and unequal variance. The result of the test is given as under:

Table No 4.7b Games Howell post hoc test on expenditure on Family Labour across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	535.519	490.118	.695
	Maal	1900.413*	314.235	.000
	Aat	2310.933*	432.065	.000
Berna	*Bahal*	-535.519	490.118	.695
	Maal	1364.894*	416.119	.009
	Aat	1775.414*	510.971	.005
Maal	*Bahal*	-1900.413*	314.235	.000
	Berna	-1364.894*	416.119	.009
	Aat	410.520	345.861	.641
Aat	*Bahal*	-2310.933*	432.065	.000
	Berna	-1775.414*	510.971	.005
	Maal	-410.520	345.861	.641

* *The mean difference is significant at the 0.05 level.*

One can see that, the difference in farmer's expenses on hired Labour to be statistically significant between *Bahal –Maal*, *Bahal-Aat* and *Maal-Berna* and *Aat-Berna* lands. It is not statistically significant between *Bahal--Berna* and *Maal-Aat* lands. Thus. there is a clear cut differences in the lower lands viz. *Bahal* and *Berna*, and the uplands viz. *Maal* and *Aat* lands. During FGD with the researcher, many farmers expressed their helplessness in arranging for hired labours for important cultivation operations, a shortage they perceived as humongous. For its reasons they identified MGNREGA and the availability of rice at Rs. 2/KG under the welfare scheme by the state govt. to be the prime reasons. Many farmers identified "*daadan*" a locally used term to refer to the labour outmigration from western Odisha to other states, especially to the bricklins in Telengana as well as to the Hirakud canal command area, as other prominent causes of labour shortages. They also pointed out a gross lack of interest by the youngsters in taking up agricultural wage labour work. The farmers narrated their predicament of the problem as in many occasions, the hired labours left their work even without completing the work they started. Overall the problem of hired labours in the surveyed area can said to be characterized as follows- it's in short supply and the supply is unreliable. Thus, wherever and whenever possible, there is a shift to opt for farm machines, and only on unavoidable practices like transplanting etc. hired labours are being engaged.

4.5.1.8 Total Input Costs

The table below presents the expenses on total input costs by the farmers in the region for paddy cultivation. The cost represents the total of all the inputs viz. seeds, chemical fertilisers, organic manures, pesticides, family labour (imputed), hired labours, cost of irrigation and other miscellaneous costs involved to undertake various agricultural operations related to paddy cultivation. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent. Whereas farmers in Aat lands spend on an average Rs. 9629 per acre, its Rs. 12855, Rs. 16971 and Rs. 18875 per acre for the farmers in *Maal*, Berna and *Bahal* land respectively. One can see that, as one moves from the Aat to *Bahal* land, the expenses keeps increasing. For various reasons stated in the discussions above the variation on the total cost too is quite expected across topoterrains.

Table No 4.8 Total Input Costs across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	18875	7872.14	F(3,278) =18.120	W(3, 278)= 3.677	F(3,69.055)=15.892
Berna	47	16971	7189.83			
Maal	141	12855	6161.30		P= 0. 013	*P=0.000*
Aat	18	9629	4852.51	*P=0.000*	Equal variance not assumed.	
Total	282	14958	7362.49			

Further, test of ANOVA reveals that, the difference in expenses on total inputs across topoterrain is statistically significant (*P value 0.000)*. However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus a follow up test was conducted to identify which of the pairs have significant difference and which have not. However, unequal variance was confirmed by Levene's statistic (*P value 0.013*), and Games Howell's post hoc test was computed that is suitable for unequal group size and unequal variance. The result of the test is given as under:

Table No 4.8a Games Howell post hoc test on expenses on total Inputs across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	1904.176	1383.932	.517
	Maal	6020.004*	1041.458	.000
	Aat	9246.491*	1457.245	.000
Berna	*Bahal*	-1904.176	1383.932	.517
	Maal	4115.828*	1170.084	.004
	Aat	7342.316*	1551.781	.000
Maal	*Bahal*	-6020.004*	1041.458	.000
	Berna	-4115.828*	1170.084	.004
	Aat	3226.488	1255.942	.074
Aat	*Bahal*	-9246.491*	1457.245	.000
	Berna	-7342.316*	1551.781	.000
	Maal	-3226.488	1255.942	.074

* *The mean difference is significant at the 0.05 level.*

One can see that,the difference in farmer's expenses on all kinds of inputs to be statistically significant between *Bahal*-*Maal*, *Bahal*-Aat and *Maal*-Berna and Aat-Berna lands. It is not statistically significant between *Bahal*-Berna and *Maal*-Aat lands. Thus, there are a clear cut differences in the two lowest topo-sequentials viz. *Bahal* and Berna, and the upper topo-sequentials viz. *Maal* and Aat lands.

4.5.1.9 Income per acre from Paddy

The table below presents the income farmers earned from an acre of land in the region. We can say this as the productivity in Rupee terms per acre of land under paddy. We see that, there is a marked variation in the way farmers spent. Whereas farmers in *Aat* lands earn on an average Rs. 18,660 per acre, its Rs. 23,165, Rs. 28,254 and Rs. 30,228 per acre for the farmers in *Maal*, *Berna* and *Bahal* land respectively. One can see that, as one moves from the *Aat* to *Bahal* land, the productivity keeps increasing. For the obvious reasons of higher spending on inputs as well as better water availability in the lower topo-sequentials the income is higher than those from the higher topoterrains.

Table No 4.9 Income per acre from Paddy across topoterrains

TopoTerrains	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Bahal	76	30229	11170.50	F(3, 278) =10.712	W(3, 278)= .136	F(3,68.071)=10.903
Berna	47	28254	9973.86			
Maal	141	23166	10769.33		P= 0.939	*P=0.000*
Aat	18	18660	9403.03	*P=0.000*	Equal variance assumed.	
Total	282	25630	11213.89			

Further, test of ANOVA reveals that, the difference in income across topoterrains is statistically significant (*P value 0.000)*. However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus a follow up test was conducted to identify which of the pairs have significant difference and which have not. However, equal variance was confirmed by Levene's statistic (*P value 0.939*), and Hochberg's post hoc test was computed that is suitable for unequal group size and equal variance. The result of the test is given as under:

Table No 4.9a Hochberg's post hoc test on Income from paddy across topoterrains

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Bahal	*Berna*	1974.377	1980.750	.900
	Maal	7062.841*	1518.960	.000
	Aat	11568.815*	2798.039	.000
Berna	*Bahal*	-1974.377	1980.750	.900
	Maal	5088.464*	1797.849	.030
	Aat	9594.438*	2958.723	.008
Maal	*Bahal*	-7062.841*	1518.960	.000
	Berna	-5088.464*	1797.849	.030
	Aat	4505.974	2671.687	.441
Aat	*Bahal*	-11568.815*	2798.039	.000
	Berna	-9594.438*	2958.723	.008
	Maal	-4505.974	2671.687	.441

* *The mean difference is significant at the 0.05 level.*

One can see that, the difference in farmer's income per acre of paddy to be statistically significant between *Bahal-Maal*, *Bahal-Aat* and *Maal-Berna* and *Aat-Berna* lands. It is not statistically significant between *Bahal-Berna* and *Maal-Aat* lands. Thus, there is a clear cut differences in the two lowest topo-sequentials viz. *Bahal* and *Berna*, and the upper topo-sequentials viz. *Maal* and *Aat* lands, which perfectly follows the pattern/characteristics of total input expenses.

Based on the discussion above, we can infer that, the general geo-environment of the land and its manifestation in terms of topography is the dominant factor dictating the overall agricultural potentials of the lands. The undulating nature of the land and local slopes are important factors which have major roles to play in putting a limit to which human intervention can harness the land resources for agricultural operation. The converted and reclaimed first order streams beds are the best stripes of land in the basin which show the highest promise for cultivation. We can conclude that, there do exist significant differences in input use across different topo-terrainic variations.

4.5.2 Input use under various sources of Irrigation

In this section, a brief discussion on the level of expenses farmers incur on inputs and the income they earn from paddy cultivation under various sources of irrigation condition is presented. The status has been analysed at four different conditions namely, 1. Farms without irrigation, 2. Farms with flowing water from a tank (hereafter termed Tank-flow). 3. Farms those have to use a pump to get water from a tank (hereafter termed Tank-pump), and 4. Farms those get water from a bore well. It may be noted here that, in many villages, it was seen for a lot many farms, water from a tank do not reach under gravity due to dilapidation of the canals, or due to reduced capacity of the tanks etc. and farmers use diesel pumps to fetch water from tanks or nearby canals or small storages located at quite some distance from their fields. In a few instances water is carried over 400-700 meters far through pipes. This adds to the cost of cultivation as the farmers have to invest or rent in pump and pipes for the purpose. Further, as already discussed previously, due to the shortages felt by farmers in accessing tank water, many of them have gone for bore wells for irrigation. It may be noted that the subsidy provided under (Biju Krushak Vikas Yojana) BKVY has further encouraged many farmers to opt for a bore well. Though there are guidelines for the bore well availed under BKVY be used for growing vegetables etc., farmers use their bore wells for irrigating their rice fields. As already outlined at the beginning of the chapter, the hypotheses is that there is higher productivity and input use in farms irrigated by borewells than those irrigated from tanks, which is more than those under unirrigated condition. With this back ground, the findings of the primary survey data is presented and analysed below.

4.5.2.1 Variation of Expenditure on Seeds

The table below presents the expenses on seeds by the farmers in the region. The cost is reflective of both their own seeds and purchased seeds. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the seeds. Whereas farmers in the unirrigated fields, spend on an average Rs. 637 per acre, its Rs. 717, Rs. 704 and Rs. 1127 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. Expenses on seeds under unirrigated condition is quite low, because on these tracts mostly the short paddy with early maturing cultivars are grown which in some cases are the traditional varieties and are usually less expensive. The unirrigated tracts are under short duration rice because this helps the crop to minimize the vagaries of the rainfall. In the farms which are having some source of irrigation, farmers are seen to be growing longer duration seeds, in many cases the HYV seeds which are higher in cost. Further, farms with bore well facility have a better scope of reliable water supply as they are unaffected by the monsoon, where as farms getting water from tanks are still not completely free from prolonged dry spells. One may note that, if the rainfall is insufficient, tanks fail to store enough water to ensure sufficient water supply. During the FGD conducted by the researcher, many farmers confided that though the tanks are the lifelines for their paddy crop, they also simultaneously recognised the limits of a tank especially in the years of scanty rain. Even in years of good rain, water from tanks do not reach all the farms equally, its supply has to negotiate the power dynamics of the society enroute to reach the farms viz. Head, Middle and Tail reaches. The relative location of the farms vis a vis the canals too has a role to affect the quantum of water that it gets.

Table 4.10 Expenditure on Paddy seeds across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	637	177.97	F (3,277) = 51.226 P=0.000	W (3,277) = 13.524 P=0.000 Equal variance *not* assumed.	F (3,115.405) = 24.765 P=0.000
Tank Flow	128	717	196.97			
Tank Pump	55	704	154.10			
Borewell	53	1127	368.32			
Total	281	779	285.29			

Further, test of ANOVA reveals that, the difference in costs of seeds under different sources of irrigation is statistically significant (*P value 0.000*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.000*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.10a Games-Howell's Post hoc test on expenditure on seeds across Sources of Irrigation

(I) Irrig. Source	(J) Irrig. Source	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-79.899	31.732	.064
	Tank Pump	-66.568	33.699	.205
	Borewell	-489.984*	57.126	.000
Tank Flow	Unirrigated	79.899	31.732	.064
	Tank Pump	13.331	27.109	.961
	Borewell	-410.085*	53.504	.000
Tank Pump	Unirrigated	66.568	33.699	.205
	Tank Flow	-13.331	27.109	.961
	Borewell	-423.416*	54.693	.000
Borewell	Unirrigated	489.984*	57.126	.000
	Tank Flow	410.085*	53.504	.000
	Tank Pump	423.416*	54.693	.000

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on seeds in farms under borewell irrigation statistically significantly higher than those on others viz. farms without irrigation, with tank flow and with tank-pump. As stated above, the farms those get water from tanks are still risk prone and hence farmers spend less on seeds as compared to those having a borewell. In farms under borewells, many farmers were growing HYV seeds which are very responsive to irrigation and are more expensive. The sheer number of farms under tanks with a pump indicates the overall status of tank water supply, as sufficient water does not reach these farms on its own through gravity flow.

4.5.2.2 Variation of Expenditure on chemical fertilizers

The table below presents the expenses on chemical fertilizers by the farmers in the region. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the chemical fertilizers. Whereas farmers in the unirrigated fields spend on an average Rs. 1189 per acre, its Rs. 2315, Rs. 2182 and Rs. 3012 per acre on the farms irrigated through tank-flow, Tank-pump and bore well respectively. Expense on chemical fertilizers under unirrigated condition is quite low, because for using chemical fertilizer water presence in the rice field is s must after its application. As already found in chapter three on precipitation, the arrival of a dryspell is never ruled out. Thus under unirrigated condition, farmers have greater risk of fertilizer application, which they prudently avoid as much as possible. Not surprisingly, expense on fertilizer in unirrigated farms is less than half than those under tank irrigation and a little less than one third in those farms with a borewell. Apart from this lands with irrigation facility tend to have longer duration paddy cultivars sown on them, thereby the requirements of fertilizer application simply increases over the short paddy land grown mostly under unirrigated conditions. Further, farms with bore well facilities have a better scope of reliable water supply as they are unaffected by the monsoon, and farmers go for liberal use of fertilizers, obviously subject to their financial capacity to do so.

Table 4.11 Expenditure on chemical fertilizers across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	1189	754.82	F (3,277) = 13.657 P=0.000	W (3,277)= 11.735 P=0.000 Equal variance *not* assumed.	F (3,124.670) = 23.460 P=0.000
Tank Flow	128	2315	1421.80			
Tank Pump	55	2182	1194.22			
Borewell	53	3012	1944.94			
Total	281	2240	1509.12			

Further, test of ANOVA reveals that, the difference in expenditure on chemical fertilizers under varying sources of irrigation is statistically significant (*P value 0.000*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not.Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.000*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.11a Games-Howell's Posthoc test on expenditure on chemical fertilizers across Sources of Irrigation

(I) Irrig. Source	(J) Irrig. Source	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-1125.740*	168.684	.000
	Tank Pump	-992.780*	196.447	.000
	Borewell	-1822.625*	289.887	.000
Tank Flow	Unirrigated	1125.740*	168.684	.000
	Tank Pump	132.961	204.263	.915
	Borewell	-696.884	295.239	.094
Tank Pump	Unirrigated	992.780*	196.447	.000
	Tank Flow	-132.961	204.263	.915
	Borewell	-829.845*	311.935	.045
Borewell	Unirrigated	1822.625*	289.887	.000
	Tank Flow	696.884	295.239	.094
	Tank Pump	829.845*	311.935	.045

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on chemical fertilizers in farms without irrigation is found to be statistically significantly lower than those with irrigation irrespective of source types. Also we can see that, the difference is significant between Borewell and Tank-pump category. No significant difference is observed between Borewell-Tank flow and between tank flow and tank-pump irrigation. The ready responsiveness of HYV seeds, mostly under borewell aided irrigation, to chemical fertilizers encourages a higher spending on it.

4.5.2.3 Variation of Expenditure on organic manures

The table below presents the expenses on organic manures by the farmers in the region. The mean cost is in rupees per acre. We see that, there is a some variation in the way farmers spent on the organic manures. Whereas farmers in the unirrigated fields spend on an average Rs. 824 per acre, its Rs. 1178, Rs. 1165 and Rs. 1732 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. Expense on organic manures under unirrigated condition is quite low, as compared to those under irrigation, but the difference is not as stark as in the case of chemical fertilizers. Application of organic manure is found to be almost similar under tank-flow and tank-pump irrigated farms. Farmers seem to be using higher amount of organic manures under borewell irrigation, because of greater intensity of input use of all kinds and they are not hesitant to apply higher amounts of manures too. As already pointed out in the previous section, organic manures are not very easily and sufficiently available as per the demand by the farmers, and most of the farmers thus tend to compensate this with comparatively higher doses of chemical fertilizers.

Table 4.12 Expenditure on organic manures across Sources of Irrigation

Irrigation sources	**N**	**Mean**	**Std. Deviation**	**ANOVA P Value**	**Levene Statistic**	**Welch F test P value**
Un irrigated	45	824	759.45	F (3,277) = 5.415	W (3,277) = 3.423	F (3,124.701) = 6.587
Tank Flow	128	1178	1237.19			
Tank Pump	55	1166	1085.01	P=0.001	P=0.018 Equal variance *not* assumed.	P=0.000
Borewell	53	1732	1242.31			
Total	281	1223	1172.48			

Further, test of ANOVA reveals that, the difference in expenditure on organic manures under varying sources of irrigation is statistically significant (*P value 0.000*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.018*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.12a Games-Howell's Post hoc test on expenditure on manures across Sources of Irrigation

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-354.130	157.401	.116
	Tank Pump	-342.006	184.990	.257
	Borewell	-907.843*	204.784	.000
Tank Flow	Unirrigated	354.130	157.401	.116
	Tank Pump	12.124	182.654	1.000
	Borewell	-553.713*	202.677	.037
Tank Pump	Unirrigated	342.006	184.990	.257
	Tank Flow	-12.124	182.654	1.000
	Borewell	-565.837	224.776	.063
Borewell	Unirrigated	907.843*	204.784	.000
	Tank Flow	553.713*	202.677	.037
	Tank Pump	565.837	224.776	.063

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on organic manures in farms under borewell irrigation is found to be statistically significantly higher than farms under tank-flow and obviously those without irrigation. In rest of the categories no significant difference is observed. For reasons stated above, there is generally subdued application of manure in the farms in the region. This is not a very encouraging sign since application of organic manure is vital for the maintenance of inherent fertility and moisture retention capability of the soil.

4.5.2.4 Variation of Expenditure on Pesticides

The table above presents the expenses on pesticides by the farmers in the region. The expenditure includes those on pesticides, insecticides, weedicides etc. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on pesticides etc.. Whereas farmers in the unirrigated fields spend on an average Rs. 721 per acre, its Rs. 933, Rs. 1206 and Rs. 1227 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. Expense on pesticides under unirrigated condition is the lowest. Application of pesticides is found to be almost similar under Bore well and tank-pump irrigated farms. Farmers seem to be using higher amount of pesticides under borewell irrigation, almost twice as much under unirrigated conditions. FGD with farmers reflected that farmers perceived no special vulnerability of pest attack towards any specific irrigation type. Difference in expenses to tackle pests and weeds is mostly determined by one's expectancy on the level of returns from the field.

Table 4.13 Expenditure on pesticides across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	721	614.31	F (3,277) = 5.063 P=0.002	W (3,277) = 3.023 P=0.030 Equal variance *not* assumed.	F (3,117.632) = 5.580 P=0.001
Tank Flow	128	933	758.14			
Tank Pump	55	1206	894.52			
Borewell	53	1228	806.42			
Total	281	1008	792.29			

Further, test of ANOVA reveals that, the difference in expenditure on pesticides under varying sources of irrigation is statistically significant (*P value 0.002*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.001*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.030*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.13 a Games-Howell's Post hoc test on expenditure on pesticides across Sources of Irrigation

(I) Irrig. Source	(J) Irrig. Source	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-211.915	113.475	.249
	Tank Pump	-484.834*	151.441	.010
	Borewell	-506.632*	143.722	.004
Tank Flow	Unirrigated	211.915	113.475	.249
	Tank Pump	-272.919	137.982	.204
	Borewell	-294.717	129.462	.111
Tank Pump	Unirrigated	484.834*	151.441	.010
	Tank Flow	272.919	137.982	.204
	Borewell	-21.798	163.763	.999
Borewell	Unirrigated	506.632*	143.722	.004
	Tank Flow	294.717	129.462	.111
	Tank Pump	21.798	163.763	.999

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on pesticides in farms under unirrigated condition is found to be statistically significantly lower than farms under tank-pump and under borewell. For any other combination, no significant difference is observed.

4.5.2.5 Variation of Expenditure on Farm machineries :-

The table above presents the expenses on farm machineries by the farmers in the region. The expenditure includes those on tractors, threshers, tillers, harvesters etc. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the farm machineries. Whereas farmers in the unirrigated fields spend on an average Rs. 437 per acre, its Rs. 1988, Rs. 1893 and Rs. 4772 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. Expense on farm machineries under unirrigated condition is the lowest. Expenses on machineries are found to be almost similar under tank-flow and tank-pump irrigated farms. In case of farms irrigated by borewells, the land is made readily available to grow some other rabi-crop, mostly vegetables etc. and in such a scenario, mechanized harvesting is invariably the choice to avoid any loss of cropping time.

Table 4,14 Expenditure on Farm machineries across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	438	1201.57	F(3,277) = 72.035 P=0.000	W(3,277) = 6.384 P=0.000 Equal variance *not* assumed.	F(3,123.518) = 77.114 P=0.000
Tank Flow	128	1988	1670.63			
Tank Pump	55	1893	1286.85			
Borewell	53	4772	1608.14			
Total	281	2246	2020.13			

Further, test of ANOVA reveals that, the difference in expenditure on farm machineries under varying sources of irrigation is statistically significant (*P value 0.000*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.000*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.14a Games-Howell's Post hoc test on expenditure on Farm machineries across Sources of Irrigation

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-1550.035*	232.139	.000
	Tank Pump	-1454.986*	249.384	.000
	Borewell	-4334.486*	284.391	.000
Tank Flow	Unirrigated	1550.035*	232.139	.000
	Tank Pump	95.049	227.845	.975
	Borewell	-2784.452*	265.705	.000
Tank Pump	Unirrigated	1454.986*	249.384	.000
	Tank Flow	-95.049	227.845	.975
	Borewell	-2879.501*	280.898	.000
Borewell	Unirrigated	4334.486*	284.391	.000
	Tank Flow	2784.452*	265.705	.000
	Tank Pump	2879.501*	280.898	.000

* *The mean difference is significant at the 0.05 level.*

It can be seen that, except for Tank-flow and Tank-pump irrigation, the difference among other combinations of sources of irrigation in terms of the expense on machineries is found to be statistically significant. Many of the agricultural operations like puddling etc. for transplanted rice under irrigated conditions are undertaken by tractors and this raises the expense. Expense under Borewell irrigated farms is ten times that of unirrigated farms and twice that under tank irrigation.

4.5.2.6 Variation of Expenditure on Family labour

The table below presents the imputed cost of family labours by the farmers in the region. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on the family labour. Whereas farmers in the unirrigated fields spend on an average Rs. 4278 per acre, its Rs. 4447, Rs. 2260 and Rs. 2618 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. Expense on family labours under Tankflow is the highest followed by that under unirrigated conditions. Substantially high imputed costs of family labours can be accounted with the fact that, the poorer farmers, usually the owners of the unirrigated lands, gets themselves hugely involved to complete most of the agricultural operations themselves to compensate for their inability to spend on farm machineries. This exactly the case, that seems to be prevailing in the study area too. The better off borewell owners seem to be moderately physically engaged in cultivation and thus would spend higher hired labour (see below) and by engaging farm machineries.

Table 4.15 Expenditure on Family labour across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	4278	2225.67	F (3,277) = 11.389 P=0.000	W (3,277) = 22.286 P=0.000 Equal variance *not* assumed.	F (3,124.466) = 13.844 P=0.000
Tank Flow	128	4447	3094.16			
Tank Pump	55	2260	3227.06			
Borewell	53	2619	1547.46			
Total	281	3647	2916.88			

Further, test of ANOVA reveals that, the difference in expenditure on family labours (imputed) under varying sources of irrigation is statistically significant (*P value 0.000*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.000*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.15a Games-Howell's Post hoc test on expenditure on family labour across Sources of Irrigation

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-168.878	429.971	.979
	Tank Pump	2017.778*	547.196	.002
	Borewell	1658.910*	394.032	.000
Tank Flow	Unirrigated	168.878	429.971	.979
	Tank Pump	2186.656*	513.945	.000
	Borewell	1827.788*	346.378	.000
Tank Pump	Unirrigated	-2017.778*	547.196	.002
	Tank Flow	-2186.656*	513.945	.000
	Borewell	-358.868	484.279	.880
Borewell	Unirrigated	-1658.910*	394.032	.000
	Tank Flow	-1827.788*	346.378	.000
	Tank Pump	358.868	484.279	.880

* *The mean difference is significant at the 0.05 level.*

It can be seen that, there is no statistically significant difference in cost of family labours between unirrigated and tank flow irrigated farms; and between borewell-tank pump irrigated farms.

4.52.7 Variation of Expenditure on hired labours

The table below presents the expenses on hired labours by the farmers in the region. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on hired labours. Whereas farmers in the unirrigated fields spend on an average Rs. 1689 per acre, its Rs. 2637, Rs. 1200 and Rs. 4527 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. Expense on hired labours under borewells irrigated farms is the substantially higher than the rest for the reasons already stated above. Lower expense on hired labours is compensated by the higher corresponding expense on family labour.

Table 4.16 Expenditure on hired labours across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	1689	1526.47	F(3,277) = 30.627 P=0.000	W(3,277) = 6.090 P=0.001 Equal variance *not* assumed.	F(3,124.902) = 38.317 P=0.000
Tank Flow	128	2638	2166.55			
Tank Pump	55	1200	1834.64			
Borewell	53	4527	1698.04			
Total	281	2561	2213.69			

Further, test of ANOVA reveals that, the difference in expenditure on hired labours under varying sources of irrigation is statistically significant (*P value 0.000*). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (*P value 0.000*) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (*P value 0.001*), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.16a Games-Howell's Post hoc test on expenditure on hired labour Sources of Irrigation

(I) Irrig. Source	(J) Irrig. Source	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-949.146*	297.408	.010
	Tank Pump	488.448	336.123	.470
	Borewell	-2838.692*	325.856	.000
Tank Flow	Unirrigated	949.146*	297.408	.010
	Tank Pump	1437.594*	312.842	.000
	Borewell	-1889.546*	301.784	.000
Tank Pump	Unirrigated	-488.448	336.123	.470
	Tank Flow	-1437.594*	312.842	.000
	Borewell	-3327.140*	340.001	.000
Borewell	Unirrigated	2838.692*	325.856	.000
	Tank Flow	1889.546*	301.784	.000
	Tank Pump	3327.140*	340.001	.000

* *The mean difference is significant at the 0.05 level.*

One can see that the difference in expense on hired labours under borewell irrigated farms and other categories is statistically significant. Similarly, except for tank-flow and unirrigated farms, the expense on hired labour is significantly different statistically for all other groups.

4.5.2.8 Variation of Expenditure on total input cost

The table below presents the total cost of inputs incurred by the farmers in the region. The mean cost is in rupees per acre. We see that, there is a marked variation in the way farmers spent on total inputs. Whereas farmers in the unirrigated fields spend on an average Rs. 10140 per acre, its Rs. 14461, Rs. 12813 and Rs. 22757 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. Expense on total inputs under borewell irrigated farms is the highest followed by that under tank-flow, tank-pump and then unirrigated fields. Substantially high costs of input costs is expected for all the reasons stated in the discussions above. There is a remarkable gap between bore well and tank-irrigated farms. The fields which are irrigated by the use of a pump witnesses lower amount of input use as compared to those receiving water through gravity flow. This highlights the challenges faced by the tank users and calls for urgent maintenance of the tank bund-culvert-canal structures, as well as desiltation of the tanks in many cases, which all combinedly result in insufficient availability of water, a problem that is not overcome even by use of a pump to get water. Apart from this, the management of the tanks also needs to be strengthened.

Table 4.17 Expenditure on total input cost across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	10140	4228.02	F(3,277) = 40.202	W(3,277) = 5.986	F(3,26.261) = 57.917
Tank Flow	128	14461	6860.55			
Tank Pump	55	12813	6350.78	P=0.000	P=0.001 Equal variance *not* assumed.	P=0.000
Borewell	53	22757	5394.46			
Total	281	15011	7321.06			

Further, test of ANOVA reveals that, the difference in expenditure on total inputs under varying sources of irrigation is statistically significant (P value 0.000). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (P value 0.000) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (P value 0.001), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4.17a Games-Howell's Post hoc test on total input cost Sources of Irrigation

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-4320.834*	874.620	.000
	Tank Pump	-2673.180	1063.281	.064
	Borewell	-12617.036*	972.784	.000
Tank Flow	Unirrigated	4320.834*	874.620	.000
	Tank Pump	1647.654	1049.300	.400
	Borewell	-8296.201*	957.482	.000
Tank Pump	Unirrigated	2673.180	1063.281	.064
	Tank Flow	-1647.654	1049.300	.400
	Borewell	-9943.855*	1132.421	.000
Borewell	Unirrigated	12617.036*	972.784	.000
	Tank Flow	8296.201*	957.482	.000
	Tank Pump	9943.855*	1132.421	.000

* *The mean difference is significant at the 0.05 level.*

One can see that, farmer's expenditure on total input costs in farms under borewell irrigation is found to be statistically significantly higher than farms under all other categories. Interestingly, no statistically significant difference is observed between farms under tank-flow irrigation and those without any irrigation, which underscores the challenges faced by some of the tank water users. Also the difference between tank-flow and tank-pump is also not significant statistically.

4.5.2.9 Variation of Income across Sources of Irrigation

The table below presents the total income from paddy by the farmers in the region. The mean cost is in rupees per acre, and hence is the productivity in money terms. We see that, there is a marked variation in the way farmers earned from paddy cultivation. Whereas farmers in the unirrigated fields earn on an average Rs. 16,699 per acre, its Rs. 25,915, Rs. 24,104 and Rs. 34,464 per acre on the farms irrigated through tank-flow, Tank-pump and borewell respectively. This follows the pattern/ intensity of inputs use by the farmers. Having a source of irrigation is proved to be crucial in the milieu of uncertain precipitation in the Ong river basin. Further the problem of Tank as a source of irrigation is recognised in that its not sufficiently meeting the requirement of water by the farmers. Also the prevalence of many farms those need a pump to draw in water from the canals from the tanks, reflects the poor state of tank infrastructures and their management. In the next chapter, a discussion on the status of tanks in the basin has been presented to see the problems afflicting tank irrigation in the present scenario that was once the lifeline of agriculture in the region.

Table 4. 18 Income per acre across Sources of Irrigation

Irrigation sources	N	Mean	Std. Deviation	ANOVA P Value	Levene Statistic	Welch F test P value
Un irrigated	45	16699	9713.28	F(3,277) = 26.773 P=0.000	W(3,277) = 4.153 P=0.007 Equal variance *not* assumed.	F(3,115.670) = 21.738 P=0.000
Tank Flow	128	25915	9619.49			
Tank Pump	55	24104	7828.93			
Borewell	53	34464	12327.92			
Total	281	25697	11176.89			

Further, test of ANOVA reveals that, the difference in income under varying sources of irrigation is statistically significant (P value 0.000). However, owing to the difference in the group sizes, Welch F-test was conducted, which also showed that there exists significant difference (P value 0.000) among them. However, these values give an overall omnibus difference among the groups and do not tell which specific groups differed. Thus, a follow up test was conducted to identify which of the pairs have significant difference and which have not. Further, owing to the unequal variances among them indicated by huge differences in the standard deviation values, and further confirmed by Levene's statistic (P value 0.001), Games Howell's post hoc test was computed. The result of the test is given as under:

Table 4. 18a Games-Howell's Post hoc test on Income across Sources of Irrigation

(I) Topo-terrain	(J) Topo-terrain	Mean Difference (I-J)	Std. Error	Sig.
Unirrigated	Tank Flow	-9216.185*	1679.151	.000
	Tank Pump	-7405.756*	1791.932	.000
	Borewell	-17765.097*	2228.031	.000
Tank Flow	Unirrigated	9216.185*	1679.151	.000
	Tank Pump	1810.429	1355.481	.542
	Borewell	-8548.912*	1894.843	.000
Tank Pump	Unirrigated	7405.756*	1791.932	.000
	Tank Flow	-1810.429	1355.481	.542
	Borewell	-10359.341*	1995.471	.000
Borewell	Unirrigated	17765.097*	2228.031	.000
	Tank Flow	8548.912*	1894.843	.000
	Tank Pump	10359.341*	1995.471	.000

* *The mean difference is significant at the 0.05 level.*

The Games-Howell's test shows that, the total income generated from borewell irrigated and unirrigated farms are significantly higher from all other types of sources of irrigation. However, per acre income from paddy cultivation from tank-flow and tank-pump irrigation were not significantly different from each other in statistical term.

4.5.3 Economic status of agriculture under different reaches of Tank Irrigation

In this section, a brief discussion on the level of expenses farmers incur on inputs and the income they earn from paddy cultivation in farms located in different reaches of Tank canals is presented. The status has been analysed at three different reaches namely, 1. Head reaches, 2. Middle reaches, and 3. Tail reaches. It may be noted here that, the farms relative location with respect to the irrigation channels is an important factor in deciding how much water they avail from the tank. Farms in the Head reaches due to their proximity to irrigation channels are the first to get water from the canal and it's usually seen that those in the Tail reaches fail to get sufficient water. Though it was not in the ambit of the present study, the researcher's informal observation and FGD with the farmers gave the impression that, in many cases, the Head reach farms are owned by the economically better off farmers. In some cases of new tanks, farmers confided that, the richer farmers also are the ones who decide the course of the channels and the channels get turned to go through or close to their lands. The village power structure also decide the quantum and timing of tank water flows across fields and water is not necessarily released, especially in the time of failure of rain, adequately by the Head and Middle reach farm owners and hence the Tail enders suffer water shortages. Thus, this also affects the level of intensified use (not cropping intensity but the quantum of spending on inputs by the farmers) a parcel of land is put to based on where the farm is located with respect to the irrigation channels. The role of the state is to ensure equitable water distribution among the beneficiary farmers irrespective of the location of their fields, and this is expected to be safeguarded by the proper functioning of the water users associations (WUAs), better maintenance of the irrigation channels, and keeping the storage capacity of the tanks to their full potential by timely desiltation of these tanks. It's interesting to see the status of the farms based on their location relative to irrigation channels in the study area. In this respect, a primary survey was conducted between 2018-19 selecting farmers from different reaches of the tank canals. By assessing the way these farmers use various inputs and their income from their lands, we will see if water is indeed equitably distributed irrespective of the location of the farms. As already outlined at the beginning of the chapter, the concerned hypotheses to be tested are: (i) there is significant difference in productivity and input use across farms located in different canal reaches like Head, Middle and Tail reaches under tank irrigated conditions and (ii) Since the farms under OCTMP projects have more equitable water distribution owing to better functioning of pani panchayats, the difference in productivity and input use is more uniform across different canal reaches, (Head, Middle and Tail) as compared to those not receiving OCTMP interventions. With this back ground, the findings of the primary survey data is presented and analysed below.

In the previous two sections concerning topoterrains and source of irrigation, the presentation was done separately for each input. To avoid repetitions, here the data for all the inputs and the final income is presented in a single table below. Here too all the figures are in Rupees per acre.

Table 4.19 Expenses and income from Paddy seeds under different Tank-canal reaches

Canal Reach (N=178)		**Seeds**	**Fertilizer**	**Manure**	**Pesticides**	**Machinery**	**Family Labour**	**Hired Labour**	**Tank pumping**		**Other**	**Total input cost**	**Income**
									N	Cost			
Head (70)		705	2814	1121	941	2435	4079	2338	3	1233	272	15938	28457
Middle (49)		739	2450	1384	1139	1967	3689	2059	9	1844	531	15802	25634
Tail (64)		702	1407	1071	1003	1422	3549	1365	43	2266	447	13232	20939
Welch *P value*		*0.436*	*0.002*	*0.363*	*0.424*	*0.004*	*0.628*	*0.000*	-	*0.001*	*0.073*	*0.139*	*0.003*
Games-Howell-*P value*	**H-M**	-	*0.128*	-	-	*0.002*	-	*0.248*	-	*0.221*	-	-	*0.328*
	H-T	-	*0.001*	-	-	*0.000*	-	*0.002*	-	*0.000*	-	-	*0.000*
	M-T	-	*0.030*	-	-	*0.311*	-	*0.032*	-	*0.002*	-	-	*0.030*

One can see from the table that, the cost on seeds by different farmers is almost same. However, we can see a clear difference in the expenditures on chemical fertilizers across different reaches farms relative to the irrigation channels. Whereas, farmers in the Head reaches spend Rs. 2814, those in the Middle and Tail end spend Rs. 2450 and Rs. 1407 respectively. Thus, farmers in the Tail reach seem to be facing water shortages which was often witnessed during the field visits and also identified as the primary reasons for not being able to use enough fertilizers by the farmers in the Tail reach during the FGDs conducted by the researcher. One can see that farmers in the Head reaches spend almost twice the amount of those in the Tail reaches on chemical fertilizers. Further, the difference in the expenditure on fertilizer was found to be statistically significant (Welch test P value= 0.002). The Games-Howell's post hoc test reveals that, the expenses on fertilizer per acre by farmers in the Head-Tail and Middle-Tail reaches is statistically significant. No significant difference on the same is observed between those on the Head and Middle reaches farms.

Farmers in all the reaches seem to be spending comparable amount on manures as well as pesticides, and whatever little inter reaches differences are there, it is not found statistically significant as indicated by Welch test *P values 0.343* and *0.424* respectively.

Farmers' spending on farm machineries can be seen to be quite varied across different reaches. Whereas, farmers in the Head reach spend on an average Rs. 2435 per acre on farm machineries, the corresponding spending by the Middle and Tail reaches are Rs. 1967 and Rs. 1422 respectively. The difference is also found to be statistically significant as given by Welch's *p-value* of *0.004*. Owing to the unequal variance, Games Howell's post hoc test was conducted to identify group wise differences and from the table we can see that, whereas the difference between Head-Middle and between Head–Tail reaches is statistically significant, that between Middle and Tail reaches is not.

The Welch test result shows that there is no significant difference in the imputed cost of family members across different reaches of tank irrigation.

So far as the farmers' spending on hired labour is concerned, again there is remarkable variation across different canal reaches. Where as in the Head reaches, farmers spend Rs. 2338 on hired labour, those in the middle and tail reaches spend Rs 2059 and Rs 1365 respectively. Further the difference among the three reaches was found to be statistically significant. To further see the group wise difference Games-Howell's post hoc test was conducted which shows that Tail reach farms witness significantly lower spending on hired labours as compared to both middle and head reach farms. However, no significant difference was seen in between head-middle reach farms in this respect.

The next two coloumns give the status of tank pumping costs. The first coloumn gives the number of farmers from each canal-reach that get the water of the tank with the help of a pump and the coloumn to its right represent the mean expenditures per acre on pumps in rupee term by them. So there are a total of 55 farmers in the basin who have to engage a pump to fetch tank water, three of them are in the Head reaches, nine from the Middle-reaches and there are as many as 43 farmers in the tail-reaches. Thus it is quite clear that, the farmers who have to resort to pumping the tank water are mostly from the Tail-reaches. Looking at the cost of pumping to fetch tank water, we can see that where as farmers in the Head reaches spend Rs. 1233 on an average, the amount is Rs. 1844 in the Middle and Rs. 2266 per acre in the Tail-reaches. Welch test also showed that the difference among the three costs is statistically significant. Games Howell's Post hoc test further revealed that the expenditure by the Tail-reach farmers is significantly higher than those from the Head and Middle-Reaches. The difference in expenditures between Head- and Middle reaches was not found to be statistically significant. Thus, it is inferred that the poor condition of the tanks and the dilapidated canals there from exert a significantly higher financial burden on the Tail end farmers, though those from the Head and Middle reaches are not completely free from it.

The total input costs per acre of paddy farming was found not significantly different across different canal-reaches, the difference of expenses on various inputs perhaps have been offset by the higher spending by the Tail reach farmers on pumping costs.

The last coloumn in the table above represents the income from an acre of paddy from the farms under different canal-reaches. There is witnessed a marked variation on what the farmers earn. Whereas the per acre income in the Head region is Rs. 28,457, that diminishes to Rs. 25,643 and to Rs. 20,939 for farmers from Middle and Tail-reaches respectively. The difference is significant as per Welch test (*P= 0.003*). Games-Howell's post hoc test on Income from paddy shows that, farmers' income from an acre of tail reach farms is significantly lower than that from the Head and Middle reaches. However, the same can't be said for the difference between Head and Middle reaches.

Thus, we can say that though on some of the inputs like seeds, Manure, pesticide, family labour and total input costs, the farmers from all the regions are spending in a similar fashion, there are significant differences in their spending on chemical fertilizers, farm machineries, Pumping costs and finally on their income per acre of paddy. This proves our hypotheses on the study area.

4.6 Economic status of agriculture under different reaches of OCTMP Tanks

Recognizing the problems of tank irrigation, Government of Odisha in partnership with the Government of India initiated the Odisha Community Tank Management Project (OCTMP) in the year 2009, with funding from the World Bank. The project aims at repairing and rehabilitating Minor Irrigation Tanks having a command area of 40 hectares to 2000 hectares. The Orissa Community Tank Development and Management Society (OCTDMS) was formed as a Special Purpose Vehicle (SPV) under the Department of Water Resources, Government of Orissa to operationalize the Orissa Community Tank Management Project (OCTMP). The project was initiated with the objective of "achieving sustainability of restored minor irrigation systems through community participation and empowerment to develop self-owned, self-managed and self-sustenance of Pani Panchayats (Water Users'

Associations). It aspired to create an enabling legal and institutional environment to implement the solutions emerging out of participatory and demand driven processes". The stated key principles underlying project design included, "a decentralized mechanism where the main tank beneficiaries play a proactive role in planning, implementing and sustaining project interventions. The tank system rehabilitation work meets technical quality safety standards and pays adequate attention to social, environment and fiduciary considerations and improving and ensuring equitable access to water by the beneficiaries.

In the Ong river basin, two Minor Irrigation Projects viz. one in Batterma and the other in Jhagadjhal were taken up under OCTMP. The two projects were also part of the primary survey under this research. The primary data from these villages were collected in the year 2018-19. Under the given objectives and principles of OCTMP, it would be interesting to see the status of agriculture in these two projects. The concerned hypotheses to be tested is : Since the farms under OCTMP projects have more equitable water distribution owing to better functioning of pani panchayats, the productivity and input use is more uniform across different canal reaches, (Head, Middle and Tail) as compared to those not receiving OCTMP interventions. With this back ground, the findings of the primary survey data is presented and analysed below.

Table 4.20 Expenses on inputs and Income from paddy under different reaches of OCTMP Tanks

Canal Reach	Seeds	Fertilizer	Manure	Pesticides	Machinery	Fam. Labour	Hired Labour	Tank pumping		Other	Total input cost	Income
								N	Cost			
Head	710	2504	1121	941	2186	4079	2284	0	0	272	14102	28498
Middle	759	2193	1384	1139	2060	3689	2199	0	0	531	13954	27677
Tail	708	2076	1071	1003	1624	3549	2124	3	387	247	12677	26033
Welch *P value*	*0.436*	*0.192*	*0.363*	*0.424*	*0.064*	*0.628*	*0.912*		-	*0.013*	*0.139*	*0.942*

We can see from the table above that, though there are differences in the expenditure on various inputs per acre of paddy by farmers from different canal-reaches, none of them were found to be statistically significant as indicated by Welch test p value, which is more than *0.05* for all the inputs (hence no post hoc test is required and therefore was not conducted). We can see that the income from an acre of paddy by the Head reach farmers is Rs. 28,498, from the Middle reach to be Rs. 27,677 and from the Tail reach to be Rs. 26,033, and there is s clear decreasing pattern as one moves from the head to the Tail reaches. However, again we see no significant difference among them as confirmed by Welch Test p value (*0.942*).

However, this is not to say that, everything is just perfect in the OCTMP tank covered villages. One cannot miss the fact that, even here there are three farmers who have to use Pumps to fulfill their need for water. In the FGD with the farmers, the researcher observed that there are complaints by many farmers regarding inadequate water they get from the tank. Some of the farmers in the Tail end have also found to be innovative to face water shortages. One case in point was Mr. Soumitri Chauhan from Batterma, who has adapted to water shortage by going in for row sowing of paddy (and not full fledged SRI methods) to optimally use whatever water reaches his farm in the farthest end of Tail reach. Whereas, in the other OCTMP project in Jhagadjhal, some of the farmers (three of them) were seen to have resorted to use of pumps to fetch water from the tank. The FGD in Jhagadjhal however showed that, though there is no serious grievance among farmers against one another, collectively they were not found to be very hopeful of overcoming the imminent water shortages that has suddenly been caused to them due to, what they term as an utterly wrong decision, by the govt. What has happened is, a new river lift point (in neighbouring village Jhar) has come up upstream on the river which is the sole source of water to the tank from which they get water. Due to this, water flow to their tank has witnessed serious reduction and subsequent overall water shortages to their fields, especially accentuated in the tail reaches. This has compelled three of the Tail reach farmers to pump water from the tank. Thus, we can say that, the challenges to tank irrigation are not always internal, or due to the mismanagement by the concerned pani panchayats, they are also threatened by factors beyond them as evidenced in Jhagadjhal.

Summary

Based on the discussion above, we can infer that, the general geo-environment of the land and its manifestation in terms of topography is the dominant factor dictating the overall agricultural potentials of the lands. The undulating nature of the land and local slopes are important factors which have major roles to play in putting a limit to which human intervention can harness the land resources for agricultural operation. The converted and reclaimed first order streams beds are the best stripes of land in the basin which show the highest promise for cultivation. We can conclude that, there do exist significant differences in input use across different topo-terrainic variations.

Similarly, tanks have served in a big way to save paddy cultivation from the vagaries of monsoon, as evident from the substantially higher intensification of cultivation practice reflected in the higher spending on inputs in farms under tank irrigation as compared to those under unirrigated conditions. There were witnessed substantial differences in the productivity under tank irrigated farms and the unirrigated farms. One may note that, most of the tanks have been built harnessing the overall undulating topography of the land. During the period of their existence, tanks have undergone through diverse challenges and depending on the institutional dynamics, they have either withstood such challenges or have suffered from them resulting in their performances taking a dip greatly. With the reduction of the tanks performance, paddy cultivation gets exposed to uncertainties of water supply. Of late this has been the case of many tanks and this has compelled many farmers to go for borewell irrigation. A comparison of cultivation of paddy in farms under borewell with those under tanks and those without irrigation, clearly showed that, farms under borewells have significantly higher input uses as well as in yield per acre. However, not every farmer can opt for a borewell, nor the cost of irrigation (which already is higher than under tank irrigation) under bore well would be at the level it currently is, in view of the fact that, soon farmers will have to pay for the electricity consumption after metering etc is completed. Also the fact that, greater spread of borewells in the area will likely lead to drop in water table, there by further increasing cost of irrigation and overall cultivation. Overall, borewells have higher operation and maintenance costs as compared to tanks. In view of such traits associated with borewells that render them unsustainable, revival of tanks needs to be pursued with greater diligence, that is not restricted to physical restoration but also involves the institutional strengthening. This has been dealt with in the next chapter.

CHAPTER V

INSTITUTIONAL ASPECTS OF TANK IRRIGATION IN THE BASIN

5.1 Introduction

Man's action mostly comes in reaction to a need; the need may be induced by an internal urge or may be produced by the conditions imposed by external environment. But his actions can't be purely isolated and completely unbounded, especially if it comes in response to a need shared by many others in the society and also if such actions have implications on others' needs. These intertwining of needs and actions by many lead to evolutions of social institutions. All social institutions thus are geared up to achieve their objectives, through collective actions. The extent to which the institutional objectives are achieved depend on institutional dynamics depending on the behaviours of its members, clarity of the objectives, appropriateness of the rules (both obligatory and prohibitive) and adherence thereof to these rules etc. It's no wonder, the nature of the institutions too will be governed by the socio-economic milieu and the time in history in which they appear and function. For example, institutions embedded in a hierarchical society and undemocratic regime can't be expected to be exhibiting equity in its service delivery, conversely institutions under democratic governmental set up, failing to deliver on the equity dimensions, needs questioning and rectifications on its functioning. Thus, any fair evaluation of an institution can't be oblivious of the *space* and *time* in which they evolve and exist. *Space* here can be understood in its all expansive sense to mean the geographical space along with their social, economic, political aspects etc.

Further, when man's need is not met from a current source, alternative sources are explored. However, more often than not, many of such sources seem to be interrelated. For example, inadequate water supply from traditional sources like tanks has led to the proliferation of borewells that can give the farmers with assured supply of water, at least in the short run. It was seen in the last chapter, with the ownership of borewells and consequent lowering of production risks, farmers are greatly encouraged to enhance farm productivity through higher intensification of input use. The increased productivity has a demonstrative effect that encourages more and more number of farmers to shift to borewell irrigation. However, high dependency of borewell irrigation ultimately adversely affects the ground water scenario. Ground water table drops down further leading to reduced water supply, increased cost on electricity consumption to draw the same amount of water etc. (Reddy, 2010), Joshi (2004), Ghosh (2005). Further, it is usually seen that, farmers with borewell ownership become passive in contributing towards the upkeep and maintenance of the tanks, setting in its collapse in the long run (Kajisa et al., 2007). This in turn adversely affects ground water recharge and the already falling water table goes down further (Palanisami, 1998), (Rao, 2002). Thus, the revival of tanks becomes crucial for a sustainable irrigation system. The steps taken by the state government for the revival of tanks thus needs a careful evaluation.

With this background and in pursuance to the fourth objective of the study, the chapter presents the institutional aspects of tanks in the Ong river basin. In this endeavour, after a brief account on the evolution of the present practice of irrigation management (participatory mode), the enabling act pertaining to it and the provisions therein will be evaluated followed by an assessment of the performance of irrigation systems have been presented. The chapter is divided into five section; section 1 deals with the development of irrigation management practice related to Participatory Irrigation Management (PIM) in the international level; section 2 discusses the context in which PIM was implemented in the state; under section 3, various provisions of the Act giving effect to PIM in the state of Odisha will be presented followed by its relevant evaluation; section 4 presents a brief discussion on the special efforts by the state government to make PIM more effective through OCTMP; section 5 gives an account of farmers assessment of irrigation system performance; and finally in section 6, an assessment on the future scope of community management of irrigation system through farmers' characteristics.

5.2 The evolution and Implications of Irrigation Management Transfer (IMT)

Every year some 90 million people are added which as per World Bank prediction may go on till 2040. To keep up with the feeding requirements of this additional population, agricultural production needs to grow annually at the rate of 2.5%. This comes as a "daunting task since in view of the plateauing of yield of major crop after green revolution, limited scope of further increase in the arable land, threat of existing cropping land from urbanisation, ecological degradation etc." (World Bank, 1992). Besides, the challenge of shortages of land, the necessary water resources required to maintain the 2-3% production increase is also fraught with challenges emanating from environmental degradation and rising demand of water from non-agricultural uses. "Many countries are now slipping below the normative per capita water availability of 2000m^3, including India (with around 1500 m^3), the level that involves temporary to continuous water shortages for both agriculture and domestic use" (WB, 1993). Further, falling international aid for agriculture (in developing countries) from $11.7 in the 80's billion to $10 billion in 90's coupled with corresponding tightening of spending by national governments has resulted in replacing the practice of extensive irrigation construction and rehabilitation that continued upto the 1970's, by an emphasis on sustainable management of the existing irrigation infrastructures.

At the front of agricultural production too, in the absence of the much expected biotechnology revolution in the aftermath of green revolution, the only way of enhancing productivity rests with management improvement viz. efficient irrigation management, credit arrangement etc" (Vermillion, 1996). More food need to be produced from the same land and yet less water. Decrease in government spending and involvement in irrigated agriculture as outlined earlier, necessitates for new institutional arrangement, where local and private sector with greater accountability to farmers seem to be the only alternative option. This may sound strange but as Ostrom (1990) proclaimed, "… local management solutions are being sought for global problems of food and resource management''. This was what was the combination of circumstances by the end of 90's, which led more than 25 countries, with reduced government involvement in irrigation, to go for a widespread strategy of irrigation Management transfer (IMT) to farmers group. Vermillion (1996) put this as, "IMT is most often an attempt by governments to reduce their expenditures on irrigation and to stabilize deterioration of irrigation systems".

IMT policies often have the "assumption that local management that is accountable to farmers are more likely to be sustainable, cost efficient and responsive to the interests of the majority of the farmers than the centrally funded agencies" (Meinzen-Dick, 1994). The string of logic enunciated by Vermillion (1996) to justify IMT is as follows:

- "Government bureaucracies tend to lack the incentives and responsiveness to optimise management performance. Farmers have a direct interest in enhancing and sustaining the quality and cost efficiency of irrigation management. Where management turnover includes a decline in government subsidy to irrigated agriculture, it will involve an increase in the cost to farmers of irrigated agriculture.
- When management turnover occurs in a supportive socio-technical context, and through arrangements which enable local organisations to take over management, it will result in improved quality and cost-efficiency of irrigation management. This, in turn, will normally enhance the profitability of irrigated agriculture enough to more than offset the increased cost to farmers of irrigation management.
- Management turnover will also save for the government, as it divests itself of the responsibility to finance routine costs of operations and maintenance of irrigation systems. The savings can then be used either to reduce government. expenditures in the irrigation subsector or to reallocate funds to other functions

which cannot be handled or financed directly by the private sector. ”

Ian Stone (1984), in his work, *Canal Irrigation in British India: Perspectives on Technological Change in a Peasant Economy*, notes that “in continuation from the British, the central and state governments of independent India inherited the idea that most water rights belong to the state”. But in the background of the Preceding discussion on IMT the world over, many state governments, by the second half of the 1990’s had already adopted participatory Irrigation Management (PIM), and “transferred the irrigation management responsibilities (mostly the operations and maintenance, water distributions and in some cases fee collections) to either water Users associations (WUAs) or to the private/ NGO contractors” (Reddy, 2005), a process that continued with much vigour post 2000 (Gulati, et al, 2005).

Participatory Irrigation Management (PIM) was conceived as the option for effective irrigation management by involving and associating the farmers in all three phases viz. planning, operation and maintenance of the irrigation system.

At the national level, the National Water Policy 1987 emphasized ensuring the participation of farmers in various aspects of the management of the irrigation system, principally in water distribution and collection of water rates. Around the same time, one of the guiding principles that came out of the Earth Summit held in Rio de Janeiro was that, water should be treated as an economic good and water management should be decentralized where farmers and other stake holders will play a more important role in the management of natural resources including water (Keating, 1993). The Vaidyanathan Committee set up to study Pricing of Irrigation Water (Planning Commission, 1992) also recommended farmer’s participation in the management of irrigation systems. The Planning Commission set up another Working Group on PIM to re-examine and recommend the strategies to be adopted for the Ninth Five Year Plan to improve the irrigation sector, which identified that considerations of the legal, financial, and institutional factors were vital for successful implementation of PIM programs across the country. Apart from this development in the government sector, many Voluntary organisations (VOs) and Non-Governmental Organization (NGOs) have made significant contribution in the area of managing Common Property Resources (CPRs) that focussed on the participatory forms of development (Chopra et al. 1990; Singh 1991a, 1991b and 1994; Sengupta, 1991).

Though the practice of irrigation systems being partly managed by farmers is continuing since antiquity, in the sense that historical inscriptions from many places mention that at least the repair and maintenance work to have been locally managed after they were initially built by the rulers, kings, in the post independent time, a formal mention of its need has been talked about for quite some time, musch before the actual arrival of IMT practices in the 1990s. For instance, Hart (1961) wrote about the need for *establishing and maintaining local institutions* to fulfill a new role of "regulating turns at the ever flowing channels night and day in the Punjab villages". The Maharashtra State Irrigation Commission, in 1962 recommended for local users associations. The Second Irrigation Commission, 1972, cited a few cases of irrigation panchayats, and accorded a 'high importance' to the formation of such societies. It also recommended the states to undertake legislation in this regard. Reidinger (1974), writing about the Bhakra Sytem also suggested the creation of "water users" associations at the watercourse level, which he thought would provide flexibility of water supply within a watercourse not hitherto possible under fixed warabandi. The Command Area Development Programme, launched during the Sixth Five Year Plan, 1980-81, adopted the formation of irrigation associations as one of its strategies for improving the canal systems.

5.3 Pani Panchayat in Odisha: The Inception

Around the late 1990s, the Orissa Government suddenly started showing a massive interest in farmers' participation in water management, albeit nudged by the World Bank. In fact, the necessity for farmer participation stemmed from the state government's assurance to the World Bank funded Orissa Water Resources Consolidation Project (OWRCP) which made it a requirement to adopt the Farmers Organisation and Turnover (FOT) programme. This programme necessitated that tertiary segments or downstream parts of the canal system such as minors and sub-minors are handed over to beneficiary farmers for their operation and maintenance by forming PPs or WUAs. The primary focus of FOT programme was to handover some responsibility to farmers by organizing them into WUAs, or Pani Panvhayats (PP) which could be collection of water rates, distribution of canal water among water users, operation and maintenance of canal at lower level such as minor, sub-minor, distributaries etc. Under this programme, PPs are structured on a three tier systems with one formal association and two informal associations over hydraulic boundaries ranging from 300 hectare to 600 ha. of command area. Area irrigated by one outlet is called as Chak. To give effect to this programme, the Pani Panchayat Act was brought in 2002.

5.3.1 Important aspects of the Pani Panchayat Act

The Orissa Farmers Management of Irrigation Act or the Pani Panchayat Act provides for the establishment of farmers organizations in all the irrigation systems. The act has 43 sections covered under seven chapters. Each chapter specifies provisions for a specific objective/activity. The Act of the Orissa Legislative Assembly having been assented to by the Governor on the 25th June 2002 was published for general information. The preamble of the Act reads:

> "Whereas in the State of Orissa, which is *essentially an agricultural State* depending on an efficient and equitable supply and distribution of water, which is a National Wealth, ensuring *optimum utilisation of water by farmers* for improvement of agricultural production is the *utmost need*;
>
> And whereas, *scientific and systematic development and maintenance of irrigation infrastructure* is considered *best possible through farmers' participation*;
>
> And whereas, such Farmers' Organisation have to be given an effective

role in the *management and maintenance* of the irrigation system for *equitable and dependable supply and distribution of water*;

And whereas, it is necessary in the State of Orissa to enact a law for farmers' participation in the management of irrigation systems by way of forming Pani Panchayat." [*emphasis added*] (GoO, 2002)

The Pani Panchayat Act, 2002 extends to the whole of the State of Orissa. Defining 'farmers organisation' the act states, 'Farmers Organisation' means and includes:

1. PP at the primary level consisting of all water users, as constituted within a specified hydraulic boundary of a major, medium, minor (flow and lift both surface and groundwater) and creek irrigation projects funded by the Government as constituted under section 3,
2. Distributary Committee at the secondary level, as constituted under section
3. Project Committee at the project level, as constituted under section 7;
4. Every PP shall consist of all the water users who are land holders in the area of a PP; provided that, where the area of the PP comes under a minor irrigation system, the fishermen of that area who do not hold any land therein but earn their livelihood by fishing may be admitted as members…
    a) Explanation I. - A land holder or Fisherman may nominate any adult member of his/her family to be the member of the Pani Panchayat;
    b) Explanation II. - A minor landholder or fisherman shall be represented by his or her legal guardian.
    c) Explanation III. – where a fisherman holds any land in the area of the PP, he may be allowed to be a member of the PP as a landholder.
5. Government may, by notification nominate at least one officer each from Department of Water Resources, Department of

Agriculture and Department of Revenue to be the members of the Pani Panchayat without having the right to vote.

As per section 4(1) of the Act, "All the land holders in a Chak will elect three members in the manner as may be prescribed to form a Chak Committee in such a way that there shall be one member from the upper reach, one from the middle reach and one from the lower reach within the Chak. They will also simultaneously elect one among those three to represent the Chak in the Executive Committee of the Pani Panchayat, on rotation basis in each term of election" and to effect this the act provides, " under 4(3) The Superintending Engineer shall cause arrangements for the election of a member of the Executive Committee from each Chak by all the land holders of the Chak by the method of secret ballot in the manner prescribed."

In chapter III, the functions of the PP has been covered and section 17 under this chapter states, "The Pani Panchayat shall perform the following functions, namely:- (a) to prepare a cropping programme suitable for the soil and agro-climatic condition with due regard to crop diversification; (b) to prepare a plan for the maintenance of irrigation system in the area of its operation at the end of each crop season and carry out the maintenance works of both distributary system and minor, sub-minor and field drains in its area of operation with the funds of the Pani Panchayat from time to time;"

Chapter IV gives the arrangement of funds and resources for the farmers' organisation wherein, section 22 states. " The funds of the Farmers' Organisation shall consist of the following namely:- (a) funds as may be granted by the State and Central Government for the development of the area of operation; (b) resources raised from any financing agency for undertaking any economic development activities in its area of operation; (c) income from the properties and assets managed by Farmers' Organisation; (d) fees collected by the Farmers' Organisation from the water users for the services rendered in better management of the irrigation systems; and (e) amounts received from any other source including M.L.A. Local Area Development Fund and M.P. Local Area Development Fund etc."

Further Section 36(1) states, “The Farmers' Organisation shall keep their funds in a Nationalised Bank or a Co-operative Bank or the District Co-operation Central Bank or the Orissa State Co-operative Central Bank in the names of such office bearers as may be prescribed”. Additionally, regarding maintaining a sinking fund, section 38. (1) states, “The Executive Committee of the Farmers' Organisation shall maintain a Sinking Fund in the manner as may be prescribed for the repayment of money borrowed and shall pay every year into the Sinking Fund such sum as may be sufficient for repayment within the period fixed of all money so borrowed. (2) The Sinking Fund or any part there of shall be applied in or towards, the discharge of the loan for which such fund was created, and until such loan is wholly discharged, it shall not be applied for any other purpose.”

It stipulates that, all the water users are members of general body of the PP. At the project level, a federation of all WUA is established with a formal but non-binding advisory role in canal system operation and maintenance known as Apex Committee. The executive members of the Apex Committee are elected out of the Presidents of all WUAs within the command area jurisdiction of the irrigation project. The basic organisational structure of the Pani Panchayat is presented in Figure 5.1. The PPs are registered as legal bodies to provide the required identity.

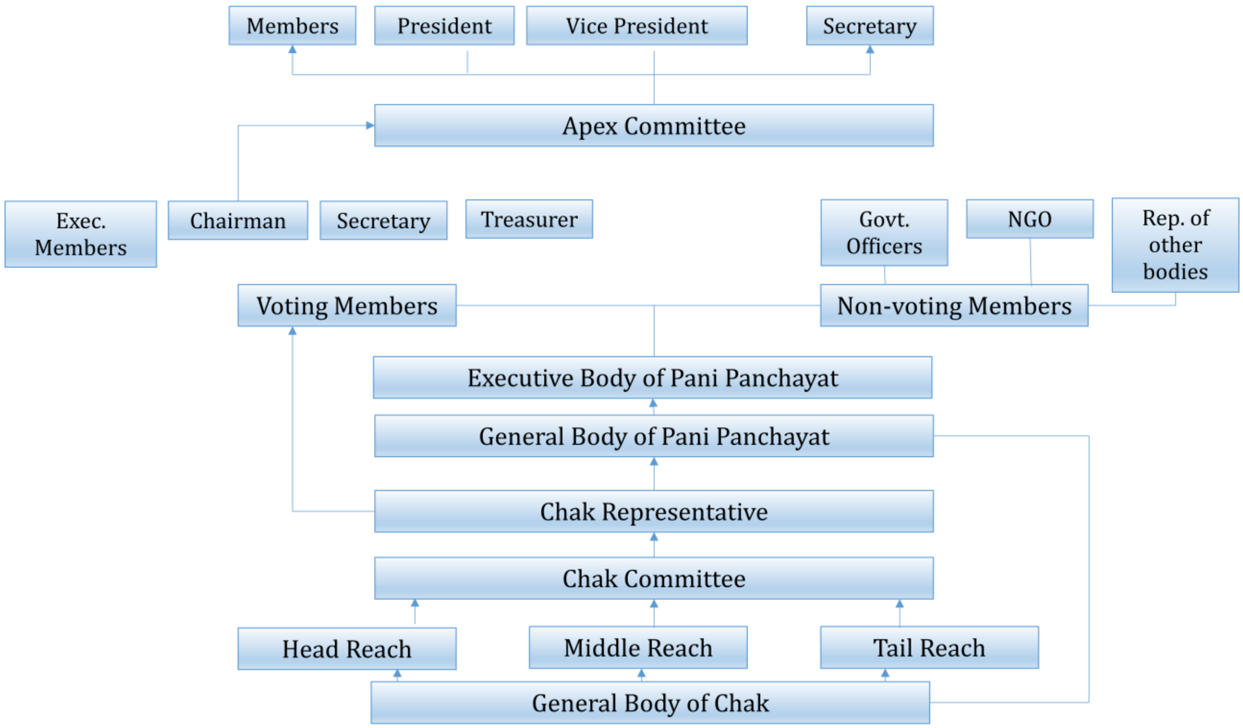

Figure 5. 1 Organisational structure of Pani Panchayat

5.3.1.1 Biju Krushak Vikash Yojana (BKVY)

The "subsidiary of PIM is Biju Krushak Vikash Yojana (BKVY) launched since 2001, which is a unique model in the minor irrigation sector (flow as well as lift) that ensures users participation at the beginning of the project itself. The unique feature of BKVY is that there is an open invitation to farmers to form themselves in to a registered PP" (Mahapatra, 2007), get it registered under Society Registration Act, 1860 in order to derive the benefit of irrigation assistance from the Government wherein the pani panchayat concerned contributes 20% of the capital cost in the either cash or in terms of labour or in the form of land. The State provides the rest 80% of the capital cost as one time assistance and also executes the project on behalf of the PP. After completion of the project it is handed over to the PP for operation and maintenance. The Government does not intend to collect any water tax from the farmers and the projects are to be maintained by the PP themselves.

5.3.2 An Assessment of Orissa Pani Panchayat Act, 2002

The following is an account of the Pani Panchayat act, 2002 assessing its positive and negative aspects.

5.3.2.1 Positive aspects of the act

For the first time in the legislative history of irrigation in Odisha, the PP act provides farmers participation a legal status thereby encouraging them for better participation. Now, the PPs are legally authorised to levy and collect additional water charges, which can be expected to enhance their financial positions. The PP Act allows farmers' participation, not only at a lower level but also at the main system level, albeit in a limited way. The farmers' collective action is made possible through the formation of PPs. Further, there is provision for the office bearers to be elected through an election through secret ballots thereby ensuring the strengthening of democratic process. The Act provides autonomy to the farmers in managing the irrigation system in so far as their maintenance and distribution is concerned. In case of disputes, since the decisions taken by the concerned committees or their higher level committees are final and binding, farmers can be spared of the legal entanglement, as appeal to court is forbidden. Another remarkable feature that ensures accountability of the elected members, in that, the general body can recall any committee member if they feel his performance is deemed sub-optimal by them. Finally, PPs once they are formed can be thought of as permanent bodies, in that even the government cannot dissolve them.

5.3.2.2 Negative aspects of the Act

It is equally important to take a critical view of the provisions of the PP Act and as such a view may help identify and rectify the inadequacies in the Act. A few fundamental questions arise viz. a. Is it essential to superimpose a new institution (e.g. PP), through legislation, on the existing ones?, b. is it appropriate on the part of the govt to alter the norms and institutionalised practices, those have evolved over a long period of time?, c. how can the State can impose some kind of non-functioning or mal-functioning irrigation system on the people through an Act? And

d. if such a law is imposed by the state, will it have genuine acceptability by the farmers to ensure collective action as desired by the law?

The Act states every Pani Panchayat shall consist of all the *water users* in such PPs area as member [Chapter-II, Section 3 (4) (i)]. The term farmer is very narrowly defined. In that sense, PP includes only those cultivators as rightful water users who own or cultivate land, then the Act is unleashing a great injustice to a village society, in which water has always been considered as a common property for all sections of the community. In the process, the Act excludes the landless population from becoming members of a PP. This has been addressed by later amendments into the Act in 2008 and 2014, to include non land owning people like fishermen as members. However, other landless farmers are still excluded.

The Government is tasked with constituting an Apex Committee, which will have an overall control over PPs. But the constituent members of this Committee have not been spelled out. The ambiguity lies, in particular, whether the members of Apex Committee are primarily from PP or from the Department of Water Resources or from any other section. This is important because, most of the final decisions are taken by the Apex Committee, and if this Committee is dominated by the DWR Officials, then the strength and autonomy of PPs will be diluted. On the other hand, if the members of the Apex Committee are nominated from political parties, it will lead to misuse of this provision favouring the ruling parties.

Section 21 (1) of the PP Act provides for the appointment of personnel from the Department of Water Resources of the Government of Orissa, as competent authorities for implementing the decisions of the Farmers Organisation but their role is not clearly specified. It is quite vague in defining the powers of the 'competent authorities' and requires the Farmers Organisation to give effect to such orders. The Government, on a later date, may issue such orders and directions of a general character as they may consider necessary and the Farmers Organisation shall have to give effect to such orders and directions. This has the potentialities to defeat the whole purpose of empowering water users weakening them and diluting the autonomy given to Farmers Organisations. Ultimately, the PPs may be reduced to a body of a mere takers of directions issued by the Department.

Section-26 of PP Act stipulates that 'any dispute or differences arising between a member and the managing committees shall be determined by the Apex Committee, whose decision shall be final'. It may be noted that, even in the case of a settlement of disputes among water users, the final decision remains in the hands of the Department of Water Resources. Currently, the matters concerning water disputes are resolved through local institutional mechanisms.

State water Policy statement clearly mentions farmers participation in irrigation management, but PP Act fails to clearly define their rights over water. The extent of users participation is limited to the operation and maintenance at local levels only. The involvement of the community in designs and construction of irrigation system are grossly neglected.

The State resorted to turning over irrigation systems to people, which were already beset with problems like gross mismatch between the demand and availability of water supply, abysmally low recovery rates, the availability of very little resources for operation and maintenance, were corruption ridden, fragmented community action and so on. For a long time, the State played a major role in deciding the rules and regulations of water management with hardly any provisions for user's participation. Further as already pointed out, there is no scope for involving farmers in the plan and design of the system right from the project formulation stage. Even the existing rules and regulations of irrigation systems, which are managerial in nature, suffer from many problems.

5.4 Odisha Community Tank Management Project (OCTMP)

5.4.1 Background & Concept of the Project

Tank Irrigation Systems in Odisha are centuries old. Tank system structures are mostly constructed under the aegis of Kingship to support the basic human needs of drinking, bathing, irrigation and especially as a hedging mechanism against drought.

Government of Odisha in partnership with the Government of India initiated the Odisha Community Tank Management Project, with funding from the World Bank. The project aimed at repairing and rehabilitating 332 Minor Irrigation Tanks having a command area of 40 hectares to 2000 hectares and covering 64,200 hectares in 12 districts namely Angul, Balasore, Bargarh, Boudh, Cuttack, Gajapati, Ganjam, Jajpur, Jharsuguda, Khurda, Mayurbhanj and Rayagada with a budget of Rs. 432 crores.

5.4.2 The key principles of OCTMP

There are three key principles underlying OCTMP project design viz. 1.) a *decentralized mechanism* where the main tank beneficiaries play a proactive role in planning, implementing and sustaining project interventions. 2.) The tank system rehabilitation work meets technical quality safety standards with *sufficient attention paid to social*, environment and fiduciary considerations and 3.) Improvement of agricultural productivity and farmer income, access to *improved agricultural technologies* and practices and facilitation of *market linkage* for agricultural producers are as important as improving access to water. Thus, OCTMP goes beyond the usual renovation of tanks, and beyond the provisions under pani panchayat. By involving the farmers in the design phase itself, it tries to achieve combining the traditional knowledge and concerns of the farmers with the technical capability of the department. The researchers FGD with farmers from OCTMP villages revealed that farmers have a greater sense of ownership and satisfactions on the irrigation infrastructure created. They proudly narrated the layout changes and design improvement that was brought in after their suggestions, which ultimately has made the entire land in their village (Batterma) brought under cultivation. Similarly, there is prominent livelihood strengthening component under OCTMP besides the core irrigation component. Researcher's interaction with the farmers and verification of records with the pani panchayat in Batterma showed that there indeed was promotion of poultry, duckery, pisciculture in the panipanchayat. However, the farmers, oblivious of the temporary nature of the measures, complained about sudden discontinuation of after two years.

5.4.3 Key components of OCTMP

The project aimed at achieving sustainability of restored minor irrigation systems through community participation and empowerment to develop self-owned, self-managed and self sustenance of Pani Panchayats. And in order to achieve the project objectives, project activities comprise of four main components namely:

1.) Institutional Strengthening: This includes inter alia, strengthening of community-based institutions to assume responsibility for the tank system improvement and management, development of human resources and developing mechanisms where by the needs of the traditionally vulnerable stakeholders can be addressed,

2.) Tank System Improvements: This includes physical investment in tank systems. The actual rehabilitation work required would be determined for each tank system individually with an upfront "Tank Improvement and Management Plan (TIMP)" prepared in consultation with tank users *prior to undertaking any investments*. In general, interventions are likely to address deficiencies in feeder channels, tank bed and structures, and the water distribution and drainage systems,

3.) Agricultural and Livelihood Support Services: This includes Agriculture, Horticulture, Livestock, Fisheries and Agri-marketing sub-components of the project. The main objective to increase production & productivity of selected agricultural produce through improved production technique and increase the share of final value obtained by farmer marketing groups in targeted commodities, and

4.) **Project Management:** The objective of this component is to ensure smooth implementation of project activities. The sub-component finance & procurement, monitoring and evaluation come under this component.

As already noted earlier, there are two MIPs located in the Ong river basin which were taken up under OCTMP. Thus, it would be interesting to compare the performance of these projects with other projects under the Minor Irrigation (MI) department, as well as with those under panchayat unions. The data for this exercise was collected through primary survey conducted in 2018-19. Farmer responses on various aspects related to the performances of their irrigation systems were captured, compared and analysed. The finding of the same is presented in the following section.

5.5 Farmers' assessment of Tank water supply

Equity in water access is an important aspect of the PP Act as it finds mention in the preamble of the Act itself. Hence this aspect has been evaluated. Mostly access to water from a tank differs based on the relative location of a farm with respect to the tank canals, viz. Head, Middle and Tail reaches. Inequitable supply of water indicates a sub-optimal capacity utilisation of the tank irrigation system as well as a poor institutional functioning of the same.

Farmers were asked about their perception on the quantity of water they got from the Tanks. Here the data has been presented for tanks which differed from each other in their institutional set up and governance or by virtue of being under different authorities. The first are those still under the Panchayt unions, these are usually smaller tanks irrigating are under 40 hectares. Under this, the farmers having their land under Budhikata and Sargikata with their command area spreading in villages Dahita, Bijamal; under khaliakata in village Dewandihi; Paikmunda and Uparkata with their command area lying in Jhungapali and Diptipur villages etc have been included. The second category of tanks are those under the Minor Irrigation department, usually having a command area between 40- 2000 hectares. Under this villages lying under Saplahar dam MIP- Bheunria (Bapuji Pani Panchayat), Kapsila and Amlipali (Jagannath PP); land under Diwankata with its land spreading in the village Palsada (Diwankata PP), land irrigated by Bandeswari nallah MIP with its land falling under Samaleswari PP, etc have been included. The third category of tanks are those under the MIP but taken up by OCTMP. Under these land spread over two villages namely 1. Battterma (Maa Mauli PP) and 2.

Jhagadjhal (Laxmidevi PP) have been included. The data collected from these tanks are presented in Table 5. 1.

Table No. 5.1 Adequacy of water supply in area under different tank categories

Status of water supply	**OCTMP**			**Non OCTMP MIP**			**PUT**		
	Head	***Middle***	***Tail***	***Head***	***Middle***	***Tail***	***Head***	***Middle***	***Tail***
Adequate	86	89	77	66	64	34	63	48	43
Inadequate	14	11	23	34	36	66	37	52	57
Total	100	100	100	100	100	100	100	100	100

All figures in Percentages

One can see that, in all types of tanks, the head reach farmers report higher adequacy than the tail end farmers, with the middle reach farmers reporting in between. However, comparing the adequacy level among head reach farmers show that, whereas less than 15% farmers under OCTMP tanks report inadequacy, there are as many as 35%-40% farmers reporting inadequacy under MIP and under PU tanks. Further, the farmers in the tail region report widespread inadequacy. Whereas only 23% of the Tail reach farmers under OCTMP tanks report inadequacy, under MIP and PU Tanks the level is as high as 66% and 57% respectively. Thus, one can see that equitable distribution has not yet been achieved even under OCTMP tanks, inequity is very high in MIP and PU tanks.

5.5.1 Reasons of inadequate tank water supply

To get the views of the farmers on the shortages of water supply to their fields, farmers were further asked to specify the reasons they believe are behind such shortages. The finding is presented in the table below. The reasons for water shortages have been analysed across different canal reaches and is presented in the table below. The responses of the farmers have been segregated across tanks under the three management types, viz. OCTMP, MIP and Panchayat unions and the data is presented separately for them.

Table No 5.2 Reasons for Inadequacy in OCTMP Tanks across Canal-Reaches

Sl No.	Reasons for Inadequacy	Head	Middle	Tail
1	Reduced capacity due to siltation	45	50	36
2	Damaged Sluice	12	11	7
3	Improper canal	3	6	9
4	Damaged canals/channels	12	18	22
5	Improper Distribution	5	6	16
6	Others	23	9	10
	Total	**100**	**100**	**100**

All figures in Percentages

Looking at the data, it is clear that the most important cause of shortages reported by the beneficiaries of OCTMP intervention is infrastructural ie most of the farmers ascribe siltation of the tanks to be the primary reason for shortages of water, followed by damaged sluice and canals. It is important to note here that, very few farmers consider the design of the canals as improper. The researcher's interaction with the farmers revealed that, in Batterma village, prior to OCTMP interventions, there were many complaints by the farmers on their canal layouts. But in 2012, when it was taken up under OCTMP, the PP was reconstituted and many stretches of canals were newly constructed after a joint reconnaissance by the Junior engineer (JE), Assistant Engineer (AE) along with the farmers. They proudly claimed that, the new innovatively laid out canals, a result of their own contribution in finalising the canal routes, now cover almost all the farms in the village. Very few farmers from the head and middle reaches have any issues with the distribution of water, while some of the tail reach farmers reported that, if proper distribution is ensured by the PP, even they will get sufficient water. The Radar diagram too clearly indicates that there are long spikes on the axis representing reduced capacity of the tanks due to siltation. A sizable number of farmers have cited other reasons for water shortages; what was found in both Batterma and Jhagadjhal villages is that, both the projects are now facing challenges which are not of their own making. In Batterma, a new check dam has come up in Gandpali some 250 metres above the point where the Diversion weir is located. Thus, water supply has drastically reduced at the D/W that diverts water to Gudhali kata, the main reservoir that supplies water to the entire village. Similarly in Jhagadjhal, as earlier pointed, a new river lift point has been set up in Jhar village upstream of the river Lambi darha, causing a drastic reduction again for the farmers in Jhagadjhal. Thus, through OCTMP tanks have been able to manage the institutional aspects quite well, they have new found challenges coming from the MIP department and OLIC department. Due to these issues, two well performing OCTMP PPs have new threats looming in their horizon. The helplessness and resentment among the farmers against the respective departments was quite palpable during the FGDs. But, closer analysis suggests that the tank irrigation system seem to have reached a point where the population density of the area has started to adversely affecting the tank irrigation system, as identified by Von Oppen and K V Subba Rao (1987), when they observe, " … the historical data on tank development in different states over the years indicate that the threshold density to begin intensive tank construction lies between 50 and 60 persons/km^2. The upper limit is clearly discernible—it seems to vary from one region to another—but there is clearly a decline in tank irrigation at very high levels of population density".

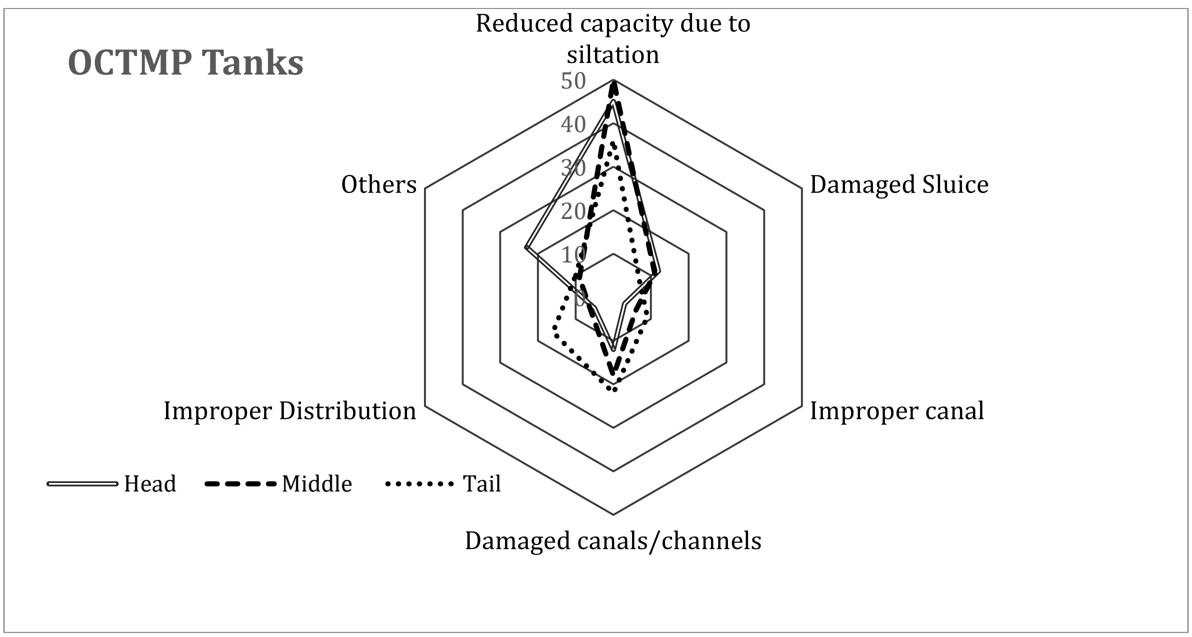

Figure No, 5. 2 Reasons for Inadequacy in OCTMP Tanks across Canal-Reaches

Table no. 5.3 Reasons for Inadequacy in Non-OCTMP Tanks across Canal-Reaches

Sl No.	Reasons for Inadequacy	Head	Middle	Tail
1	Reduced capacity due to siltation	23	22	12
2	Damaged Sluice	20	18	8
3	Improper canal	4	5	13
4	Damaged canals/channels	15	21	34
5	Improper Distribution	3	6	28
6	Others	35	28	5
	Total	**100**	**100**	**100**

All figures in Percentages

We see that, in non-OCTMP tanks, farmers in the tail region feel that they do not get enough water primarily due to the fact that, the channels are badly damaged and water does not reach them adequately. The next big reason they identify is improper distribution. Here, the complaints about improper distribution of tank water, by the tail reach farmers are almost twice as high as those in the OCTMP tanks. Interestingly, the head and middle reach farmers have no such qualms, which is indicative of a highly inequitable distribution of water. Mere formation of PPs has gathered significant attention under PIM Programs. The number of organisations registered or in the process being formed has been construed as the scale of achievement of PIM. But, far more important institutional aspects of farmer participation in irrigation that has been proved so crucial to the success of irrigation systems receive far less attention in the current PIM policies as put forward by the government. The relative share of damaged canals is also higher than the OCTMP tanks. One clarification for the high percentages of other reason here must be put in place. It was found that in two of the villages, Dahita and Palsada, the alternative use of tanks have led to huge shortage of water there. In Dahita, the tank has been auctioned at a price of Rs 35,000 for three years for fish cultivation. Now, to maintain water level in the tank, the contractor has built a concrete structure at a much higher level, thereby obstructing water flow to the field, including during the crucial growth phases. This, the farmers believe, cause them a loss of 6-9 quintal of rice per acre depending on the type of land. During the FGD, the farmers were visibly anguished by this. During the FGD, it came out how absurd was the decision even from an economic point of view. A simple calculation would show that, if there is an average loss of say 7quintals per acre, it translates into a monetary loss of Rs. 1700* 7 quintals= Rs. 11, 900 (~Rs. 12k). Now Budhi-kata irrigates around 240 acres of land. Even if we round up the loss in productivity to some 200 acres of land, the total loss in a season is 200*Rs.12000= Rs. 2,40,000. From a three year contract at Rs 35000, fishery earns the Panchayat only around Rs 12,000 per annum. So at this estimate, per season loss from the tank due to fishery is Rs. 2,40,00 - Rs. 12,000= Rs. 2,22,000. This defies all logic to go for auctioning the tank for fishery. The farmers are even ready to pay the amount themselves to the panchayats, if it stops auction the tank for fishery, but to no avail. Thus we can say that, contrary to the belief that, multiple use of tanks should be promoted (Palanisamy, Ruth Meinzen Dick et.al, 2011) to cover for the cost of repairing etc., allowing multiple use needs thorough scrutiny before and should only be allowed when such uses are complementary to raise total income from the tank as well as the command area.

Similarly in Palsada, panchayat built a similar obstructing structure on Diwankata, so as to preserve sufficient water for bathing. And this happened 4 years ago, when rain failed, water shortage was acute and there was too little water left even for bathing. Interestingly, in the succeeding year, when there was good rain (sufficient enough to store water for bathing), the structure remained, even though not needed any more, and water supply to the fields from the tank remained curtailed. The panchayats does not wish to dismantle the structure or lower its height because of lack of fund for the same. So we can see that, the challenges faced by tanks are varied and in the absence of stake holder participation and their consents, interventions to the system may bring in adverse consequences.

Looking at the radar chart, we can see that, the spikes have shifted from the tank structure to either damaged channels or to institutional collapse axis. Thus, the differences from OCTMP tanks are characteristically different.

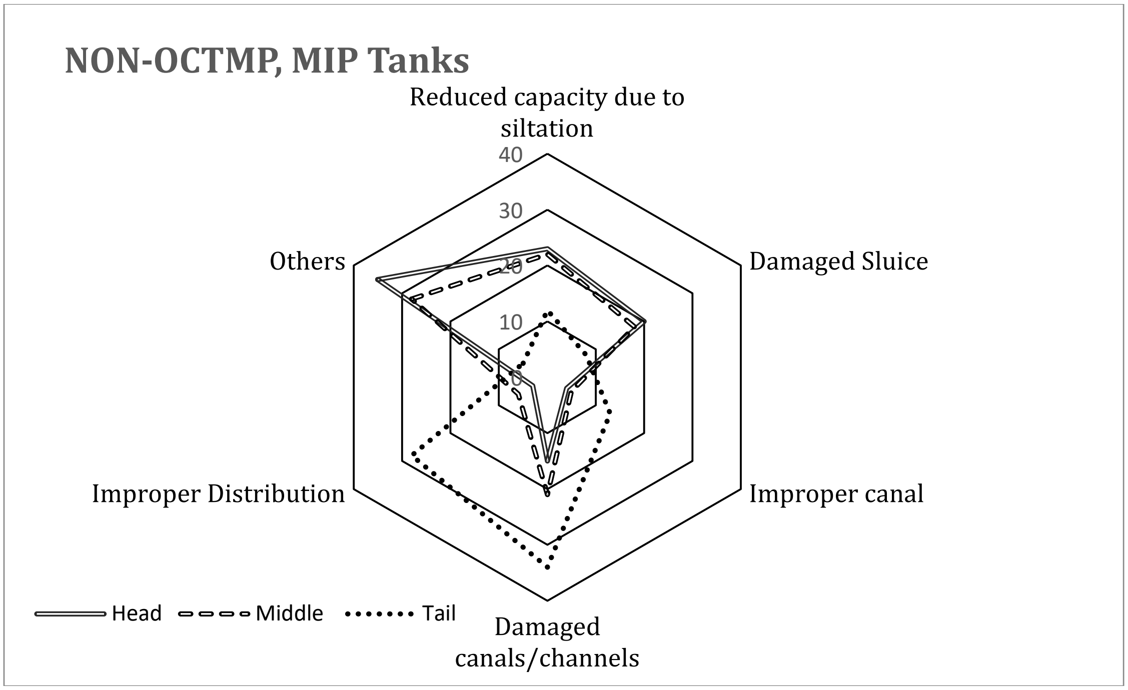

Figure No, 5. 3 Reasons for Inadequacy in Non-OCTMP Tanks across Canal-Reaches

Table no. 5.4 Reasons for Inadequacy in Tanks under Panchayat Union across Canal-Reaches

Sl No.	Reasons for Inadequacy	Head	Middle	Tail
1	Reduced capacity due to siltation	22	28	8
2	Damaged Sluice	28	17	6
3	Improper canal	4	5	12
4	Damaged canals/channels	15	28	40
5	Improper Distribution	8	15	31
6	Others	23	7	3
	Total	**100**	**100**	**100**

All figures in Percentages

A similar pattern (as in Non-OCTMP) is observed with the tanks under Panchayat unions too. we can clearly see that, the share of damaged channels and institutional collapse is still more heightened here. Another remarkable feature is that, there is a peak on the axis of damaged sluice, indicating still worse upkeep of the tank structures. A word of caution however is that, the radar chart may give one the impression that, problems of siltation and in canal design are absent in the latter two categories of tanks, while this may not necessarily be the case. As all the factors outlined by the farmers are relative to each other, a higher value in one axis will bring down the relative share of another. Thus, all these scores need to be read relative to each other. The spikes are indicative of their relative importance inside the group. Thus, intergroup comparison (OCTMP, Non-OCTMP and PUT) of the magnitude on any particular indicator (reason) is not recommended.

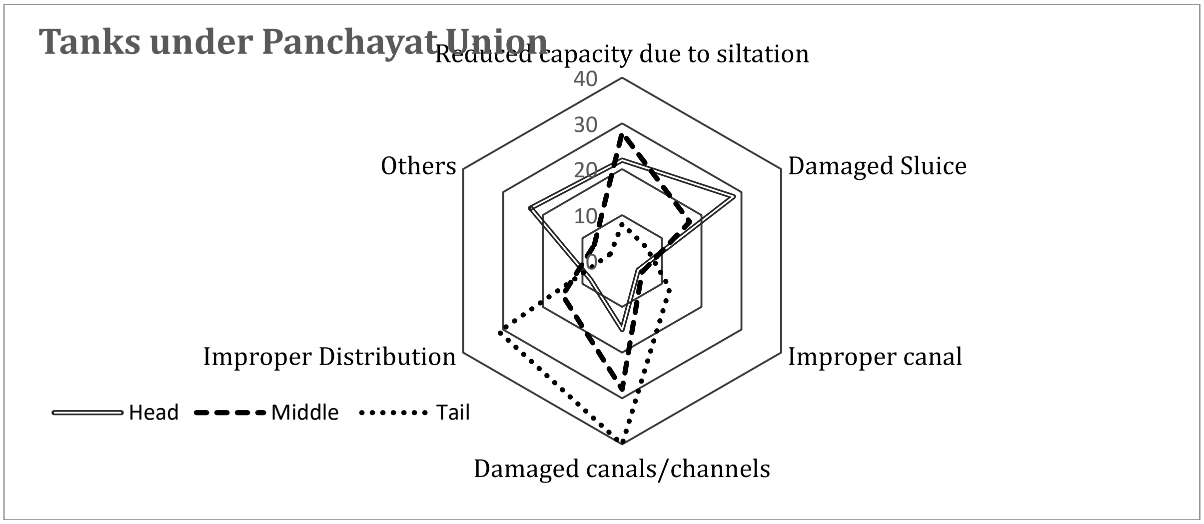

Figure No, 5. 4 Reasons for Inadequacy in Panchayat Union Tanks across Canal-Reaches

5.6 Borewells as the alternative option for Irrigation

The discussion presented above shows that farmers in the basin face varying degree of water shortages and many of them have opted for borewell to face the imminent threats of dwindling water supply to their farms. Whereas the deterioration of tank irrigation structures and its institution have played the role of "*push factors*" for the farmers to look beyond it, it is also important to understand farmers' opinion on the positives borewells provide and any external factors that acted as "*pull factors*" inducing them to opt for borewells.

Table 5. 5 Pattern of growth of Borewells in different blocks in Ong river basin

Sl. No	Blocks	2012	2013	2014	2015	2016	2017	2018	Total
1	**Bijepur**	8	12	60	319	88	264	566	**1317**
2	**Gaisilet**	27	32	95	51	225	188	108	**726**
3	**Jharbandh**	47	55	395	147	838	481	329	**2292**
4	**Padampur**	99	137	289	165	717	265	491	**2163**
5	**Paikmal**	178	52	401	137	392	303	311	**1774**
6	**Sohela**	61	251	469	847	1067	339	2193	**5227**

Source: OLIC, Bargarh, Odisha

Figures denote number of bore wells electrified upto December 2018.

5.6.1 Reasons for Shifting to Borewell

Farmers were asked to provide their reasons for shifting to borewell irrigation. The data is presented in the table below. Looking at the table, one can realise that there are four different groups of reasons on which the farmers were asked to respond. The first group is related to different aspects of water supply under which there are three reasons namely, Reliable water Supply, Adequacy of Water and Control over Water supply. Insufficient water supply especially at crucial crop growth stages curtails productivity, which can be addressed through the use of a borewell, thus next reason was, Productivity Increase. The next group of reasons is related to the cost aspect, viz. Free Electricity, Reduction in Cost of Well Digging and Reduction in cost of Pump sets. The last reason is related to the policy of the state government that is in place to help farmers acquire borewells for irrigation, which is also overlaps the cost aspect in some sense, though.

Table No. 5.6 Reasons for Shifting to Borewell by Non-OCTMP Farmers across canal-reaches

Sl No.	Reasons	Head	Middle	Tail
1	Reliable water Supply	10	12	24
2	Adequacy of Water	8	6	30
3	Control over Water supply	24	23	5
4	Productivity Increase	3	8	4
5	Free Electricity	11	14	6
6	Reduction in Cost of Well Digging	8	5	9
7	Reduction in cost of Pump sets	6	10	4
8	BKVY Subsidy	30	22	18
	Total	**100**	**100**	**100**

All figures in Percentages

For farmers in the head reach, the primary reasons to shift to borewell are BKVY subsidy (30%) wherein the government provides a subsidy of 80-90% on digging a borewell, and achieving greater control over water supply (24%). Adequacy and reliability are not the primary factors for shifting to borewells. A similar pattern is found for farmers in the middle reach too. However, for the farmers in the tail reaches, it's the adequacy of water (30%) which is the primary reasons, for water does not reach their farms in adequate quantity to fully meet the crops requirement. The second reasons specified by them is reliability of water supply (24%). One can note that, free electricity has not come up as an important reason for shifting towards borewell for any group. Further, though we saw in the previous chapter, productivity in borewell irrigated farms to be substantially higher than other farms, not many farmers specify this as *the* reason for shifting. Thus, one can say that, for the majority of the surveyed farmers opting for a borewell is more of a protective measure, than an aspirational one. These observations support our previous findings that tanks under the MIPs are not able to provide sufficient water for paddy, especially in the tail reaches.

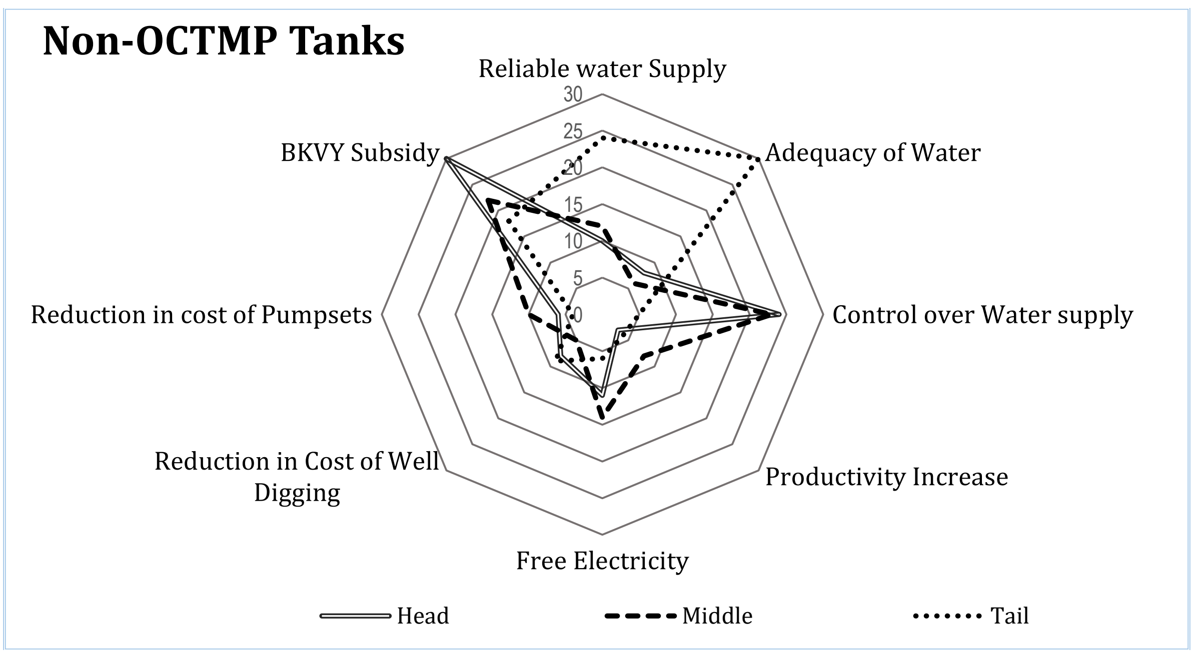

Figure No. 5.5 Reasons for Shifting to Borewell by Non OCTMP

Table No. 5.7 Reasons for Shifting to Borewell by OCTMP Farmers across canal reaches

Sl No.	Reasons	Head	Middle	Tail
1	Reliable water Supply	8	6	19
2	Adequacy of Water	8	6	18
3	Control over Water supply	30	28	8
4	Productivity Increase	3	8	5
5	Free Electricity	8	7	3
6	Reduction in Cost of Well Digging	3	5	7
7	Reduction in cost of Pumpsets	2	4	6
8	BKVY Subsidy	38	36	34
	Total	**100**	**100**	**100**

All figures in Percentages

In contrast to the farmers of the non-OCTMP MIPs, the Tail reach farmers from the OCTMP tanks identify BKVY subsidy as the prime mover of their decision for opting for a borewell, see the spikes in the radar chart, where all three are in unison. Again, even though about 1/5th the tail end farmers view adequacy and reliability of water supply to be important, the share is far less than in case of non-OCTMP farmers (more than a quarter). For the head reach and middle reach farmers the other spike is observed in the axis of control over water supply.

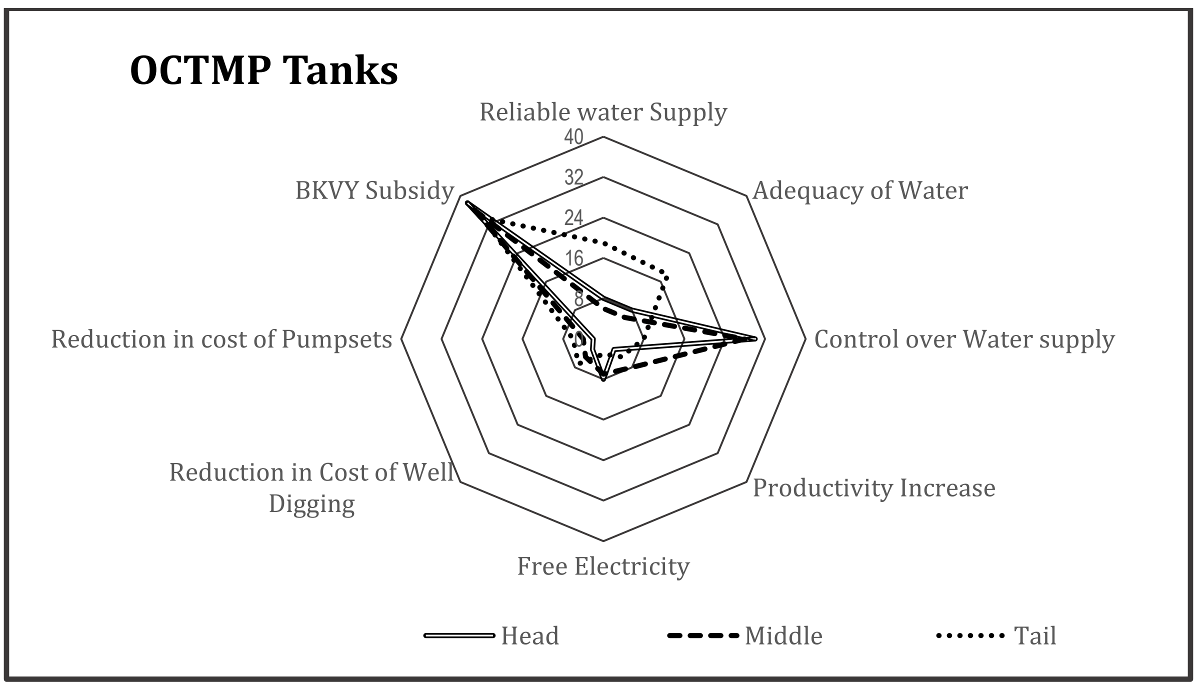

Figure No. 5. 6 Reasons for Shifting to Borewell by OCTMP Farmers.

In both the above groups, the radars failed to detect any activities in the directions of cost factors of pumps and digging under marketed conditions, thereby indicating that these factors are not perceived very important by the farmers when they choose to go for borewells. One corollary of this can be that, electricity charge doesn't matter at all and its manipulation would be toothless while making policies related to ground water exploitation. The researcher's suggestions would be to refrain from such liberal interpretations. This is so, because most of the surveyed farmers having a borewell are beneficiaries of BKVY subsidy. Further, in majority of the cases, they are not paying electricity charges, because mostly due to non-generation of bills, as they have not yet been metered. Many farmers newly owning borewells, have a general idea that, they won't have to pay for electricity, since no one is paying now. The situations may change, once farmers would be charged for electricity. The responses in such an altered scenario may change, and thus it warrants a cautioned interpretation in this regard, in so far as the impact of change in electricity charges in devising ground water use policy.

5.7 Probability of Expected Cooperation from farmers for Community Work

As already seen in the previous discussion and as expected through the IMTs the entire world over as well as enunciated by the Odisha Pani Panchayat Act 2002, the farmers' cooperation is crucial for the sustenance of tank Irrigation and its success. It's thus quite important to identify the presence of any relationship of farmers' likelihood of cooperation in the community management of irrigation works based on their characteristics. In pursuit of this, a binary logistic regression model has been construed. Following previous attempts by authors in predicting peoples' tendency towards collective actions especially in the management of CPRs viz. by Ostrom (1990), Baland and Plateau (1997), Wade (1998), and Bardhan (2005), a model has been built considering farmer's propensity towards cooperation on community work as the binary dependent variable and their characteristics like, their literacy status, land holding size, engagement in cultivation, past contribution towards maintenance of irrigation, their being members in other CPR groups (see

Table 5.8) etc. as the independent or predictor variables, which can be given as under :

$Y_i = f(X_1, X_2, X_3, X_4, X_5, X_6)$

Where, $X_1, X_2 \ldots, X_6$ are the Predictor variables, either in continuous or in binary forms, and Y is the response / dependent variable, here 1= cooperate, 0= No cooperation

$$\text{Pr.}(\text{Y}i) = \frac{1}{1 + e^{-zi}}$$

Where, Pr.(Y_i) is the probability of *i*th farmer towards cooperating in community work.

And $Zi = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \ldots + \beta_6 X6 + ui$

The list of variables used in the logit model and the result of the logistic regression is presented below:

Table 5. 8 List of Variables used in the Logit Model

Variables	Particulars	Probable effect
Lit_Farmer	A binary variable; Literacy status of farmer- Literate=1, Illiterate=0	Positive
Land_holding	Continuous variable; Land holding size of the farmer in acre	+ve/-ve
Prim_Inc	A binary Variable; Cultivation=1, others=0	Positive
Contb_Irg	Continuous variable; Contribution of the farmers for maintenance of Irrigation works	+ve/-ve
Water_Adq	A binary variable; Farmer's own assessment of getting adequate water=1, Inadequate=0	Positive
Memb_CPR	A binary variable; Membership of the farmers in other CPR / Community groups like JFM / SHG, Yes=1, No=0	Positive
Part_CW	The Dependent binary Variable; Farmer's readiness for Community Work participation for Tank, Yes=1, No=0	Dep. Variable

Farmers' cooperation on the community maintenance of tank irrigation depends on a host of factors. Here, in this study a total of six different attributes of a farmer have been tested for their effect on increasing a farmer's cooperative behaviour in this regard. Table 5.9 above lists out all the six attributes and their likely impact on farmers' cooperation in community works. We have tried to see the *nature* association between the attributes of the farmers and their predicted positive behaviours, rather than the *magnitudes* of such relationships.

Table 5. 9 Predicted scores of determinants of farmers Cooperative behaviour

Variables	***Regression Coefficient***	***Significance Status***
Lit_Farmer	*0.4*	**
Land_holding	*0.58*	*
Prim_Inc	*0.118*	**
Contb_Irg	*0.32*	**
Water_Adq	*-1.32*	**
Memb_CPR	*1.67*	*
Part_CW	--	--
Constant	*-2.29*	**
Chi ^{2} (Prob.)	0.00	
R^2 (Pseudo)	0.21	
*Sig. * @90% ; ** @95%*		

A farmer being educated or literate is expected to make him aware of the scarce nature of water resource and he is more likely to participate in the Water Users Association's meetings, which in their turn may increase his tendency to contribute towards tank maintenance. We can see from the Table above that, literacy of the farmer has a positive effect on farmers' cooperation in community endevours in the operation and maintenance of the tank irrigation system.

The land holding size of a farmer also has been found to be significantly affecting the dependent variable. It may be because, higher the land ownership by a farmer, higher is his water requirements and in the study area many of the bigger farmers were seen to be cultivating long duration paddy, which in turn are high in demand for irrigated water especially at the end of monsoon season. In such cases, poor conditions of the tanks and or canals reduce their capacity to avail sufficient water for the standing paddy in the field.

The next predictor used was whether or not a farmer's primary source of income comes from cultivation or not. As expected if the farmer's primary source of income comes from cultivation, he is more likely to contribute for the maintenance of the tank system. Naturally, he has a greater stake in the better upkeep of the tank bunds and the canals etc. so that his income is optimally sustained.

Farmers' past contributions towards tank maintenance has also been found to be significantly predicting the dependent variable being in the affirmative. This also bring to the fore the farmers belief that, the tank system is vibrant, in whatever little way they are, is due to their contributions and they are not very pessimistic about the tanks. Having said that, it must be noted here that, in the FGDs by the researcher with the farmers in various villages, farmers particularly mentioned about the resource crunch they felt in maintaining the tanks. This was especially so in the tanks maintained by the Panchayat unions. They also expressly mentioned their inability to take upon them the repairing work of the tank bunds/ desiltation etc., which requires substantial expenses. Its only minor works on the canals, like, cleaning the channels, cutting the grasses and other bushes, etc. they can take care up at the maximum.

It can be seen from the logistic regression analysis that, when farmers feel they get *inadequate* water, they have a greater tendency to cooperate in the community work of tank maintenance. The relationship is significant. This is quite expected. As we have seen that, farmers have adapted to the problem of inadequate water either by going in for a borewell, whoever could get one, or by keeping the existing source of irrigation, in this case the tanks, in the best possible condition so as to avoid the vagaries of monsoonal rains. It was found that many of the farmers who have got dug wells, in the vicinity of tanks, to tide over the shortage of water from the tanks, observe that with the deterioration of the tanks, the water supply from their tanks too dip down and these farmers were ready to cooperate in the community management of tanks system.

Finally, farmers who are members of other cooperative/collective institutions like self help groups, or Joint Forest Management committees seem to learn and enjoy the benefits of cooperation in such activities. The table above shows that, the membership of such groups seems to be significantly increasing farmers' cooperative behaviour in the community management of tank irrigation system as well.

Some of the important takeaways from the discussion above can be:

- The literacy status of the farmers is seen to have a positive and significant predictive relationship with cooperative behaviours of the farmers. Since its not an easy task to go for increasing the literacy status of the farmers at their age, the best alternative doable approach to achieve enhanced cooperative behaviour among the illiterate farmers is that, extensive awareness campaign be launched for them regarding the importance of cooperation in community management of tank irrigation system.
- It is often found that many of the CPR management bodies and other collective institutions are seen to be embedded in the societal set up. Such institutions symbiotically cohabiting needs greater promotion. They cannot be seen in an isolated fashion rather, while evaluating their performances, their spinoff benefits, as witnessed in this case, must be accounted for and all efforts be made for their sustenance.
- There is a ray of hope, that can be seen in the predictive relationship that inadequacy of water supply has with the cooperative tendency of the farmers in community management of tanks, in that, there is a great scope for revival of institutions, where they have collapsed. All they may need is some promotional initiatives by the NGOs, and necessary provisions of enabling support environment by the Government.
- Finally, the belief that making farmers pay for the maintenance of tanks sets in a decrease in their cooperative tendency was not found to be valid for the study area. However, the relationship that higher the farmers pay, more is the likelihood that he would cooperate, may be misleading. Farmers cannot be charged too high to cover all sorts of expenses related to tanks. Rather, recognizing their limited ability to pay, the government must set aside adequate funds for capital intensive expenses like, desiltation and repairing of the dam/bunds, which must be conducted at regular interval as per need.

CHAPTER VI

CONCLUSION

The study was conducted in an orderly fashion, where the chapter on morphometry and precipitation primarily focussed on understanding the challenges that Ong river basin faces from nature, whereas in the next two chapters, all attempts were geared up to understand the ranges of geo-environmental innovations which have come up in response to such challenges and as a result of continued interactions between man and nature. Simultaneously, the institutional dynamics of tank irrigations has been discussed, starting with their evolutionary history to the current state's provisions, prescriptions and restrictions related governance of tank irrigation systems. The fall out of sub optimal performance of tank irrigation system has been assessed in terms of the reasons behind them and also in terms of their effects in compelling farmers to explore for alternative source of irrigation in the form of bore well irrigation. The repercussion of such shifts to borewells has been discussed in the way they may affect the health of Tanks.

In spite of the fact that, Ong river basin faces typical problems of a drought prone area and heightened gravity of problems, on several occasions resulting in farmers resorting to suicide, which is in a uprising trend of late, it has received very scanty attention for a detailed analysis of the causality of the problems and for possible intervention. The present study attempted to fill this gap by looking at the inherent challenges the basin faces from nature and the way such challenges are sought to be overcome through human endevours. In pursuit of this, the problems pertaining to the surface topography and water resource availability were taken up. Morphometric analysis was undertaken using ALOS –PALSAR Data, fortified with data derived from survey of India toposheets and GPS survey data. Though the method was found capable of providing data with reasonable quality and accuracy, caution is warranted especially when deciding on the delineation of the first order streams, which in many occasions can be misleading. While the DEM derived first order reasonably matched with the reality in hilly and less intervened areas, in the low slope areas, most of the first order channel beds have been converted into cultivated lands and they coincided frequently with the

Bahal land, the local terms for lowest topo-sequential land. Thus, ideally a DEM derived products should be verified with other secondary data and field observations before their uses.

In the Ong river basin, distributions of steams as measured through the morphometry suggest that the underlying geology seems to be quite homogeneous without much structural disturbances. The oval shape of the basin indicated average discharge efficiency and thereby a potential of a moderately accentuated peak of flow of medium duration does exist.

The basin has ‘fine’ drainage texture. Further, the drainage density and stream frequency of the basin indicate somewhat high permeable subsoil and moderate relief. This indicates relatively long overland flow of surface water; that is also found to be related with the surface roughness, runoff and climate of the region. This Ong basin has ‘dendritic’ drainage pattern composed of fairly homogeneous rock and indicating that the underlying geologic structure do not control surface drainage much.

On the basis of the analysis of the various parameters of the basin, it can be said that, the Horton’s first law of stream numbers is applicable to the sub-basin. The average ratio is 4.424 which lies between 3.0 and 5.0. It indicates that the drainage pattern have not been distorted by the geologic structures of the basin. A higher value of bifurcation ratio indicates an extended peak flow, whereas the lower value of the same indicates a shorter peak. The Ong basin would yield flood hydrograph somewhere between these two extremes.

Low drainage density, low stream frequency and subdued drainage intensity indicate that the surface runoff is not quickly discharged from the basin, thereby enhancing its susceptibility to flash flooding and consequent soil erosion. The basin has relatively low infiltration number that indicates high rate of infiltration and reduced surface run-off. These are also confirmed from the length of overland flow. Though morphometric parameters pertaining to Ong river basin are somewhat favorable for infiltration and run-off, heavy rainfall events can occasionally result in flooding, which can be accentuated by inefficiency of surface storage structures like check dams, tanks, reservoirs and degeneration/ modification of streams and landuse changes due to increased human interventions on the natural landscape.

The above observations point to the fact that the Ong River basin displays all the potential to perform the drainage function more effectively. The analysis leads to the greater need to further increase the storage capacity of all the water bodies, rehabilitation and restoring of channels which will go a long way in enhancing the basin's water holding capacity. This in turn, will be of great use in meeting the growing demands for water for agriculture, urban as well as for industrial usages.

Further, the general undulating land in the basin has led into a fourfold topo-terrainic differentiation of the agricultural land, which is of great economic significance in terms of the way it challenges farming practices and also from the standpoint of costs of cultivation and productivity from these lands.

The next big challenge the river basin faces is of availability of water for cultivation. It's not to suggest that, for other sector, water is readily available in sufficient quantity, but since agriculture is the dominant occupation of the majority of the populace in the region, the supply of water has been studied from the stand point of its availability for agriculture in this study. It may be noted that, there are no major or medium irrigation project in the basin and thus cultivation doesn't enjoy an assured supply of water throughout the growing season. Hence, an analysis of water supply through precipitation warrants its pattern to be unravelled through analysis. Further, rice being the dominant crop in the region, the pattern of precipitation has been analysed vis a vis paddy cultivation calendar. The analysis of rain fall in the basin showed that, around 90% of the rainfall is received in the monsoon months alone. Further, the coefficient of variation of rainfall across seasons revealed that, it's very high for monsoon season as compared to rest of the seasons. Apart from such analysis of total rainfall received in a year or in a season as a whole, weekly rainfall analysis was attempted.

The weekly analysis of rainfall has been undertaken in *two different ways* which have great practical utility for understanding its importance for paddy cultivation. Under rainfed condition, the cropping calendar of paddy closely follows rainfall. Since, a particular level of moisture is required before the cropping, whether sowing of dry seeded rice or transplanting of wet rice, pattern of rain fall can potentially shift such dates substantially. Further, if the shifting of such dates is substantial, expected yield takes a beating, making cultivation risk prone for the farmers. Such risk analysis was attempted by estimating the probability of receiving a desired level of accumulated rainfall, so that cropping can begin from the nth week out of the 52 SMWs in a year. This was the *first type of analysis for weekly rainfall* that was undertaken, which lets us know, the level of risks farmers are exposed to as a result of delay of crop sowing dates. The estimation was done at 75% probability level. The analysis showed that, where as for Bijepur and Paikmal, the accumulated 75mm Rainfall are received in the 24th week, for Gaisilet, Padampur, Jharbandh and Sohela, the same amount is received only in the 25th week. Similarly, the same graphs also show that, 200 mm of accumulated Rainfall is received in the 26th week in Bijepur and Paikmal and the same is received in the 28th week in rest of the stations. It can be noticed that, for Gaisilet, Padampur, Jharbandh and Sohela, not only the receipt of 75 mm is delayed by a week, it takes another 3weeks to accumulate 200 mm rainfall. In Bijepur, the receipt of 75mm is earlier and also the accumulation to 200 mm is one week shorter than the rest. Similarly, where as for Bijepur and Paikmal, the accumulated 75mm Rainfall are received in the 24th week, for Gaisilet, Padampur, Jharbandh and Sohela, the same amount is received only in the 25th week. Similarly, the same graphs also show that, 200 mm of accumulated Rainfall is received in the 26th week in Bijepur and Paikmal and the same is received in the 28th week in rest of the stations. It can be noticed that, for Gaisilet, Padampur, Jharbandh and Sohela, not only the receipt of 75 mm is delayed by a week, it takes another 3weeks to accumulate 200 mm rainfall. In Bijepur, the receipt of 75mm is earlier and also the accumulation to 200 mm is one week shorter than the rest. Similarly, It was also seen that, in case of dry seeding, growing season at the earliest can be started in the 24th week (ending on 17th June). For half of the stations in the basin, it takes 3 long weeks for accumulating 200mm rainfall from 75mm, the time when the transplanted rice growing season can be started. In case of backward accumulation, increase in accumulated rainfall from 100mm to 500mm, the cut off date for all the stations is 32nd week.

Though the knowledge of such appropriate dates of sowing is important, under rainfed conditions, paddy faces another threat, wherein, if the standing crop has to face prolonged dry periods, yields are significantly affected. Thus, weekly rainfall was analysed to find out to see the probability of a particular week being dry during the paddy growing period (SMW 17 to SMW 45). Further, if a week is followed by (or preceded by) another dry week, the impact is accentuated. One may note that, rice is a very water sensitive crop, especially some of the crucial crop growth stage have their requisite water requirement, below which the yield get hugely impacted. The occurrence of a week being dry, its probability has been calculated through Markov chain model, that a week being dry in the initial 4-5 weeks ranges between 0.63 to 0.89 in Bijepur, 0.70 to 0.92 in Gaisilet, from 0.63 to 1 in Jharbandh, 0.59 to 0.93 in Paikmal, from 0.74 to 0.96 in Padampur, from 0.74 to 1 in Sohela. Less than 50 % probability of a week being dry ranges from SMW 27 to SMW 36 overall in all the stations in Ong river basin.

It was seen from the analysis that the season with heavy rainfall sufficient to grow paddy is from around 23rd week to 36th week, a total of around 13 weeks (91 days). Thus, short paddy cultivars which can mature in 90 days like short height early and very early maturing high yielding varieties can be grown under rainfed conditions. Taking into consideration the weekly accumulated rainfall along with the probability of two consecutive dry weeks, it can be concluded that, though the paddy cultivation operation is possible to be started from the 24th-25th week, it is not risk free, because till around 25th -26th week, more than 50% probability of two consecutive weeks being dry still persists in some of the stations. Thus, even the cultivation of dry seeded rice has its own risk in the study area.

Thus, there are two kinds of disadvantages imposed by nature related to uneven topography and erratic precipitation. There have been attempts to face these disadvantages through geo-environmental innovations by the farmers of the Ong river basin through sustained interventions. Firstly, the unevenness of the land has been worked upon by the farmers through ages by leveling the undulated surface topography and carving out cultivable lands out of them. Years of negotiation with nature by ingenuous farmers have nonetheless resulted in a four-fold topo-sequential classification of farmlands based on water retention capacity of the soil viz, *Aat, Maal, Berna and Bahal*. No wonder, this diversity of topoterrain types have their inherent advantages and challenges. Similarly, the uncertainty of rainfall distributions has been traditionally been worked upon by conserving water in the time of abundance for its utilization during scarcity. Such conservation efforts greatly utilized the undulating terrain to somehow check the gushing waters down the slope by bunding them. The resulting structures, once to be found in abundance throughout the landscape, were diversely named as *Kata, Munda, Bandh and chahala* etc. depending on their scales of operation. All such structures can be generically termed as tanks. Based on the analysis of data collected through field survey, we saw that, the general geo-environment of the land and its manifestation in terms of topography is the dominant factor dictating the overall agricultural potentials of the lands. The undulating nature of the land and local slopes are important factors which have major roles to play in putting a limit to which human intervention can harness the land resources for agricultural operation. The converted and reclaimed first order streams beds are the best stripes of land in the basin which show the highest promise for cultivation. We can conclude that, there do exist significant differences in input use across different topo-terrainic variations.

Similarly, tanks have served in a big way to save paddy cultivation from the vagaries of monsoon, as evident from the substantially higher intensification of cultivation practice reflected in the higher spending on inputs in farms under tank irrigation as compared to those under unirrigated conditions. There were witnessed substantial differences in the productivity under tank irrigated farms and the unirrigated farms. One may note that, most of the tanks have been built harnessing the overall undulating topography of the land. During the period of their existence, tanks have undergone through diverse challenges and depending on the institutional dynamics, they have either withstood such challenges or have suffered from them resulting in their performances taking a dip greatly. With the reduction of the tanks performance, paddy cultivation gets exposed to uncertainties of water supply. Of late this has been the case of many tanks and this has compelled many farmers to go for borewell irrigation. A comparison of cultivation of paddy in farms under borewell with those under tanks and those without irrigation, clearly showed that, farms under borewells have significantly higher input uses as well as in yield per acre. However, not every farmer can opt for a borewell, nor the cost of irrigation (which already is higher than under tank irrigation) under bore well would be at the level it currently is, in view of the fact that, soon farmers will have to pay for the electricity consumption after metering etc is completed. Also the fact that, greater spread of borewells in the area will likely lead to drop in water table, there by further increasing cost of irrigation and overall cultivation. Overall, borewells have higher operation and maintenance costs as compared to tanks. In view of such traits associated with borewells that render them unsustainable, revival of tanks needs to be pursued with greater diligence that is not restricted to physical restoration but also involves the institutional strengthening. One of the intervention directed towards institutional strengthening resulted in the creation of a special program christened as OCTMP by the state government. The evaluation of OCTMP tanks irrigation schemes vis a vis the rest, revealed they they did stand out on the dimensions of equity in water supply to farmers of different canal reaches viz. *Head, Middle* and *Tail* reaches.

In the study, thus an attempt was made to understand the institutional dynamics related to tank irrigation in the basin. A comparison of adequacy of water supply in tanks under different types of institutions viz. panchayat Union, MIP(non-OCTMP), and OCTMP tanks revealed the following: i. in all types of tanks, the head reach farmers report higher adequacy than the tail end farmers, with the middle reach farmers reporting in between, ii. whereas less than 15% farmers under OCTMP tanks report inadequacy, there are as many as 35%-40% farmers reporting inadequacy under MIP and under PU tanks, iii. Whereas only 23% of the Tail reach farmers under

OCTMP tanks report inadequacy, under MIP and PU Tanks the level is as high as 66% and 57% respectively, iv. though equitable distribution has not yet been achieved completely even under OCTMP tanks, inequity is very high in MIP and PU tanks.

Further, the reasons as expressed by the farmers under these three tank types, showed that, broadly, under Panchayat Union tanks (PUT) and non-OCTMP tanks, the reasons are mostly institutional failures and utter negligence of operational maintenance of distributaries, again a reflection of poor working of the Pani Panchayats and Gram Panchayats. In OCTMP tanks, its primarily related to the capital maintenance of tank system as reflected in most farmers citing reduced capacity due to siltation being the primary reason for inadequacy of water supply.

Similarly, a probe into the reasons of shifting from tanks to bore wells as provided by the farmers, reveals the following: in the non-OCTMP tanks, i. for farmers in the head reach, the primary reasons to shift to borewell are BKVY subsidy (30%) wherein the government provides a subsidy of 80-90% on digging a borewell, and achieving greater control over water supply (24%). Adequacy and reliability are not the primary factors for shifting to borewells. A similar pattern is found for farmers in the middle reach too, ii. for the farmers in the tail reaches, it's the adequacy of water (30%) which is the primary reasons, for water does not reach their farms in adequate quantity to fully meet the crops requirement. The second reason specified by them is reliability of water supply (24%). One can note that, free electricity has not come up as an important reason for shifting towards borewell for any group, iii. not many farmers specify productivity increase as *the* reason for shifting, which indicates, for the majority of the surveyed farmers opting for a borewell is more of a protective measure, than an aspirational one. These observations support our previous findings that tanks under the MIPs are not able to provide sufficient water for paddy, especially in the tail reaches, iv. in contrast to the farmers of the non-OCTMP MIPs, the Tail reach farmers from the OCTMP tanks identify BKVY subsidy as the prime mover of their decision for opting for a borewell, v. for the head reach and middle reach farmers under OCTMP tanks, farmers' other dominant reason given was control over water supply.

In both the above groups, the not many farmers chose the cost factors of pumps and digging under marketed conditions as the dominant reasons, thereby indicating that these factors are not perceived very important by the farmers when they choose to go for borewells. One corollary of this can be that, electricity charge doesn't matter at all and its manipulation would be toothless while making policies related to ground water exploitation. The researcher's suggestions would be to refrain from such liberal interpretations. This is so, because most of the surveyed farmers having a borewell are beneficiaries of BKVY subsidy. Further, in majority of the cases, they are not paying electricity charges, because mostly due to non-generation of bills, as they have not yet been metered. Many farmers newly owning borewells, have a general idea that, they won't have to pay for electricity, since no one is paying now. The situations may change, once farmers would be charged for electricity.

Logistic regression computed to understand farmers' likelihood of cooperation in the community management of irrigation works, deemed very crucial under PIM, throws the following takeaways:

- The literacy status of the farmers is seen to have a positive and significant predictive relationship with cooperative behaviours of the farmers. Since its not an easy task to go for increasing the literacy status of the farmers at their age, the best alternative doable approach to achieve enhanced cooperative behaviour among the illiterate farmers is that, extensive awareness campaign be launched for them regarding the importance of cooperation in community management of tank irrigation system.

- It is often found that many of the CPR management bodies and other collective institutions are seen to be embedded in the societal set up. Such institutions symbiotically cohabiting needs greater promotion. They cannot be seen in an isolated fashion rather, while evaluating their performances, their spinoff benefits, as witnessed in this case, must be accounted for and all efforts be made for their sustenance.

- There is a ray of hope, that can be seen in the predictive relationship that inadequacy of water supply has with the cooperative tendency of the farmers in community management of tanks, in that, there is a great scope for revival of institutions, where they have collapsed. All they may need is some promotional initiatives by the NGOs, and necessary provisions of enabling support environment by the Government.

- Finally, the belief that making farmers pay for the maintenance of tanks sets in a decrease in their cooperative tendency was not found to be valid for the study area. However, the relationship that higher the farmers pay, more is the likelihood that he would cooperate, may be misleading. Farmers cannot be charged too high to cover all sorts of expenses related to tanks. Rather, recognizing their limited ability to pay, the government must set aside adequate funds for capital intensive expenses like, desiltation and repairing of the dam/bunds, which must be conducted at regular interval as per need.

Thus, finally we can conclude that, tanks have been very effective geo-environmental innovations those were built by ingenuous farmers harnessing the inherent undulating topography of the area. With the change in hands and consequent negligence under post independent governance structures, have suffered huge reduction in their performance. Tanks and their performance must never be thought of as mere structures of storages, as the benefits that flows out of the tanks is greatly influenced by the institutional dynamics governing them. Even though, the institutional arrangements governing tanks have been sought to be reinvigorated trough Pani Panchayat Act, it has not really brought much difference in their functioning. In many occasions, the demands of water far exceeds what the tanks can actually supply even if they perform to the fullest of their capacity. Further, Govt is gradually withdrawing from investing in newer projects of late. In such a situation, the scarcity of water reported by farmers is palpable. The result is that, farmers are resorting to opt for borewells, due mainly to water inadequacy from tanks and partially because the government is pushing it through cost incentivisation. As discussed borewells have traits those make them economically and ecologically unsustainable in the long run. So, we can say that, an exclusive dependence on either tanks or on borewells cannot be an option in the Ong river basin. Under the current scenario, and with the level of population, tanks are found constrained to fully meet the growing demand. Similarly, borewells to be sustainably supplying water, needs a permanent provisions for ground water recharge. Besides, affordability is a big issue in the basin, where not many farmers pay for a borewell, even under current subsidy provisions. As was witnessed, with large number of ownerships of borewell which make them (bore well owning farmers) apathetic towards maintenance if tanks, even the current performance of tanks would be difficult to be maintained. Thus, tanks and borewells can't be considered as options which can be promoted in a mutually exclusive way. Thus, it calls for a conjunctive promotion of the two irrigation sources, maintaining a harmonious balance between them. Any deviation from this would prove to be a retrogressive option. Further, as demonstrated by OCTMP, there is a huge scope for improvement in the performance of tanks, and definitely tanks are not a past story. They do have a lot of promises left and they can indeed perform far better than the present scenario, provided proper institutional arrangement, necessary financial support and non-negotiable adherence to the participatory aspects are affected.

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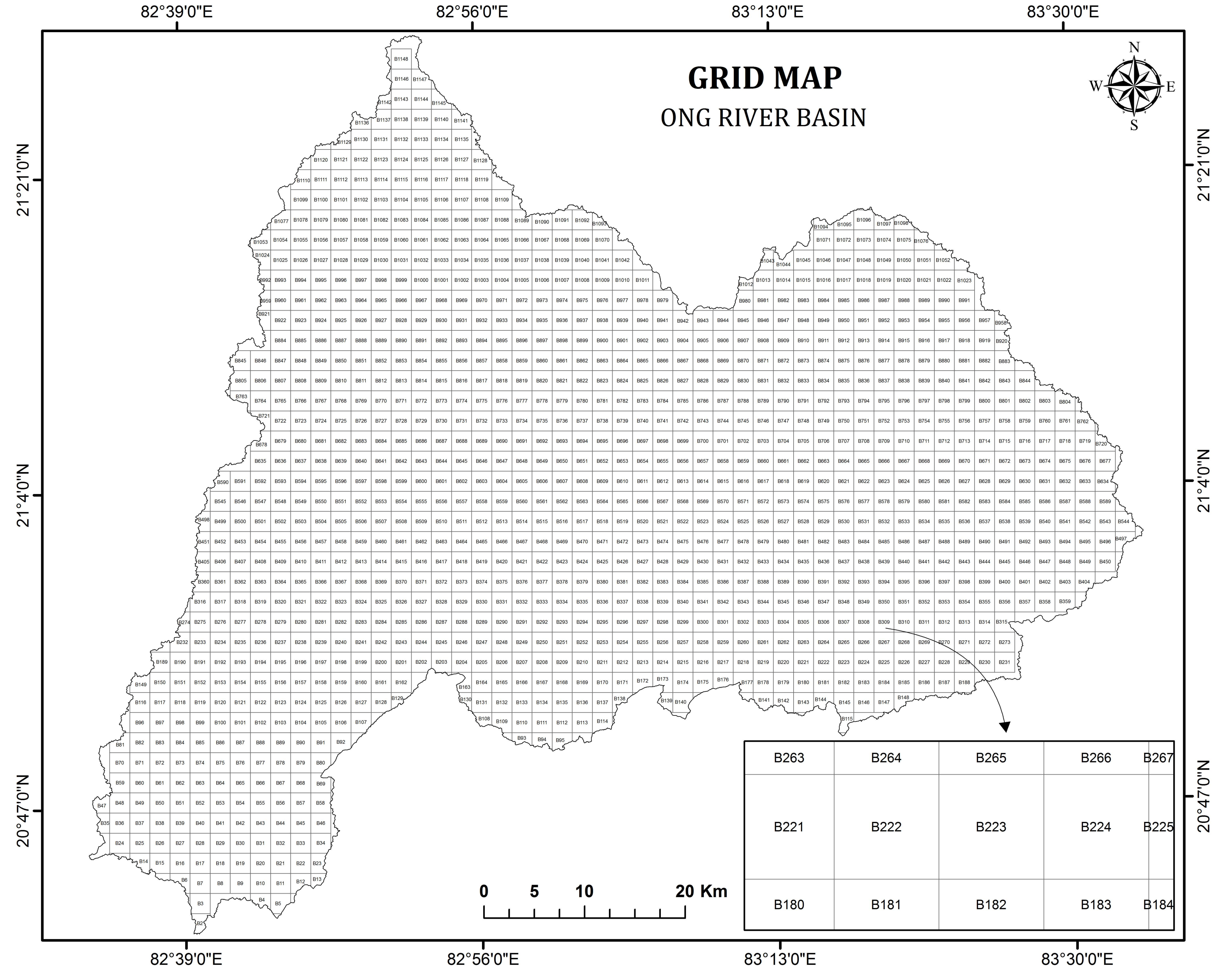

GRID MAP
ONG RIVER BASIN
82°39'0"E
82°56'0"E
83°13'0"E
83°30'0"E
21°21'0"N
21°4'0"N
20°47'0"N
N
S
E
W
0
5
10
20 Km
B263
B264
B265
B266
B267
B221
B222
B223
B224
B225
B180
B181
B182
B183
B184

APPENDIX- II

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B10	0	260	1.4	1.0	0.7	0.7	1.4	0.4	0.0	0.0	0.5
B100	20	240	0.6	0.2	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B1000	0	200	1.3	0.8	0.8	0.6	1.0	0.4	0.0	0.0	0.4
B1001	0	200	0.0	0.3	38.7	9.7	0.0	19.3	0.0	0.0	0.1
B1002	0	200	0.8	0.3	1.3	0.3	0.2	0.6	0.0	0.0	0.1
B1003	20	200	0.5	0.5	1.9	0.9	0.3	0.9	0.1	0.0	0.3
B1004	0	180	1.2	1.0	0.8	0.8	1.2	0.4	0.0	0.0	0.5
B1005	40	220	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B1006	0	180	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B1007	0	180	0.6	0.3	1.7	0.4	0.2	0.8	0.0	0.0	0.1
B1008	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1009	20	200	0.7	0.8	1.4	1.0	0.5	0.7	0.1	0.0	0.4
B101	0	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1010	20	200	0.2	0.3	5.0	1.3	0.0	2.5	0.1	0.0	0.1
B1011	80	280	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B1012	160	420	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B1013	160	380	0.0	0.3	20.8	5.4	0.0	10.4	0.4	0.0	0.1
B1014	140	340	0.8	0.5	1.2	0.6	0.4	0.6	0.4	0.1	0.3
B1015	60	240	0.1	0.3	17.5	4.4	0.0	8.8	0.3	0.0	0.1
B1016	0	180	0.2	0.3	5.0	1.2	0.1	2.5	0.0	0.0	0.1
B1017	20	180	0.4	0.3	2.5	0.6	0.1	1.3	0.1	0.0	0.1
B1018	20	180	0.6	0.2	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B1019	0	160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B102	0	220	0.1	0.2	12.4	3.1	0.0	6.2	0.0	0.0	0.1
B1020	0	160	0.4	0.3	2.4	0.6	0.1	1.2	0.0	0.0	0.1
B1021	60	200	0.7	0.8	1.5	1.1	0.5	0.8	0.3	0.0	0.4
B1022	20	160	0.5	0.5	2.1	1.1	0.2	1.1	0.1	0.0	0.3
B1023	20	160	0.1	0.3	8.6	2.2	0.0	4.3	0.1	0.0	0.1
B1024	20	240	0.1	0.4	14.5	5.2	0.0	7.2	0.1	0.0	0.1
B1025	20	240	0.6	0.8	1.6	1.2	0.5	0.8	0.1	0.0	0.4
B1026	0	220	1.0	0.7	1.0	0.8	0.7	0.5	0.0	0.0	0.4
B1027	0	220	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B1028	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1029	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B103	20	220	0.7	0.7	1.5	1.1	0.5	0.8	0.1	0.0	0.4
B1030	0	200	0.4	0.5	2.7	1.3	0.2	1.3	0.0	0.0	0.3
B1031	0	200	0.4	0.3	2.3	0.6	0.1	1.2	0.0	0.0	0.1
B1032	0	200	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B1033	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B1034	0	200	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B1035	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1036	0	200	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B1037	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1038	20	220	0.5	0.3	2.2	0.6	0.1	1.1	0.1	0.0	0.1
B1039	20	220	0.4	0.3	2.3	0.6	0.1	1.2	0.1	0.0	0.1
B104	20	220	0.1	0.2	11.6	2.9	0.0	5.8	0.1	0.0	0.1
B1040	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1041	20	200	0.4	0.3	2.3	0.6	0.1	1.1	0.1	0.0	0.1
B1042	20	200	0.2	0.3	4.0	1.0	0.1	2.0	0.1	0.0	0.1
B1043	80	320	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B1044	120	340	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B1045	120	320	0.3	0.3	3.6	0.9	0.1	1.8	0.4	0.0	0.1
B1046	120	300	0.7	0.3	1.5	0.4	0.2	0.7	0.4	0.1	0.1
B1047	40	220	0.2	0.3	4.9	1.2	0.1	2.5	0.2	0.0	0.1
B1048	0	160	1.3	1.0	0.7	0.7	1.3	0.4	0.0	0.0	0.5
B1049	20	180	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B105	40	260	0.9	0.7	1.2	0.9	0.7	0.6	0.2	0.0	0.4
B1050	0	160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1051	0	160	0.7	0.3	1.5	0.4	0.2	0.8	0.0	0.0	0.1
B1052	0	160	0.0	0.3	24.9	6.6	0.0	12.4	0.0	0.0	0.1
B1053	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1054	40	260	0.8	0.3	1.3	0.3	0.2	0.7	0.2	0.0	0.1
B1055	0	220	0.1	0.2	19.7	4.9	0.0	9.9	0.0	0.0	0.1
B1056	0	220	0.7	0.3	1.5	0.4	0.2	0.8	0.0	0.0	0.1
B1057	0	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1058	0	220	0.4	0.3	2.4	0.6	0.1	1.2	0.0	0.0	0.1
B1059	0	200	1.3	0.8	0.8	0.6	1.0	0.4	0.0	0.0	0.4
B106	580	820	0.4	0.5	2.4	0.0	0.2	1.2	0.7	0.2	0.3
B1060	0	200	0.3	0.3	3.1	0.8	0.1	1.5	0.0	0.0	0.1
B1061	0	200	0.3	0.3	3.0	0.8	0.1	1.5	0.0	0.0	0.1
B1062	20	220	0.1	0.3	11.6	2.9	0.0	5.8	0.1	0.0	0.1
B1063	0	200	0.4	0.5	2.7	1.4	0.2	1.4	0.0	0.0	0.3
B1064	0	200	0.0	0.3	33.3	8.3	0.0	16.6	0.0	0.0	0.1
B1065	0	200	0.9	0.8	1.1	0.8	0.7	0.5	0.0	0.0	0.4
B1066	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1067	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1068	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1069	0	200	0.2	0.5	5.0	2.5	0.1	2.5	0.0	0.0	0.3
B107	560	920	0.9	0.8	1.2	0.0	0.7	0.6	0.6	0.5	0.4

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B1070	0	200	0.7	0.3	1.4	0.3	0.2	0.7	0.0	0.0	0.1
B1071	120	320	0.6	0.3	1.7	0.4	0.1	0.8	0.4	0.1	0.1
B1072	20	200	0.4	0.3	2.3	0.6	0.1	1.2	0.1	0.0	0.1
B1073	0	180	0.7	0.5	1.5	0.8	0.3	0.8	0.0	0.0	0.3
B1074	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1075	20	180	0.4	0.3	2.5	0.6	0.1	1.3	0.1	0.0	0.1
B1076	0	160	0.1	0.3	6.9	2.2	0.0	3.5	0.0	0.0	0.1
B1077	40	280	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1078	20	240	0.2	0.2	6.4	1.6	0.0	3.2	0.1	0.0	0.1
B1079	20	240	0.3	0.3	3.8	1.0	0.1	1.9	0.1	0.0	0.1
B108	20	260	1.1	1.5	0.9	0.0	1.7	0.4	0.1	0.0	0.4
B1080	0	220	0.4	0.3	2.7	0.7	0.1	1.4	0.0	0.0	0.1
B1081	20	220	1.0	0.8	1.0	0.8	0.7	0.5	0.1	0.0	0.4
B1082	20	220	0.9	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B1083	20	220	0.3	0.3	3.0	0.8	0.1	1.5	0.1	0.0	0.1
B1084	20	220	0.3	0.3	3.9	1.0	0.1	1.9	0.1	0.0	0.1
B1085	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1086	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1087	0	200	0.5	0.3	1.8	0.5	0.1	0.9	0.0	0.0	0.1
B1088	0	200	0.2	0.3	6.5	1.6	0.0	3.2	0.0	0.0	0.1
B1089	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B109	240	460	0.6	0.9	1.7	1.5	0.5	0.9	0.5	0.1	0.4
B1090	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1091	20	220	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B1092	0	200	0.4	0.5	2.6	1.4	0.2	1.3	0.0	0.0	0.3
B1093	0	200	0.2	0.5	5.1	2.5	0.1	2.5	0.0	0.0	0.1
B1094	40	240	0.1	0.6	12.9	7.2	0.0	6.5	0.2	0.0	0.1
B1095	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1096	0	180	0.3	0.3	3.3	0.8	0.1	1.6	0.0	0.0	0.1
B1097	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1098	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1099	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B11	80	340	1.8	2.0	0.5	1.1	3.6	0.3	0.2	0.1	1.0
B110	60	260	0.4	0.5	2.4	1.2	0.2	1.2	0.2	0.0	0.3
B1100	20	240	0.2	0.3	5.7	1.4	0.0	2.8	0.1	0.0	0.1
B1101	0	220	0.9	1.0	1.2	1.2	0.9	0.6	0.0	0.0	0.5
B1102	0	220	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B1103	0	220	0.6	0.5	1.6	0.8	0.3	0.8	0.0	0.0	0.3
B1104	0	220	0.1	0.3	13.8	3.5	0.0	6.9	0.0	0.0	0.1
B1105	0	220	0.3	0.3	4.0	1.0	0.1	2.0	0.0	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B1106	20	220	0.3	0.3	3.1	0.8	0.1	1.5	0.1	0.0	0.1
B1107	0	200	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B1108	0	200	1.2	0.8	0.8	0.6	0.9	0.4	0.0	0.0	0.4
B1109	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B111	20	220	0.2	0.2	5.4	1.3	0.0	2.7	0.1	0.0	0.1
B1110	0	240	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1111	20	240	0.5	0.3	1.9	0.5	0.1	1.0	0.1	0.0	0.1
B1112	20	240	0.4	0.3	2.3	0.6	0.1	1.2	0.1	0.0	0.1
B1113	0	220	0.6	0.3	1.7	0.4	0.2	0.8	0.0	0.0	0.1
B1114	0	220	0.2	0.3	4.8	1.2	0.1	2.4	0.0	0.0	0.1
B1115	0	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1116	0	220	0.1	0.3	11.1	2.8	0.0	5.6	0.0	0.0	0.1
B1117	0	200	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B1118	0	200	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B1119	20	220	0.2	0.3	4.2	1.0	0.1	2.1	0.1	0.0	0.1
B112	20	220	0.4	0.2	2.4	0.6	0.1	1.2	0.1	0.0	0.1
B1120	0	240	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1121	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1122	20	240	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B1123	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1124	80	300	0.1	0.3	8.9	2.2	0.0	4.4	0.3	0.0	0.1
B1125	0	220	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B1126	20	220	0.3	0.5	3.3	1.7	0.2	1.7	0.1	0.0	0.3
B1127	20	220	0.7	0.8	1.4	1.1	0.5	0.7	0.1	0.0	0.4
B1128	0	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B1129	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B113	60	240	0.1	0.2	17.0	4.2	0.0	8.5	0.3	0.0	0.1
B1130	20	260	0.2	0.3	6.0	1.5	0.0	3.0	0.1	0.0	0.1
B1131	60	300	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B1132	80	300	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B1133	0	220	0.8	0.5	1.3	0.6	0.4	0.6	0.0	0.0	0.3
B1134	0	220	0.5	0.3	1.8	0.5	0.1	0.9	0.0	0.0	0.1
B1135	0	220	0.7	0.3	1.4	0.4	0.2	0.7	0.0	0.0	0.1
B1136	40	300	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1137	60	300	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B1138	40	260	0.6	0.5	1.5	0.8	0.3	0.8	0.2	0.0	0.3
B1139	20	240	0.9	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B114	200	380	0.1	0.3	15.3	4.4	0.0	7.6	0.5	0.0	0.1
B1140	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B1141	0	220	0.0	0.3	75.6	22.9	0.0	37.8	0.0	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B1142	100	360	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B1143	120	360	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B1144	40	260	0.8	0.3	1.3	0.3	0.2	0.7	0.2	0.0	0.1
B1145	140	380	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B1146	100	340	0.6	0.8	1.7	1.3	0.4	0.9	0.3	0.1	0.4
B1147	60	300	0.5	0.3	1.9	0.6	0.2	0.9	0.2	0.0	0.1
B1148	100	360	0.2	0.3	4.6	1.2	0.1	2.3	0.3	0.0	0.1
B115	280	500	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B116	20	280	0.0	0.3	32.2	8.4	0.0	16.1	0.1	0.0	0.1
B117	20	260	0.7	0.3	1.4	0.4	0.2	0.7	0.1	0.0	0.1
B118	0	240	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B119	0	240	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B12	380	640	0.6	1.6	1.6	0.0	1.0	0.8	0.6	0.2	0.6
B120	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B121	0	220	0.5	0.3	2.0	0.5	0.1	1.0	0.0	0.0	0.1
B122	0	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B123	20	220	0.2	0.3	4.3	1.1	0.1	2.1	0.1	0.0	0.1
B124	0	200	1.2	0.5	0.8	0.4	0.6	0.4	0.0	0.0	0.3
B125	20	220	0.6	0.5	1.6	0.8	0.3	0.8	0.1	0.0	0.3
B126	180	400	0.7	0.3	1.5	0.0	0.2	0.7	0.5	0.1	0.1
B127	620	860	1.0	0.8	1.0	0.7	0.8	0.5	0.7	0.6	0.4
B128	560	920	1.0	0.8	1.0	0.0	0.8	0.5	0.6	0.6	0.4
B129	360	920	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B13	200	520	1.1	0.6	1.0	0.0	0.6	0.5	0.4	0.2	0.1
B130	40	320	1.4	1.9	0.7	1.3	2.7	0.3	0.1	0.1	0.4
B131	40	280	1.3	1.3	0.8	1.0	1.6	0.4	0.1	0.1	0.6
B132	20	240	1.6	2.0	0.6	1.3	3.2	0.3	0.1	0.0	1.0
B133	300	500	1.3	1.8	0.8	1.3	2.3	0.4	0.6	0.4	0.9
B134	60	260	1.5	1.0	0.7	0.7	1.5	0.3	0.2	0.1	0.5
B135	120	300	1.8	1.3	0.6	0.7	2.2	0.3	0.4	0.2	0.6
B136	100	280	0.8	0.5	1.2	0.6	0.4	0.6	0.4	0.1	0.3
B137	280	460	0.0	0.3	175.3	43.8	0.0	87.7	0.6	0.0	0.1
B138	340	520	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
B139	360	620	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B14	0	280	1.1	0.7	1.0	0.0	0.7	0.5	0.0	0.0	0.3
B140	240	460	0.7	0.3	1.4	0.4	0.2	0.7	0.5	0.2	0.1
B141	0	180	0.0	0.3	328.1	####	0.0	164.1	0.0	0.0	0.1
B142	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B143	80	260	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B144	100	300	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B145	200	380	0.3	0.3	3.3	0.9	0.1	1.7	0.5	0.1	0.1
B146	120	280	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B147	60	200	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B148	20	160	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B149	20	280	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B15	0	280	1.4	1.3	0.7	0.0	1.8	0.4	0.0	0.0	0.6
B150	0	260	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B151	20	260	0.1	0.3	15.0	3.7	0.0	7.5	0.1	0.0	0.1
B152	0	240	0.1	0.3	7.0	1.7	0.0	3.5	0.0	0.0	0.1
B153	40	260	0.3	0.3	3.6	0.9	0.1	1.8	0.2	0.0	0.1
B154	0	220	0.0	0.3	51.3	12.8	0.0	25.6	0.0	0.0	0.1
B155	20	220	0.7	0.3	1.5	0.4	0.2	0.7	0.1	0.0	0.1
B156	0	200	0.5	0.3	2.0	0.5	0.1	1.0	0.0	0.0	0.1
B157	0	200	0.7	1.8	1.5	2.5	1.2	0.7	0.0	0.0	0.9
B158	0	200	0.7	0.8	1.4	1.1	0.5	0.7	0.0	0.0	0.4
B159	40	260	1.0	0.5	1.0	0.5	0.5	0.5	0.2	0.0	0.3
B16	0	280	0.8	1.0	1.2	1.2	0.8	0.6	0.0	0.0	0.5
B160	300	520	1.1	0.8	0.9	0.7	0.8	0.5	0.6	0.3	0.4
B161	360	600	0.8	0.5	1.3	0.0	0.4	0.6	0.6	0.3	0.3
B162	600	900	0.2	0.3	4.2	1.1	0.1	2.1	0.7	0.1	0.1
B163	420	720	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B164	320	580	1.8	0.8	0.6	0.4	1.3	0.3	0.6	0.6	0.4
B165	220	460	1.4	2.0	0.7	1.5	2.7	0.4	0.5	0.3	1.0
B166	160	380	1.5	2.8	0.7	0.0	4.2	0.3	0.4	0.2	1.4
B167	240	440	1.1	1.8	0.9	1.5	2.0	0.4	0.5	0.3	0.9
B168	60	240	0.9	0.5	1.1	0.6	0.4	0.6	0.3	0.1	0.3
B169	0	180	1.3	1.3	0.7	0.9	1.7	0.4	0.0	0.0	0.6
B17	20	280	0.7	0.3	1.4	0.3	0.2	0.7	0.1	0.0	0.1
B170	0	160	0.9	0.5	1.1	0.5	0.5	0.5	0.0	0.0	0.3
B171	200	360	0.0	0.3	25.1	6.3	0.0	12.6	0.6	0.0	0.1
B172	360	540	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
B173	460	680	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
B174	320	520	0.5	0.3	2.1	0.5	0.1	1.1	0.6	0.1	0.1
B175	260	460	0.2	0.3	6.6	1.7	0.0	3.3	0.6	0.0	0.1
B176	280	460	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B177	200	380	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B178	60	220	0.8	0.5	1.3	0.6	0.4	0.6	0.3	0.0	0.3
B179	20	180	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B18	0	260	0.6	0.5	1.7	0.8	0.3	0.8	0.0	0.0	0.3
B180	40	200	0.7	0.3	1.4	0.3	0.2	0.7	0.2	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B181	120	280	0.2	0.3	5.5	1.4	0.0	2.8	0.4	0.0	0.1
B182	100	240	0.7	0.3	1.5	0.4	0.2	0.8	0.4	0.1	0.1
B183	120	260	0.2	0.3	4.9	1.2	0.1	2.5	0.5	0.0	0.1
B184	0	140	0.3	0.3	2.9	0.7	0.1	1.5	0.0	0.0	0.1
B185	20	140	0.3	0.3	2.9	0.7	0.1	1.5	0.1	0.0	0.1
B186	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B187	60	180	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B188	60	180	0.2	0.3	6.3	1.6	0.0	3.2	0.3	0.0	0.1
B189	0	260	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B19	20	260	0.9	0.5	1.1	0.5	0.5	0.5	0.1	0.0	0.3
B190	20	260	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B191	20	240	0.6	0.3	1.8	0.4	0.1	0.9	0.1	0.0	0.1
B192	20	240	1.0	0.5	1.0	0.5	0.5	0.5	0.1	0.0	0.3
B193	20	240	0.6	0.8	1.6	1.2	0.5	0.8	0.1	0.0	0.4
B194	20	220	0.2	0.3	4.9	1.2	0.1	2.5	0.1	0.0	0.1
B195	0	200	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B196	0	200	1.5	1.3	0.7	0.8	1.9	0.3	0.0	0.0	0.6
B197	0	200	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B198	20	220	0.7	1.0	1.5	1.5	0.7	0.7	0.1	0.0	0.5
B199	60	280	0.7	0.5	1.4	0.0	0.4	0.7	0.2	0.0	0.3
B2	80	360	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B20	0	260	0.5	1.0	2.0	2.0	0.5	1.0	0.0	0.0	0.5
B200	220	440	0.4	0.3	2.3	0.6	0.1	1.2	0.5	0.1	0.1
B201	480	720	0.5	0.3	2.0	0.5	0.1	1.0	0.7	0.2	0.1
B202	540	840	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B203	420	860	0.7	1.0	1.4	0.0	0.8	0.7	0.5	0.3	0.5
B204	400	780	1.4	2.8	0.7	2.0	3.7	0.4	0.5	0.5	1.4
B205	480	780	0.2	0.5	4.9	2.4	0.1	2.4	0.6	0.1	0.3
B206	520	800	0.4	0.8	2.3	0.0	0.3	1.1	0.7	0.2	0.4
B207	560	800	1.0	1.0	1.0	0.0	1.0	0.5	0.7	0.5	0.5
B208	320	540	1.3	0.8	0.8	0.6	1.0	0.4	0.6	0.4	0.4
B209	440	640	0.5	0.5	2.0	0.0	0.2	1.0	0.7	0.2	0.3
B21	0	260	0.8	1.3	1.3	1.7	0.9	0.7	0.0	0.0	0.6
B210	140	300	1.2	1.3	0.8	0.0	1.5	0.4	0.5	0.2	0.6
B211	20	180	1.4	0.8	0.7	0.5	1.1	0.4	0.1	0.0	0.4
B212	0	160	0.1	0.3	9.2	2.3	0.0	4.6	0.0	0.0	0.1
B213	60	220	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B214	380	540	0.2	0.3	5.9	1.5	0.0	2.9	0.7	0.1	0.1
B215	160	340	0.8	0.3	1.2	0.3	0.2	0.6	0.5	0.1	0.1
B216	220	400	0.2	0.3	6.0	1.5	0.0	3.0	0.6	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B217	180	340	0.3	0.3	2.9	0.7	0.1	1.4	0.5	0.1	0.1
B218	180	320	0.5	0.5	2.2	1.1	0.2	1.1	0.6	0.1	0.3
B219	80	220	0.8	0.5	1.2	0.6	0.4	0.6	0.4	0.1	0.3
B22	140	400	1.7	1.8	0.6	1.0	3.0	0.3	0.4	0.2	0.9
B220	20	160	0.4	0.5	2.5	1.2	0.2	1.2	0.1	0.0	0.3
B221	20	180	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B222	40	180	0.7	0.3	1.3	0.3	0.2	0.7	0.2	0.0	0.1
B223	40	180	1.0	0.8	1.0	0.8	0.7	0.5	0.2	0.0	0.4
B224	0	140	0.6	0.2	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B225	20	140	0.6	0.5	1.6	0.8	0.3	0.8	0.1	0.0	0.3
B226	20	140	0.8	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B227	40	160	0.6	0.8	1.8	1.3	0.4	0.9	0.3	0.0	0.4
B228	60	180	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B229	60	180	0.9	0.8	1.1	0.8	0.7	0.6	0.3	0.1	0.4
B23	180	460	1.3	1.8	0.8	0.0	2.3	0.4	0.4	0.2	0.6
B230	20	140	0.4	0.5	2.5	1.2	0.2	1.2	0.1	0.0	0.3
B231	40	160	0.1	0.3	7.2	1.8	0.0	3.6	0.3	0.0	0.1
B232	0	260	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B233	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B234	20	240	0.4	0.3	2.4	0.6	0.1	1.2	0.1	0.0	0.1
B235	20	240	0.8	1.0	1.3	1.3	0.8	0.6	0.1	0.0	0.5
B236	20	220	1.0	0.8	1.0	0.7	0.8	0.5	0.1	0.0	0.4
B237	60	260	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B238	0	200	0.4	0.2	2.3	0.6	0.1	1.2	0.0	0.0	0.1
B239	0	200	0.3	0.5	2.9	1.4	0.2	1.4	0.0	0.0	0.3
B24	80	360	1.9	1.5	0.5	0.0	2.8	0.3	0.2	0.2	0.8
B240	0	200	0.6	0.3	1.8	0.4	0.1	0.9	0.0	0.0	0.1
B241	20	220	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B242	60	280	0.2	0.3	4.5	1.1	0.1	2.3	0.2	0.0	0.1
B243	80	300	0.5	0.3	2.1	0.5	0.1	1.1	0.3	0.0	0.1
B244	260	500	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B245	560	820	0.4	0.8	2.3	0.0	0.3	1.2	0.7	0.2	0.4
B246	540	800	0.4	1.0	2.6	0.0	0.4	1.3	0.7	0.2	0.5
B247	460	680	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
B248	300	520	1.0	0.5	1.1	0.0	0.5	0.5	0.6	0.3	0.3
B249	580	800	0.3	0.5	3.8	1.9	0.1	1.9	0.7	0.2	0.3
B25	0	280	1.2	1.3	0.8	1.1	1.5	0.4	0.0	0.0	0.6
B250	380	680	0.5	0.5	2.1	0.0	0.2	1.1	0.6	0.2	0.3
B251	460	660	0.3	0.5	3.1	0.0	0.2	1.5	0.7	0.1	0.3
B252	260	420	1.1	1.3	0.9	0.0	1.3	0.5	0.6	0.3	0.6

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B253	20	180	1.1	1.8	0.9	1.6	1.9	0.5	0.1	0.0	0.9
B254	20	160	0.7	0.5	1.4	0.7	0.4	0.7	0.1	0.0	0.3
B255	20	160	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B256	20	160	1.0	0.5	1.0	0.5	0.5	0.5	0.1	0.0	0.3
B257	40	180	0.3	0.3	3.3	0.8	0.1	1.6	0.2	0.0	0.1
B258	160	320	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B259	120	260	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B26	20	280	1.6	1.8	0.6	1.1	2.8	0.3	0.1	0.0	0.9
B260	80	220	0.3	0.3	3.9	1.0	0.1	1.9	0.4	0.0	0.1
B261	20	160	1.2	1.0	0.8	0.8	1.2	0.4	0.1	0.0	0.5
B262	20	160	0.6	0.3	1.7	0.4	0.1	0.9	0.1	0.0	0.1
B263	60	200	0.1	0.3	11.3	2.8	0.0	5.6	0.3	0.0	0.1
B264	20	160	0.4	0.3	2.5	0.6	0.1	1.2	0.1	0.0	0.1
B265	20	140	0.5	0.3	2.0	0.5	0.1	1.0	0.1	0.0	0.1
B266	0	120	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B267	20	140	0.2	0.5	6.1	3.0	0.1	3.0	0.1	0.0	0.3
B268	0	120	0.8	0.8	1.3	1.0	0.6	0.6	0.0	0.0	0.4
B269	0	120	0.8	0.3	1.3	0.3	0.2	0.6	0.0	0.0	0.1
B27	20	280	0.3	0.5	3.6	0.0	0.1	1.8	0.1	0.0	0.3
B270	20	120	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B271	20	120	0.6	0.3	1.6	0.4	0.2	0.8	0.2	0.0	0.1
B272	80	200	0.1	0.3	10.6	2.6	0.0	5.3	0.4	0.0	0.1
B273	80	200	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B274	0	260	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B275	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B276	20	240	0.3	0.5	3.2	1.6	0.2	1.6	0.1	0.0	0.3
B277	20	240	0.2	0.3	4.5	1.1	0.1	2.3	0.1	0.0	0.1
B278	100	320	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B279	120	320	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B28	0	260	0.8	0.8	1.3	0.0	0.6	0.6	0.0	0.0	0.4
B280	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B281	0	200	1.1	0.5	0.9	0.4	0.6	0.4	0.0	0.0	0.3
B282	0	200	0.1	0.3	6.9	1.7	0.0	3.5	0.0	0.0	0.1
B283	0	200	0.6	0.3	1.7	0.4	0.1	0.9	0.0	0.0	0.1
B284	20	220	0.6	0.3	1.7	0.4	0.2	0.8	0.1	0.0	0.1
B285	40	240	0.7	0.8	1.5	1.1	0.5	0.7	0.2	0.0	0.4
B286	40	240	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B287	160	360	0.4	0.5	2.3	1.1	0.2	1.1	0.4	0.1	0.3
B288	120	340	0.6	0.3	1.8	0.0	0.1	0.9	0.4	0.1	0.1
B289	80	280	0.5	0.3	2.2	0.5	0.1	1.1	0.3	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B29	20	260	1.0	1.3	1.0	1.3	1.2	0.5	0.1	0.0	0.6
B290	40	220	0.6	1.0	1.6	1.6	0.6	0.8	0.2	0.0	0.5
B291	160	340	1.2	1.0	0.8	0.8	1.2	0.4	0.5	0.2	0.5
B292	240	400	1.3	1.3	0.7	0.9	1.7	0.4	0.6	0.3	0.6
B293	240	400	1.7	1.5	0.6	0.0	2.5	0.3	0.6	0.4	0.8
B294	80	240	0.9	0.8	1.2	0.0	0.6	0.6	0.3	0.1	0.4
B295	20	160	1.6	1.0	0.6	0.0	1.6	0.3	0.1	0.0	0.5
B296	20	160	1.3	1.0	0.8	0.8	1.3	0.4	0.1	0.0	0.5
B297	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B298	0	140	0.6	0.3	1.5	0.4	0.2	0.8	0.0	0.0	0.1
B299	20	160	1.0	0.5	1.0	0.5	0.5	0.5	0.1	0.0	0.3
B3	60	340	0.1	0.3	14.3	3.7	0.0	7.2	0.2	0.0	0.1
B30	0	240	1.2	0.8	0.9	0.6	0.9	0.4	0.0	0.0	0.4
B300	20	160	0.3	0.3	2.9	0.7	0.1	1.4	0.1	0.0	0.1
B301	80	220	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B302	0	140	0.3	0.3	3.7	0.9	0.1	1.8	0.0	0.0	0.1
B303	20	140	0.7	0.5	1.4	0.7	0.4	0.7	0.1	0.0	0.3
B304	20	140	0.8	0.5	1.3	0.6	0.4	0.6	0.1	0.0	0.3
B305	0	120	0.4	0.3	2.6	0.7	0.1	1.3	0.0	0.0	0.1
B306	0	140	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B307	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B308	20	140	0.9	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B309	40	140	1.3	0.5	0.8	0.4	0.6	0.4	0.3	0.1	0.3
B31	20	260	1.0	0.5	1.0	0.0	0.5	0.5	0.1	0.0	0.3
B310	20	120	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B311	0	120	0.2	0.3	5.5	1.4	0.0	2.8	0.0	0.0	0.1
B312	20	120	0.7	0.5	1.4	0.7	0.4	0.7	0.2	0.0	0.3
B313	0	100	0.9	0.5	1.1	0.6	0.4	0.6	0.0	0.0	0.3
B314	60	160	0.5	0.3	2.0	0.5	0.1	1.0	0.4	0.0	0.1
B315	340	460	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
B316	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B317	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B318	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B319	60	260	0.4	0.5	2.3	1.2	0.2	1.2	0.2	0.0	0.3
B32	160	420	0.4	0.5	2.3	0.0	0.2	1.1	0.4	0.1	0.3
B320	20	220	0.5	0.3	1.9	0.5	0.1	0.9	0.1	0.0	0.1
B321	0	200	0.7	0.5	1.5	0.7	0.3	0.7	0.0	0.0	0.3
B322	20	200	1.1	0.8	0.9	0.7	0.8	0.5	0.1	0.0	0.4
B323	20	200	0.5	0.3	2.2	0.5	0.1	1.1	0.1	0.0	0.1
B324	20	200	0.4	0.5	2.8	1.4	0.2	1.4	0.1	0.0	0.3

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B325	20	200	1.2	1.3	0.9	1.1	1.5	0.4	0.1	0.0	0.6
B326	0	200	0.8	0.8	1.3	1.0	0.6	0.6	0.0	0.0	0.4
B327	0	200	0.5	0.3	2.1	0.5	0.1	1.0	0.0	0.0	0.1
B328	20	220	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B329	40	220	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B33	60	320	1.7	2.2	0.6	1.3	3.8	0.3	0.2	0.1	1.1
B330	20	200	0.6	0.3	1.7	0.4	0.2	0.8	0.1	0.0	0.1
B331	20	200	0.3	0.5	4.0	2.0	0.1	2.0	0.1	0.0	0.3
B332	20	180	1.8	1.3	0.5	0.7	2.3	0.3	0.1	0.0	0.6
B333	0	160	1.0	1.3	1.0	1.2	1.3	0.5	0.0	0.0	0.6
B334	0	160	1.8	2.0	0.5	1.1	3.7	0.3	0.0	0.0	1.0
B335	0	140	1.5	1.3	0.7	0.9	1.8	0.3	0.0	0.0	0.6
B336	0	140	1.1	0.8	0.9	0.7	0.8	0.4	0.0	0.0	0.4
B337	0	140	1.2	1.0	0.8	0.8	1.2	0.4	0.0	0.0	0.5
B338	0	120	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B339	20	140	1.2	1.0	0.8	0.8	1.2	0.4	0.1	0.0	0.5
B34	120	400	0.6	0.8	1.6	1.2	0.5	0.8	0.3	0.1	0.4
B340	0	120	0.6	0.5	1.7	0.8	0.3	0.8	0.0	0.0	0.3
B341	20	140	0.1	0.3	9.8	2.4	0.0	4.9	0.1	0.0	0.1
B342	20	140	0.5	0.3	1.9	0.5	0.1	1.0	0.1	0.0	0.1
B343	20	140	0.6	0.3	1.7	0.4	0.1	0.9	0.1	0.0	0.1
B344	0	120	0.7	0.3	1.5	0.4	0.2	0.8	0.0	0.0	0.1
B345	0	120	0.7	0.8	1.5	1.1	0.5	0.8	0.0	0.0	0.4
B346	0	120	0.6	0.5	1.8	0.9	0.3	0.9	0.0	0.0	0.3
B347	20	140	0.6	0.3	1.8	0.4	0.1	0.9	0.1	0.0	0.1
B348	20	140	0.3	0.3	3.3	0.8	0.1	1.7	0.1	0.0	0.1
B349	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B35	100	400	0.9	0.9	1.2	0.0	0.8	0.6	0.3	0.1	0.3
B350	20	120	0.0	0.3	37.7	9.4	0.0	18.9	0.2	0.0	0.1
B351	20	120	0.8	0.5	1.3	0.6	0.4	0.6	0.2	0.0	0.3
B352	20	120	0.2	0.3	6.6	1.7	0.0	3.3	0.2	0.0	0.1
B353	20	120	0.1	0.3	11.9	3.0	0.0	6.0	0.2	0.0	0.1
B354	0	100	1.1	1.3	0.9	1.2	1.4	0.5	0.0	0.0	0.6
B355	40	140	0.2	0.3	4.2	1.1	0.1	2.1	0.3	0.0	0.1
B356	40	140	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B357	100	200	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B358	60	160	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B359	80	160	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B36	100	380	1.1	1.3	0.9	0.0	1.4	0.4	0.3	0.1	0.6
B360	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B361	20	240	0.6	0.3	1.7	0.4	0.1	0.9	0.1	0.0	0.1
B362	20	240	0.3	0.3	3.6	0.9	0.1	1.8	0.1	0.0	0.1
B363	60	260	0.5	0.5	2.0	1.0	0.3	1.0	0.2	0.0	0.3
B364	40	240	1.0	0.5	1.0	0.5	0.5	0.5	0.2	0.0	0.3
B365	0	200	0.8	0.7	1.2	0.9	0.6	0.6	0.0	0.0	0.4
B366	20	200	0.8	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B367	0	180	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B368	160	340	1.3	2.0	0.8	1.5	2.6	0.4	0.5	0.2	1.0
B369	300	480	1.4	2.8	0.7	0.0	3.9	0.4	0.6	0.4	1.4
B37	20	280	0.7	1.0	1.4	0.0	0.7	0.7	0.1	0.0	0.5
B370	0	200	0.3	1.0	3.4	0.0	0.3	1.7	0.0	0.0	0.5
B371	20	200	1.3	1.3	0.7	0.9	1.7	0.4	0.1	0.0	0.6
B372	20	200	0.7	0.5	1.4	0.7	0.4	0.7	0.1	0.0	0.3
B373	0	180	0.7	0.5	1.5	0.7	0.3	0.7	0.0	0.0	0.3
B374	0	180	1.1	1.3	0.9	1.2	1.3	0.5	0.0	0.0	0.6
B375	20	180	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B376	0	160	0.5	0.5	1.9	0.9	0.3	0.9	0.0	0.0	0.3
B377	0	160	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B378	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B379	0	140	0.2	0.3	5.3	1.3	0.0	2.7	0.0	0.0	0.1
B38	20	280	1.1	1.0	0.9	0.9	1.1	0.5	0.1	0.0	0.5
B380	0	140	0.3	0.3	3.7	0.9	0.1	1.8	0.0	0.0	0.1
B381	0	140	0.6	0.3	1.8	0.4	0.1	0.9	0.0	0.0	0.1
B382	20	140	0.2	0.5	4.7	2.4	0.1	2.4	0.1	0.0	0.3
B383	0	120	1.0	0.8	1.0	0.7	0.8	0.5	0.0	0.0	0.4
B384	0	120	1.5	1.3	0.7	0.8	1.9	0.3	0.0	0.0	0.6
B385	0	120	0.5	0.5	2.1	1.0	0.2	1.0	0.0	0.0	0.3
B386	0	120	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B387	0	120	0.8	1.0	1.2	1.2	0.8	0.6	0.0	0.0	0.5
B388	0	120	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B389	0	120	0.4	0.3	2.3	0.6	0.1	1.1	0.0	0.0	0.1
B39	0	260	0.8	1.0	1.3	1.3	0.8	0.7	0.0	0.0	0.5
B390	0	120	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B391	0	120	0.2	0.3	5.4	1.3	0.0	2.7	0.0	0.0	0.1
B392	0	120	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B393	20	120	0.7	0.2	1.4	0.4	0.2	0.7	0.2	0.0	0.1
B394	0	100	0.7	0.5	1.5	0.7	0.3	0.7	0.0	0.0	0.3
B395	0	100	1.3	0.8	0.7	0.6	1.0	0.4	0.0	0.0	0.4
B396	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B397	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B398	20	120	0.1	0.3	9.4	2.3	0.0	4.7	0.2	0.0	0.1
B399	0	100	0.6	0.3	1.8	0.4	0.1	0.9	0.0	0.0	0.1
B4	0	260	1.1	1.3	0.9	0.0	1.3	0.5	0.0	0.0	0.4
B40	0	260	1.6	1.5	0.6	0.0	2.4	0.3	0.0	0.0	0.8
B400	0	100	0.5	0.3	2.0	0.5	0.1	1.0	0.0	0.0	0.1
B401	0	100	0.1	0.3	13.2	3.3	0.0	6.6	0.0	0.0	0.1
B402	0	80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B403	0	80	0.7	0.8	1.4	1.0	0.5	0.7	0.0	0.0	0.4
B404	0	80	0.6	0.3	1.7	0.5	0.2	0.8	0.0	0.0	0.1
B405	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B406	20	240	0.5	0.3	2.1	0.5	0.1	1.1	0.1	0.0	0.1
B407	20	240	1.0	0.8	1.0	0.7	0.8	0.5	0.1	0.0	0.4
B408	20	220	0.4	0.3	2.3	0.6	0.1	1.1	0.1	0.0	0.1
B409	40	240	0.8	0.3	1.3	0.3	0.2	0.6	0.2	0.0	0.1
B41	20	260	0.9	1.5	1.2	1.7	1.3	0.6	0.1	0.0	0.8
B410	20	220	0.1	0.2	9.9	2.5	0.0	5.0	0.1	0.0	0.1
B411	100	280	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B412	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B413	180	360	0.9	1.0	1.1	1.1	0.9	0.5	0.5	0.2	0.5
B414	260	480	0.4	0.5	2.3	0.0	0.2	1.2	0.5	0.1	0.3
B415	260	460	0.9	1.3	1.1	0.0	1.2	0.5	0.6	0.2	0.6
B416	20	200	1.2	1.0	0.8	0.8	1.2	0.4	0.1	0.0	0.5
B417	20	200	1.2	0.8	0.8	0.6	0.9	0.4	0.1	0.0	0.4
B418	20	200	1.8	1.5	0.5	0.8	2.7	0.3	0.1	0.0	0.8
B419	40	220	0.2	0.3	4.4	1.1	0.1	2.2	0.2	0.0	0.1
B42	20	260	0.4	0.5	2.7	1.3	0.2	1.3	0.1	0.0	0.3
B420	60	220	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B421	40	200	0.2	0.3	5.4	1.4	0.0	2.7	0.2	0.0	0.1
B422	20	180	0.4	0.5	2.5	1.3	0.2	1.3	0.1	0.0	0.3
B423	20	160	1.0	1.0	1.0	1.0	1.0	0.5	0.1	0.0	0.5
B424	0	140	1.1	0.8	1.0	0.7	0.8	0.5	0.0	0.0	0.4
B425	0	140	0.3	0.3	3.2	0.8	0.1	1.6	0.0	0.0	0.1
B426	0	140	0.3	0.3	3.9	1.0	0.1	1.9	0.0	0.0	0.1
B427	0	120	1.1	0.5	0.9	0.4	0.6	0.4	0.0	0.0	0.3
B428	0	120	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B429	0	120	0.1	0.3	11.0	2.7	0.0	5.5	0.0	0.0	0.1
B43	0	240	1.4	0.8	0.7	0.5	1.1	0.4	0.0	0.0	0.4
B430	0	120	0.5	0.3	2.1	0.5	0.1	1.1	0.0	0.0	0.1
B431	0	120	0.9	0.5	1.1	0.6	0.4	0.6	0.0	0.0	0.3
B432	0	120	1.2	1.0	0.8	0.8	1.2	0.4	0.0	0.0	0.5

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B433	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B434	20	120	0.2	0.3	6.5	1.6	0.0	3.2	0.2	0.0	0.1
B435	20	120	0.8	0.5	1.2	0.6	0.4	0.6	0.2	0.0	0.3
B436	20	120	0.2	0.3	5.2	1.3	0.0	2.6	0.2	0.0	0.1
B437	20	120	0.4	0.3	2.4	0.6	0.1	1.2	0.2	0.0	0.1
B438	0	100	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B439	0	100	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B44	280	520	0.4	0.8	2.3	0.0	0.3	1.2	0.5	0.1	0.4
B440	0	100	0.3	0.3	3.4	0.8	0.1	1.7	0.0	0.0	0.1
B441	0	100	0.6	0.3	1.7	0.4	0.1	0.9	0.0	0.0	0.1
B442	0	100	0.4	0.3	2.2	0.6	0.1	1.1	0.0	0.0	0.1
B443	0	100	0.5	0.5	1.9	0.9	0.3	0.9	0.0	0.0	0.3
B444	20	100	0.9	0.5	1.1	0.5	0.5	0.5	0.2	0.0	0.3
B445	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B446	0	80	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B447	0	80	0.9	0.8	1.2	0.9	0.6	0.6	0.0	0.0	0.4
B448	0	80	0.5	0.3	2.0	0.5	0.1	1.0	0.0	0.0	0.1
B449	0	80	0.9	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B45	140	420	1.3	1.5	0.8	0.0	1.9	0.4	0.3	0.2	0.8
B450	0	80	1.2	1.0	0.9	0.9	1.2	0.4	0.0	0.0	0.5
B451	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B452	0	240	0.0	0.3	30.2	7.5	0.0	15.1	0.0	0.0	0.1
B453	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B454	0	220	0.5	0.3	1.9	0.5	0.1	0.9	0.0	0.0	0.1
B455	20	220	0.1	0.3	7.9	2.0	0.0	4.0	0.1	0.0	0.1
B456	40	240	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B457	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B458	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B459	20	200	1.0	1.3	1.0	1.3	1.2	0.5	0.1	0.0	0.6
B46	20	300	1.7	1.8	0.6	1.1	2.9	0.3	0.1	0.0	0.9
B460	280	460	0.5	1.3	1.9	0.0	0.7	0.9	0.6	0.1	0.6
B461	240	440	1.6	2.5	0.6	1.6	4.0	0.3	0.5	0.4	1.3
B462	220	420	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.2	0.5
B463	20	200	1.9	1.8	0.5	0.9	3.3	0.3	0.1	0.0	0.9
B464	0	180	1.4	2.0	0.7	1.5	2.7	0.4	0.0	0.0	1.0
B465	20	200	0.1	0.3	11.6	2.9	0.0	5.8	0.1	0.0	0.1
B466	40	220	0.2	0.3	6.5	1.6	0.0	3.3	0.2	0.0	0.1
B467	40	200	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B468	20	180	0.0	0.3	28.3	7.1	0.0	14.1	0.1	0.0	0.1
B469	20	160	0.8	0.3	1.2	0.3	0.2	0.6	0.1	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B47	120	400	0.6	1.2	1.7	0.0	0.7	0.8	0.3	0.1	0.4
B470	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B471	0	140	0.4	0.5	2.6	1.3	0.2	1.3	0.0	0.0	0.3
B472	0	140	0.4	0.3	2.5	0.6	0.1	1.2	0.0	0.0	0.1
B473	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B474	20	140	0.6	0.3	1.7	0.4	0.1	0.9	0.1	0.0	0.1
B475	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B476	0	120	0.3	0.3	3.3	0.8	0.1	1.6	0.0	0.0	0.1
B477	0	120	0.8	0.5	1.3	0.7	0.4	0.7	0.0	0.0	0.3
B478	0	120	0.7	0.8	1.5	1.1	0.5	0.7	0.0	0.0	0.4
B479	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B48	0	280	1.1	0.5	0.9	0.0	0.5	0.5	0.0	0.0	0.3
B480	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B481	20	120	0.2	0.3	5.5	1.4	0.0	2.7	0.2	0.0	0.1
B482	20	120	1.0	0.5	1.0	0.5	0.5	0.5	0.2	0.0	0.3
B483	0	100	0.5	0.3	1.9	0.5	0.1	0.9	0.0	0.0	0.1
B484	20	120	0.8	0.5	1.2	0.6	0.4	0.6	0.2	0.0	0.3
B485	20	120	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B486	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B487	0	100	0.3	0.3	3.2	0.8	0.1	1.6	0.0	0.0	0.1
B488	0	100	0.9	0.5	1.1	0.5	0.5	0.5	0.0	0.0	0.3
B489	0	100	0.2	0.3	4.3	1.1	0.1	2.1	0.0	0.0	0.1
B49	20	280	1.0	1.3	1.0	1.2	1.3	0.5	0.1	0.0	0.6
B490	0	80	0.9	0.8	1.2	0.9	0.6	0.6	0.0	0.0	0.4
B491	0	80	0.6	0.5	1.7	0.8	0.3	0.8	0.0	0.0	0.3
B492	0	80	0.5	0.3	1.9	0.5	0.1	1.0	0.0	0.0	0.1
B493	0	80	0.2	0.3	4.1	1.0	0.1	2.1	0.0	0.0	0.1
B494	0	80	0.3	0.3	3.0	0.7	0.1	1.5	0.0	0.0	0.1
B495	20	100	0.7	0.5	1.5	0.7	0.3	0.7	0.2	0.0	0.3
B496	20	100	0.8	0.5	1.2	0.6	0.4	0.6	0.2	0.0	0.3
B497	0	100	0.6	0.4	1.6	0.6	0.2	0.8	0.0	0.0	0.1
B498	20	260	0.1	0.4	13.0	5.5	0.0	6.5	0.1	0.0	0.1
B499	0	240	1.0	0.8	1.0	0.7	0.8	0.5	0.0	0.0	0.4
B5	360	620	0.8	0.9	1.2	0.0	0.7	0.6	0.6	0.3	0.4
B50	20	260	1.9	1.5	0.5	0.8	2.9	0.3	0.1	0.0	0.8
B500	20	240	0.7	0.3	1.3	0.3	0.2	0.7	0.1	0.0	0.1
B501	60	260	0.2	0.3	5.1	1.3	0.0	2.5	0.2	0.0	0.1
B502	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B503	40	220	0.1	0.3	10.6	2.7	0.0	5.3	0.2	0.0	0.1
B504	0	180	0.8	0.3	1.3	0.3	0.2	0.6	0.0	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B505	20	200	0.5	0.3	1.8	0.5	0.1	0.9	0.1	0.0	0.1
B506	0	180	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B507	260	440	1.7	2.0	0.6	1.2	3.3	0.3	0.6	0.4	1.0
B508	260	440	0.6	1.8	1.8	0.0	1.0	0.9	0.6	0.1	0.9
B509	320	540	0.6	1.3	1.7	0.0	0.8	0.8	0.6	0.2	0.6
B51	40	280	0.3	0.8	3.2	2.4	0.2	1.6	0.1	0.0	0.4
B510	340	540	1.1	1.0	0.9	0.0	1.1	0.4	0.6	0.4	0.5
B511	40	220	1.5	1.3	0.7	0.0	1.9	0.3	0.2	0.1	0.6
B512	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B513	60	220	0.8	0.8	1.2	0.9	0.6	0.6	0.3	0.0	0.4
B514	40	200	0.5	0.3	1.9	0.5	0.1	1.0	0.2	0.0	0.1
B515	0	160	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B516	0	160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B517	20	160	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B518	0	140	0.3	0.3	3.6	0.9	0.1	1.8	0.0	0.0	0.1
B519	0	140	0.9	0.5	1.1	0.6	0.4	0.6	0.0	0.0	0.3
B52	60	300	0.7	0.5	1.5	0.0	0.3	0.7	0.2	0.0	0.3
B520	20	140	0.8	0.5	1.3	0.6	0.4	0.6	0.1	0.0	0.3
B521	20	140	0.2	0.3	4.7	1.2	0.1	2.3	0.1	0.0	0.1
B522	0	140	0.2	0.3	4.3	0.0	0.1	2.1	0.0	0.0	0.1
B523	0	140	0.8	1.0	1.3	1.3	0.8	0.6	0.0	0.0	0.5
B524	20	140	0.2	0.5	4.7	2.4	0.1	2.4	0.1	0.0	0.3
B525	0	140	0.7	0.3	1.3	0.0	0.2	0.7	0.0	0.0	0.1
B526	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B527	0	120	0.5	0.3	1.8	0.5	0.1	0.9	0.0	0.0	0.1
B528	0	120	1.4	1.5	0.7	1.1	2.1	0.4	0.0	0.0	0.8
B529	0	120	0.3	0.5	3.4	1.7	0.1	1.7	0.0	0.0	0.3
B53	0	240	1.0	1.8	1.0	1.7	1.8	0.5	0.0	0.0	0.9
B530	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B531	0	120	0.6	0.5	1.7	0.8	0.3	0.8	0.0	0.0	0.3
B532	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B533	0	100	0.2	0.3	5.2	1.3	0.0	2.6	0.0	0.0	0.1
B534	0	100	0.5	0.3	1.9	0.5	0.1	0.9	0.0	0.0	0.1
B535	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B536	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B537	0	100	0.4	0.3	2.5	0.6	0.1	1.2	0.0	0.0	0.1
B538	0	100	0.4	0.3	2.4	0.6	0.1	1.2	0.0	0.0	0.1
B539	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B54	20	240	0.5	0.3	1.9	0.5	0.1	1.0	0.1	0.0	0.1
B540	0	100	0.6	0.3	1.7	0.4	0.2	0.8	0.0	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B541	0	100	0.8	1.0	1.2	1.2	0.8	0.6	0.0	0.0	0.5
B542	0	100	0.1	0.3	13.2	3.3	0.0	6.6	0.0	0.0	0.1
B543	0	100	0.6	0.5	1.7	0.9	0.3	0.9	0.0	0.0	0.3
B544	0	100	0.6	0.3	1.8	0.5	0.2	0.9	0.0	0.0	0.1
B545	0	240	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B546	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B547	20	220	0.5	0.3	1.9	0.5	0.1	1.0	0.1	0.0	0.1
B548	20	220	1.1	0.8	0.9	0.7	0.8	0.4	0.1	0.0	0.4
B549	0	200	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B55	0	240	1.1	0.8	0.9	0.7	0.8	0.5	0.0	0.0	0.4
B550	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B551	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B552	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B553	20	180	1.2	1.0	0.9	0.9	1.2	0.4	0.1	0.0	0.5
B554	280	440	1.0	1.3	1.0	1.3	1.2	0.5	0.6	0.3	0.6
B555	320	500	0.0	0.3	35.9	0.0	0.0	18.0	0.6	0.0	0.1
B556	300	520	0.5	0.3	1.8	0.5	0.1	0.9	0.6	0.2	0.1
B557	200	400	0.5	0.3	1.9	0.5	0.1	1.0	0.5	0.1	0.1
B558	20	200	0.8	0.3	1.2	0.3	0.2	0.6	0.1	0.0	0.1
B559	20	180	0.4	0.5	2.4	1.2	0.2	1.2	0.1	0.0	0.3
B56	60	300	1.9	1.0	0.5	0.0	1.9	0.3	0.2	0.1	0.5
B560	0	160	0.1	0.3	11.7	2.9	0.0	5.9	0.0	0.0	0.1
B561	0	160	0.2	0.3	4.5	1.1	0.1	2.2	0.0	0.0	0.1
B562	20	160	0.6	0.3	1.8	0.4	0.1	0.9	0.1	0.0	0.1
B563	20	160	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B564	0	140	0.5	0.3	1.9	0.5	0.1	0.9	0.0	0.0	0.1
B565	0	140	0.7	0.3	1.4	0.4	0.2	0.7	0.0	0.0	0.1
B566	0	140	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B567	20	160	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B568	0	140	0.9	0.5	1.1	0.0	0.5	0.5	0.0	0.0	0.3
B569	0	140	1.5	1.0	0.7	0.7	1.5	0.3	0.0	0.0	0.5
B57	180	440	0.8	0.7	1.2	0.0	0.6	0.6	0.4	0.1	0.4
B570	20	160	0.6	0.3	1.7	0.4	0.1	0.9	0.1	0.0	0.1
B571	0	140	0.3	0.5	3.3	1.7	0.2	1.7	0.0	0.0	0.3
B572	0	140	0.6	0.3	1.7	0.4	0.2	0.8	0.0	0.0	0.1
B573	20	140	0.5	0.5	2.0	1.0	0.3	1.0	0.1	0.0	0.3
B574	0	120	1.4	0.5	0.7	0.4	0.7	0.4	0.0	0.0	0.3
B575	0	120	0.6	0.3	1.7	0.4	0.1	0.8	0.0	0.0	0.1
B576	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B577	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B578	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B579	20	120	0.4	0.3	2.3	0.6	0.1	1.2	0.2	0.0	0.1
B58	120	420	2.0	1.5	0.5	0.0	3.0	0.3	0.3	0.2	0.8
B580	0	100	0.9	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B581	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B582	20	120	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B583	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B584	0	100	0.7	0.5	1.4	0.7	0.4	0.7	0.0	0.0	0.3
B585	0	100	0.1	0.3	17.8	4.5	0.0	8.9	0.0	0.0	0.1
B586	0	100	0.3	0.3	3.0	0.7	0.1	1.5	0.0	0.0	0.1
B587	0	100	0.9	0.5	1.1	0.6	0.4	0.6	0.0	0.0	0.3
B588	0	100	0.3	0.3	2.9	0.7	0.1	1.5	0.0	0.0	0.1
B589	0	100	0.4	0.3	2.5	0.6	0.1	1.2	0.0	0.0	0.1
B59	0	280	0.0	0.3	205.0	0.0	0.0	102.5	0.0	0.0	0.1
B590	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B591	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B592	20	240	0.0	0.3	20.5	5.1	0.0	10.3	0.1	0.0	0.1
B593	20	220	0.4	0.5	2.3	1.2	0.2	1.2	0.1	0.0	0.3
B594	60	260	0.8	0.2	1.2	0.3	0.2	0.6	0.2	0.0	0.1
B595	40	240	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B596	80	260	0.4	0.3	2.6	0.6	0.1	1.3	0.3	0.0	0.1
B597	80	260	0.8	0.5	1.3	0.6	0.4	0.6	0.3	0.1	0.3
B598	40	200	1.0	0.5	1.0	0.5	0.5	0.5	0.2	0.0	0.3
B599	20	180	1.4	0.8	0.7	0.6	1.0	0.4	0.1	0.0	0.4
B6	20	300	0.4	0.8	2.4	1.9	0.3	1.2	0.1	0.0	0.3
B60	20	280	1.0	0.8	1.0	0.7	0.8	0.5	0.1	0.0	0.4
B600	280	440	1.3	1.0	0.8	0.0	1.3	0.4	0.6	0.4	0.5
B601	280	460	0.8	1.0	1.2	0.0	0.8	0.6	0.6	0.2	0.5
B602	260	460	1.0	1.0	1.0	1.0	1.0	0.5	0.6	0.3	0.5
B603	240	420	1.6	1.8	0.6	0.0	2.9	0.3	0.6	0.4	0.9
B604	20	180	1.8	3.0	0.5	1.6	5.5	0.3	0.1	0.0	1.5
B605	0	160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B606	0	160	0.3	0.3	3.2	0.8	0.1	1.6	0.0	0.0	0.1
B607	20	160	0.0	0.3	27.0	6.7	0.0	13.5	0.1	0.0	0.1
B608	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B609	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B61	20	260	0.5	0.5	2.0	1.0	0.3	1.0	0.1	0.0	0.3
B610	0	140	0.9	0.8	1.1	0.8	0.7	0.5	0.0	0.0	0.4
B611	20	160	0.2	0.3	5.6	1.4	0.0	2.8	0.1	0.0	0.1
B612	0	160	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B613	20	180	1.1	1.0	0.9	0.0	1.1	0.5	0.1	0.0	0.5
B614	20	180	0.8	0.5	1.3	0.7	0.4	0.7	0.1	0.0	0.3
B615	20	180	1.1	1.0	0.9	0.9	1.1	0.4	0.1	0.0	0.5
B616	0	160	0.7	1.5	1.4	2.1	1.1	0.7	0.0	0.0	0.8
B617	20	160	1.2	0.8	0.9	0.6	0.9	0.4	0.1	0.0	0.4
B618	0	140	0.9	0.8	1.1	0.8	0.7	0.6	0.0	0.0	0.4
B619	20	140	0.7	0.8	1.5	1.1	0.5	0.7	0.1	0.0	0.4
B62	20	260	0.5	0.3	2.1	0.5	0.1	1.0	0.1	0.0	0.1
B620	20	140	0.6	0.5	1.5	0.8	0.3	0.8	0.1	0.0	0.3
B621	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B622	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B623	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B624	0	120	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B625	0	120	0.6	0.3	1.7	0.4	0.1	0.9	0.0	0.0	0.1
B626	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B627	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B628	0	100	0.6	0.3	1.7	0.4	0.1	0.9	0.0	0.0	0.1
B629	0	100	0.9	0.5	1.1	0.6	0.4	0.6	0.0	0.0	0.3
B63	20	260	0.9	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B630	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B631	0	100	0.1	0.3	10.7	2.7	0.0	5.3	0.0	0.0	0.1
B632	0	100	0.9	0.5	1.1	0.6	0.4	0.6	0.0	0.0	0.3
B633	0	100	1.0	0.8	1.0	0.8	0.7	0.5	0.0	0.0	0.4
B634	0	100	0.3	0.3	3.1	0.8	0.1	1.5	0.0	0.0	0.1
B635	40	260	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B636	20	240	0.4	0.3	2.6	0.7	0.1	1.3	0.1	0.0	0.1
B637	120	340	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B638	60	260	0.3	0.3	3.1	0.8	0.1	1.5	0.2	0.0	0.1
B639	140	320	0.8	0.5	1.3	0.7	0.4	0.7	0.4	0.1	0.3
B64	0	240	0.1	0.3	18.7	4.7	0.0	9.4	0.0	0.0	0.1
B640	20	200	0.7	0.8	1.4	1.0	0.5	0.7	0.1	0.0	0.4
B641	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B642	40	200	0.5	0.5	2.0	1.0	0.3	1.0	0.2	0.0	0.3
B643	20	180	1.8	2.0	0.6	1.1	3.6	0.3	0.1	0.0	1.0
B644	40	200	1.4	1.8	0.7	0.0	2.4	0.4	0.2	0.1	0.9
B645	300	460	1.4	2.3	0.7	0.0	3.2	0.4	0.7	0.4	1.1
B646	260	440	0.8	1.3	1.3	0.0	1.0	0.6	0.6	0.2	0.6
B647	260	420	1.3	2.0	0.7	1.5	2.7	0.4	0.6	0.3	1.0
B648	40	200	2.1	2.0	0.5	0.9	4.3	0.2	0.2	0.1	1.0
B649	0	160	0.8	1.3	1.2	1.5	1.1	0.6	0.0	0.0	0.6

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B65	20	240	1.0	0.5	1.0	0.5	0.5	0.5	0.1	0.0	0.3
B650	20	160	0.4	0.3	2.8	0.7	0.1	1.4	0.1	0.0	0.1
B651	20	160	0.6	0.3	1.8	0.5	0.1	0.9	0.1	0.0	0.1
B652	20	160	1.0	1.0	1.0	1.0	1.0	0.5	0.1	0.0	0.5
B653	60	200	1.6	1.8	0.6	1.1	2.9	0.3	0.3	0.1	0.9
B654	40	200	1.5	1.8	0.7	1.2	2.7	0.3	0.2	0.1	0.9
B655	160	320	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.2	0.5
B656	300	480	0.9	0.8	1.1	0.0	0.7	0.5	0.6	0.3	0.4
B657	300	460	0.8	1.0	1.2	1.2	0.8	0.6	0.7	0.3	0.5
B658	20	200	1.1	1.3	0.9	1.1	1.4	0.4	0.1	0.0	0.6
B659	40	200	1.6	0.8	0.6	0.0	1.2	0.3	0.2	0.1	0.4
B66	0	220	0.9	1.0	1.1	1.1	0.9	0.5	0.0	0.0	0.5
B660	20	180	1.3	1.0	0.8	0.0	1.3	0.4	0.1	0.0	0.5
B661	20	160	1.3	1.8	0.7	1.3	2.4	0.4	0.1	0.0	0.9
B662	0	140	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B663	0	140	0.2	0.5	4.7	2.4	0.1	2.4	0.0	0.0	0.3
B664	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B665	20	140	0.1	0.2	7.2	1.8	0.0	3.6	0.1	0.0	0.1
B666	0	120	0.8	0.8	1.3	0.9	0.6	0.6	0.0	0.0	0.4
B667	0	120	0.1	0.3	7.9	2.0	0.0	3.9	0.0	0.0	0.1
B668	0	120	0.3	0.3	3.2	0.8	0.1	1.6	0.0	0.0	0.1
B669	0	120	0.4	0.3	2.7	0.7	0.1	1.4	0.0	0.0	0.1
B67	0	240	0.4	0.8	2.4	0.0	0.3	1.2	0.0	0.0	0.4
B670	0	100	1.0	0.8	1.0	0.8	0.7	0.5	0.0	0.0	0.4
B671	0	100	0.4	0.3	2.4	0.6	0.1	1.2	0.0	0.0	0.1
B672	0	100	0.5	0.3	2.0	0.5	0.1	1.0	0.0	0.0	0.1
B673	0	100	0.1	0.3	6.8	1.7	0.0	3.4	0.0	0.0	0.1
B674	0	100	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B675	0	100	1.0	0.8	1.0	0.8	0.7	0.5	0.0	0.0	0.4
B676	0	100	0.4	0.3	2.5	0.6	0.1	1.3	0.0	0.0	0.1
B677	0	120	0.8	0.5	1.3	0.7	0.4	0.7	0.0	0.0	0.3
B678	40	280	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B679	80	320	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B68	360	600	1.3	1.8	0.8	0.0	2.2	0.4	0.6	0.5	0.9
B680	40	260	0.0	0.2	26.0	6.5	0.0	13.0	0.2	0.0	0.1
B681	20	220	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B682	140	340	0.3	0.3	3.5	0.9	0.1	1.7	0.4	0.0	0.1
B683	20	200	0.0	0.3	150.8	37.7	0.0	75.4	0.1	0.0	0.1
B684	40	220	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B685	0	180	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B686	40	200	0.2	0.3	5.8	1.5	0.0	2.9	0.2	0.0	0.1
B687	40	200	0.7	0.5	1.4	0.7	0.4	0.7	0.2	0.0	0.3
B688	20	180	1.6	1.5	0.6	1.0	2.3	0.3	0.1	0.0	0.8
B689	220	380	1.4	2.0	0.7	1.4	2.8	0.4	0.6	0.3	1.0
B69	440	740	0.7	0.8	1.4	0.0	0.6	0.7	0.6	0.3	0.4
B690	260	420	0.8	0.5	1.3	0.0	0.4	0.6	0.6	0.2	0.3
B691	180	340	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.2	0.5
B692	0	160	1.2	1.0	0.8	0.8	1.2	0.4	0.0	0.0	0.5
B693	20	160	0.4	0.3	2.5	0.6	0.1	1.3	0.1	0.0	0.1
B694	60	200	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B695	360	500	1.1	0.8	0.9	0.7	0.8	0.5	0.7	0.4	0.4
B696	340	520	0.9	1.8	1.1	0.0	1.5	0.6	0.7	0.3	0.9
B697	340	520	0.7	1.3	1.4	0.0	0.9	0.7	0.7	0.2	0.6
B698	340	540	0.6	1.0	1.5	0.0	0.6	0.8	0.6	0.2	0.5
B699	300	600	0.4	1.3	2.5	0.0	0.5	1.2	0.5	0.1	0.6
B7	60	340	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B70	20	280	0.2	0.3	5.4	1.3	0.0	2.7	0.1	0.0	0.1
B700	360	580	0.8	1.8	1.2	0.0	1.4	0.6	0.6	0.3	0.9
B701	260	460	1.3	1.8	0.8	1.4	2.2	0.4	0.6	0.3	0.9
B702	320	500	1.2	1.5	0.8	0.0	1.8	0.4	0.6	0.4	0.8
B703	320	480	0.7	1.3	1.3	0.0	0.9	0.7	0.7	0.2	0.6
B704	60	220	1.4	1.0	0.7	0.7	1.4	0.4	0.3	0.1	0.5
B705	20	160	0.6	0.3	1.8	0.4	0.1	0.9	0.1	0.0	0.1
B706	20	160	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B707	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B708	20	140	0.3	0.5	3.6	1.8	0.1	1.8	0.1	0.0	0.3
B709	0	120	0.9	0.8	1.1	0.8	0.7	0.6	0.0	0.0	0.4
B71	0	260	0.6	0.3	1.5	0.4	0.2	0.8	0.0	0.0	0.1
B710	0	120	0.4	0.5	2.7	1.3	0.2	1.3	0.0	0.0	0.3
B711	20	140	0.2	0.3	5.3	1.3	0.0	2.6	0.1	0.0	0.1
B712	0	120	0.4	0.5	2.2	1.1	0.2	1.1	0.0	0.0	0.3
B713	0	120	0.9	0.8	1.1	0.9	0.7	0.6	0.0	0.0	0.4
B714	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B715	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B716	0	120	0.6	0.3	1.8	0.5	0.1	0.9	0.0	0.0	0.1
B717	0	120	0.2	0.5	4.0	2.0	0.1	2.0	0.0	0.0	0.3
B718	20	120	0.9	0.5	1.2	0.6	0.4	0.6	0.2	0.0	0.3
B719	20	120	0.4	0.3	2.5	0.6	0.1	1.2	0.2	0.0	0.1
B72	0	260	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B720	0	120	0.2	0.4	4.9	2.0	0.1	2.5	0.0	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B721	60	300	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B722	60	280	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B723	0	220	0.1	0.2	10.0	2.5	0.0	5.0	0.0	0.0	0.1
B724	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B725	80	280	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B726	40	240	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B727	40	220	0.1	0.3	6.7	1.7	0.0	3.4	0.2	0.0	0.1
B728	20	200	0.2	0.3	4.0	1.0	0.1	2.0	0.1	0.0	0.1
B729	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B73	0	260	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B730	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B731	40	200	0.1	0.3	13.7	3.4	0.0	6.8	0.2	0.0	0.1
B732	0	160	0.2	0.3	4.6	1.2	0.1	2.3	0.0	0.0	0.1
B733	0	160	1.2	1.3	0.8	1.0	1.6	0.4	0.0	0.0	0.6
B734	220	380	2.1	2.3	0.5	1.1	4.7	0.2	0.6	0.5	1.1
B735	260	420	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B736	240	400	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B737	140	300	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B738	320	480	0.6	0.5	1.6	0.8	0.3	0.8	0.7	0.2	0.3
B739	340	520	1.0	0.8	1.0	0.0	0.7	0.5	0.7	0.3	0.4
B74	20	260	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B740	260	460	1.2	1.0	0.8	0.0	1.2	0.4	0.6	0.3	0.5
B741	260	480	1.3	2.0	0.8	0.0	2.6	0.4	0.5	0.3	1.0
B742	260	480	1.3	1.3	0.7	0.0	1.7	0.4	0.5	0.3	0.6
B743	240	480	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B744	200	460	1.0	2.8	1.0	0.0	2.9	0.5	0.4	0.2	1.4
B745	340	600	0.9	1.5	1.1	0.0	1.4	0.5	0.6	0.3	0.8
B746	260	480	1.2	2.3	0.9	2.0	2.6	0.4	0.5	0.3	1.1
B747	100	260	0.7	0.8	1.3	1.0	0.6	0.7	0.4	0.1	0.4
B748	20	180	0.0	0.3	54.1	13.5	0.0	27.1	0.1	0.0	0.1
B749	20	160	0.6	0.3	1.7	0.4	0.1	0.9	0.1	0.0	0.1
B75	20	240	0.6	0.3	1.8	0.5	0.1	0.9	0.1	0.0	0.1
B750	0	140	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B751	20	140	0.7	0.5	1.4	0.7	0.4	0.7	0.1	0.0	0.3
B752	40	160	0.6	0.8	1.7	1.3	0.4	0.9	0.3	0.0	0.4
B753	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B754	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B755	0	120	0.7	0.3	1.5	0.4	0.2	0.8	0.0	0.0	0.1
B756	0	120	0.9	0.8	1.1	0.8	0.7	0.5	0.0	0.0	0.4
B757	0	120	0.1	0.3	11.1	2.8	0.0	5.5	0.0	0.0	0.1

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B758	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B759	0	120	0.6	0.3	1.8	0.4	0.1	0.9	0.0	0.0	0.1
B76	0	220	0.1	0.3	9.0	2.2	0.0	4.5	0.0	0.0	0.1
B760	0	120	0.0	0.3	21.5	5.4	0.0	10.7	0.0	0.0	0.1
B761	0	120	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B762	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B763	80	320	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B764	60	280	0.1	0.3	9.4	2.4	0.0	4.7	0.2	0.0	0.1
B765	0	220	0.6	0.5	1.6	0.8	0.3	0.8	0.0	0.0	0.3
B766	0	220	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B767	20	220	0.8	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B768	20	220	0.7	0.3	1.5	0.4	0.2	0.8	0.1	0.0	0.1
B769	40	240	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B77	0	220	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B770	40	240	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B771	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B772	0	180	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B773	20	200	0.2	0.3	4.7	1.2	0.1	2.3	0.1	0.0	0.1
B774	40	200	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B775	0	160	0.2	0.3	4.0	1.0	0.1	2.0	0.0	0.0	0.1
B776	40	200	0.7	0.5	1.3	0.7	0.4	0.7	0.2	0.0	0.3
B777	240	400	0.4	0.5	2.8	0.0	0.2	1.4	0.6	0.1	0.3
B778	220	420	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B779	220	420	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B78	20	240	0.9	1.0	1.1	1.1	0.9	0.5	0.1	0.0	0.5
B780	80	260	0.5	0.5	2.2	1.1	0.2	1.1	0.3	0.0	0.3
B781	0	180	1.4	1.0	0.7	0.7	1.4	0.4	0.0	0.0	0.5
B782	20	200	2.0	2.0	0.5	1.0	4.0	0.3	0.1	0.0	1.0
B783	140	320	0.7	0.8	1.5	0.0	0.5	0.8	0.4	0.1	0.4
B784	100	300	1.6	2.5	0.6	0.0	4.1	0.3	0.3	0.2	1.3
B785	20	220	1.7	1.8	0.6	1.0	3.0	0.3	0.1	0.0	0.9
B786	200	400	0.7	0.3	1.5	0.4	0.2	0.7	0.5	0.1	0.1
B787	180	420	2.0	2.5	0.5	1.2	5.0	0.2	0.4	0.4	1.3
B788	360	620	0.6	1.3	1.8	0.0	0.7	0.9	0.6	0.2	0.6
B789	360	600	0.6	1.3	1.8	0.0	0.7	0.9	0.6	0.2	0.6
B79	120	340	1.2	2.0	0.8	0.0	2.4	0.4	0.4	0.1	1.0
B790	160	340	0.1	0.3	8.3	2.1	0.0	4.2	0.5	0.0	0.1
B791	100	260	0.0	0.3	22.4	5.6	0.0	11.2	0.4	0.0	0.1
B792	0	160	0.6	0.3	1.7	0.4	0.1	0.9	0.0	0.0	0.1
B793	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B794	0	140	0.7	0.5	1.4	0.7	0.4	0.7	0.0	0.0	0.3
B795	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B796	20	140	0.1	0.3	10.4	2.6	0.0	5.2	0.1	0.0	0.1
B797	0	120	1.1	0.5	0.9	0.5	0.5	0.5	0.0	0.0	0.3
B798	0	120	0.1	0.3	8.1	2.0	0.0	4.1	0.0	0.0	0.1
B799	0	120	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B8	60	320	0.6	0.3	1.7	0.4	0.1	0.8	0.2	0.0	0.1
B80	480	720	1.1	1.1	0.9	0.0	1.2	0.4	0.7	0.5	0.5
B800	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B801	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B802	0	120	0.8	0.8	1.3	1.0	0.6	0.6	0.0	0.0	0.4
B803	0	120	0.5	0.3	2.2	0.5	0.1	1.1	0.0	0.0	0.1
B804	0	120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B805	20	260	0.0	0.3	145.2	37.7	0.0	72.6	0.1	0.0	0.1
B806	20	240	0.6	0.3	1.8	0.4	0.1	0.9	0.1	0.0	0.1
B807	20	240	1.0	0.8	1.0	0.8	0.7	0.5	0.1	0.0	0.4
B808	0	220	1.1	0.7	0.9	0.7	0.8	0.5	0.0	0.0	0.4
B809	140	340	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B81	20	280	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B810	20	220	0.2	0.3	6.5	1.6	0.0	3.2	0.1	0.0	0.1
B811	0	200	1.1	0.5	0.9	0.5	0.5	0.5	0.0	0.0	0.3
B812	0	200	0.8	0.3	1.2	0.3	0.2	0.6	0.0	0.0	0.1
B813	20	200	0.7	0.3	1.5	0.4	0.2	0.8	0.1	0.0	0.1
B814	20	200	0.9	0.5	1.1	0.5	0.5	0.5	0.1	0.0	0.3
B815	20	180	1.0	0.8	1.0	0.7	0.8	0.5	0.1	0.0	0.4
B816	0	160	1.2	0.5	0.8	0.4	0.6	0.4	0.0	0.0	0.3
B817	0	160	1.5	1.3	0.7	0.8	1.9	0.3	0.0	0.0	0.6
B818	0	160	1.2	1.0	0.8	0.8	1.2	0.4	0.0	0.0	0.5
B819	120	280	0.6	0.3	1.6	0.4	0.2	0.8	0.4	0.1	0.1
B82	20	280	0.3	0.3	3.5	0.9	0.1	1.8	0.1	0.0	0.1
B820	160	340	0.1	0.3	8.7	2.2	0.0	4.4	0.5	0.0	0.1
B821	120	300	0.3	0.3	3.1	0.8	0.1	1.5	0.4	0.0	0.1
B822	0	180	0.5	0.5	2.0	1.0	0.2	1.0	0.0	0.0	0.3
B823	0	180	1.2	0.8	0.8	0.6	0.9	0.4	0.0	0.0	0.4
B824	0	180	1.2	1.3	0.8	1.0	1.5	0.4	0.0	0.0	0.6
B825	120	300	0.7	0.5	1.5	0.0	0.3	0.7	0.4	0.1	0.3
B826	20	200	2.1	3.0	0.5	1.4	6.4	0.2	0.1	0.0	1.5
B827	0	200	1.1	1.5	0.9	1.3	1.7	0.4	0.0	0.0	0.8
B828	200	400	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B829	100	360	0.8	1.5	1.3	0.0	1.2	0.6	0.3	0.1	0.8

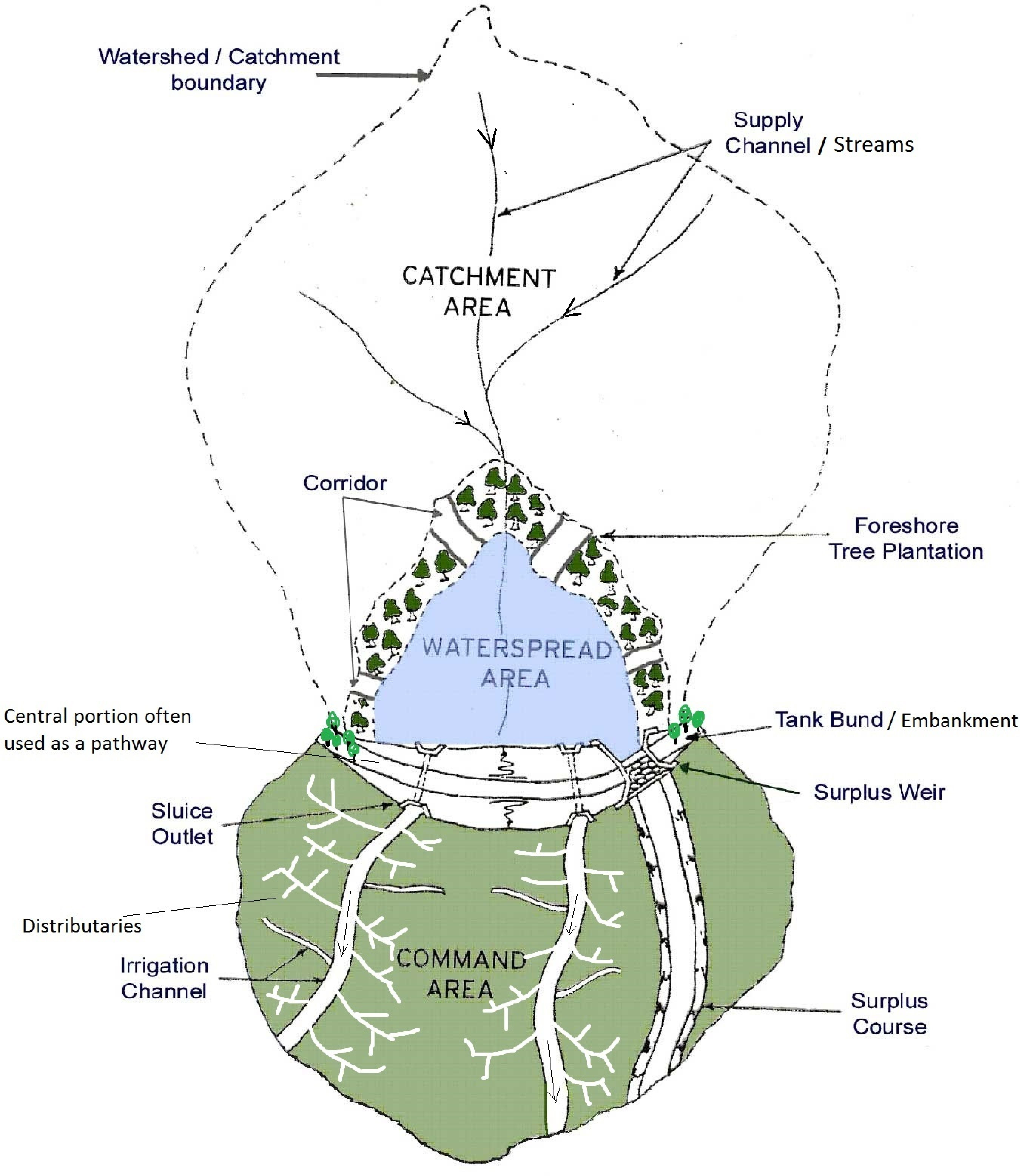
Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B83	20	260	0.7	0.3	1.4	0.3	0.2	0.7	0.1	0.0	0.1
B830	360	620	0.9	1.3	1.2	0.0	1.1	0.6	0.6	0.3	0.6
B831	400	620	0.3	0.3	3.0	0.7	0.1	1.5	0.6	0.1	0.1
B832	100	300	1.1	0.8	0.9	0.7	0.8	0.5	0.3	0.1	0.4
B833	80	240	1.0	1.0	1.0	1.0	1.0	0.5	0.3	0.1	0.5
B834	0	160	0.1	0.3	12.6	3.2	0.0	6.3	0.0	0.0	0.1
B835	20	160	0.6	0.3	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B836	0	140	1.2	0.7	0.8	0.6	0.9	0.4	0.0	0.0	0.4
B837	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B838	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B839	20	140	0.2	0.3	4.2	1.1	0.1	2.1	0.1	0.0	0.1
B84	20	260	0.0	0.3	23.6	5.9	0.0	11.8	0.1	0.0	0.1
B840	20	140	0.3	0.3	3.0	0.7	0.1	1.5	0.1	0.0	0.1
B841	20	140	0.5	0.3	1.9	0.5	0.1	1.0	0.1	0.0	0.1
B842	0	120	0.2	0.3	5.9	1.5	0.0	2.9	0.0	0.0	0.1
B843	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B844	0	140	0.3	0.5	3.6	1.8	0.1	1.8	0.0	0.0	0.3
B845	60	300	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B846	20	240	0.7	0.2	1.4	0.3	0.2	0.7	0.1	0.0	0.1
B847	20	240	0.2	0.2	5.3	1.3	0.0	2.6	0.1	0.0	0.1
B848	0	220	0.3	0.2	3.7	0.9	0.1	1.9	0.0	0.0	0.1
B849	20	240	0.0	0.2	23.9	6.0	0.0	11.9	0.1	0.0	0.1
B85	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B850	20	220	0.7	0.5	1.4	0.7	0.4	0.7	0.1	0.0	0.3
B851	20	220	0.1	0.2	9.9	2.5	0.0	5.0	0.1	0.0	0.1
B852	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B853	20	200	0.0	0.2	42.3	10.6	0.0	21.1	0.1	0.0	0.1
B854	0	180	0.2	0.2	4.6	1.1	0.1	2.3	0.0	0.0	0.1
B855	60	220	0.6	0.5	1.7	0.9	0.3	0.9	0.3	0.0	0.3
B856	20	180	0.4	0.7	2.2	1.7	0.3	1.1	0.1	0.0	0.4
B857	20	180	0.3	0.2	3.2	0.8	0.1	1.6	0.1	0.0	0.1
B858	20	180	0.5	0.5	2.0	1.0	0.2	1.0	0.1	0.0	0.3
B859	40	200	0.7	0.2	1.4	0.4	0.2	0.7	0.2	0.0	0.1
B86	20	240	0.1	0.3	7.3	1.8	0.0	3.7	0.1	0.0	0.1
B860	20	200	0.3	0.2	3.4	0.8	0.1	1.7	0.1	0.0	0.1
B861	20	200	0.1	0.2	8.2	2.1	0.0	4.1	0.1	0.0	0.1
B862	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B863	0	180	0.7	0.2	1.5	0.4	0.2	0.8	0.0	0.0	0.1
B864	0	180	0.1	0.2	12.3	3.1	0.0	6.2	0.0	0.0	0.1
B865	0	180	1.3	1.0	0.8	0.8	1.3	0.4	0.0	0.0	0.5

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B866	100	280	0.5	0.2	1.9	0.5	0.1	1.0	0.4	0.1	0.1
B867	120	300	0.9	1.0	1.1	1.1	0.9	0.5	0.4	0.1	0.5
B868	200	400	0.6	0.5	1.6	0.8	0.3	0.8	0.5	0.1	0.3
B869	120	360	0.1	0.5	15.8	7.9	0.0	7.9	0.3	0.0	0.3
B87	0	220	0.6	0.3	1.8	0.4	0.1	0.9	0.0	0.0	0.1
B870	160	400	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B871	320	540	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
B872	140	340	0.6	0.2	1.7	0.4	0.1	0.8	0.4	0.1	0.1
B873	80	260	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B874	20	180	0.8	0.5	1.2	0.6	0.4	0.6	0.1	0.0	0.3
B875	20	160	0.7	0.5	1.4	0.7	0.4	0.7	0.1	0.0	0.3
B876	0	140	1.1	0.7	0.9	0.7	0.8	0.5	0.0	0.0	0.4
B877	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B878	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B879	20	140	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B88	0	220	1.0	0.5	1.0	0.5	0.5	0.5	0.0	0.0	0.3
B880	20	140	0.6	0.2	1.8	0.4	0.1	0.9	0.1	0.0	0.1
B881	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B882	20	140	0.6	0.2	1.6	0.4	0.2	0.8	0.1	0.0	0.1
B883	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B884	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B885	20	240	0.2	0.2	4.2	1.1	0.1	2.1	0.1	0.0	0.1
B886	140	360	0.6	0.3	1.7	0.4	0.1	0.8	0.4	0.1	0.1
B887	0	220	0.0	0.3	22.4	5.6	0.0	11.2	0.0	0.0	0.1
B888	0	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B889	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B89	0	220	1.2	1.0	0.9	0.9	1.2	0.4	0.0	0.0	0.5
B890	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B891	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B892	0	180	1.0	0.3	1.0	0.3	0.2	0.5	0.0	0.0	0.1
B893	20	200	0.7	0.3	1.5	0.4	0.2	0.7	0.1	0.0	0.1
B894	40	220	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B895	20	200	0.1	0.3	8.2	2.0	0.0	4.1	0.1	0.0	0.1
B896	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B897	20	200	0.1	0.3	15.2	3.8	0.0	7.6	0.1	0.0	0.1
B898	0	180	0.6	0.5	1.5	0.8	0.3	0.8	0.0	0.0	0.3
B899	0	180	0.8	0.3	1.3	0.3	0.2	0.7	0.0	0.0	0.1
B9	0	260	0.5	0.3	1.9	0.0	0.1	1.0	0.0	0.0	0.1
B90	20	240	1.5	1.5	0.7	1.0	2.2	0.3	0.1	0.0	0.8
B900	0	180	1.0	1.3	1.0	1.2	1.3	0.5	0.0	0.0	0.6

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B901	0	180	0.2	0.3	6.3	1.6	0.0	3.1	0.0	0.0	0.1
B902	120	300	0.2	0.3	5.5	1.4	0.0	2.7	0.4	0.0	0.1
B903	420	600	0.4	0.3	2.3	0.6	0.1	1.2	0.7	0.2	0.1
B904	380	580	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
B905	240	440	0.7	0.3	1.5	0.4	0.2	0.8	0.5	0.2	0.1
B906	120	360	0.1	0.3	10.3	2.6	0.0	5.1	0.3	0.0	0.1
B907	180	420	0.5	0.3	2.1	0.5	0.1	1.0	0.4	0.1	0.1
B908	220	500	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B909	200	400	0.0	0.3	27.2	6.8	0.0	13.6	0.5	0.0	0.1
B91	100	340	1.2	1.0	0.8	0.0	1.2	0.4	0.3	0.1	0.5
B910	60	240	0.6	0.3	1.7	0.4	0.1	0.9	0.3	0.0	0.1
B911	60	220	0.6	0.5	1.7	0.8	0.3	0.8	0.3	0.0	0.3
B912	0	160	0.6	0.3	1.7	0.4	0.1	0.9	0.0	0.0	0.1
B913	0	140	0.9	0.7	1.1	0.9	0.7	0.6	0.0	0.0	0.4
B914	0	160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B915	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B916	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B917	20	140	0.6	0.3	1.8	0.5	0.1	0.9	0.1	0.0	0.1
B918	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B919	0	140	0.1	0.3	7.1	1.8	0.0	3.6	0.0	0.0	0.1
B92	580	840	0.9	0.5	1.1	0.0	0.5	0.5	0.7	0.5	0.3
B920	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B921	0	240	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B922	20	240	0.3	0.3	3.7	0.9	0.1	1.9	0.1	0.0	0.1
B923	180	400	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B924	180	400	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B925	0	220	0.2	0.3	4.9	1.2	0.1	2.4	0.0	0.0	0.1
B926	20	220	0.7	0.3	1.5	0.4	0.2	0.7	0.1	0.0	0.1
B927	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B928	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B929	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B93	80	300	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B930	0	180	0.0	0.3	28.7	7.2	0.0	14.3	0.0	0.0	0.1
B931	0	180	0.1	0.3	7.6	1.9	0.0	3.8	0.0	0.0	0.1
B932	20	200	0.1	0.3	8.7	2.2	0.0	4.3	0.1	0.0	0.1
B933	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B934	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B935	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B936	0	180	0.5	0.5	2.0	1.0	0.2	1.0	0.0	0.0	0.3
B937	0	180	0.9	0.5	1.1	0.5	0.5	0.5	0.0	0.0	0.3

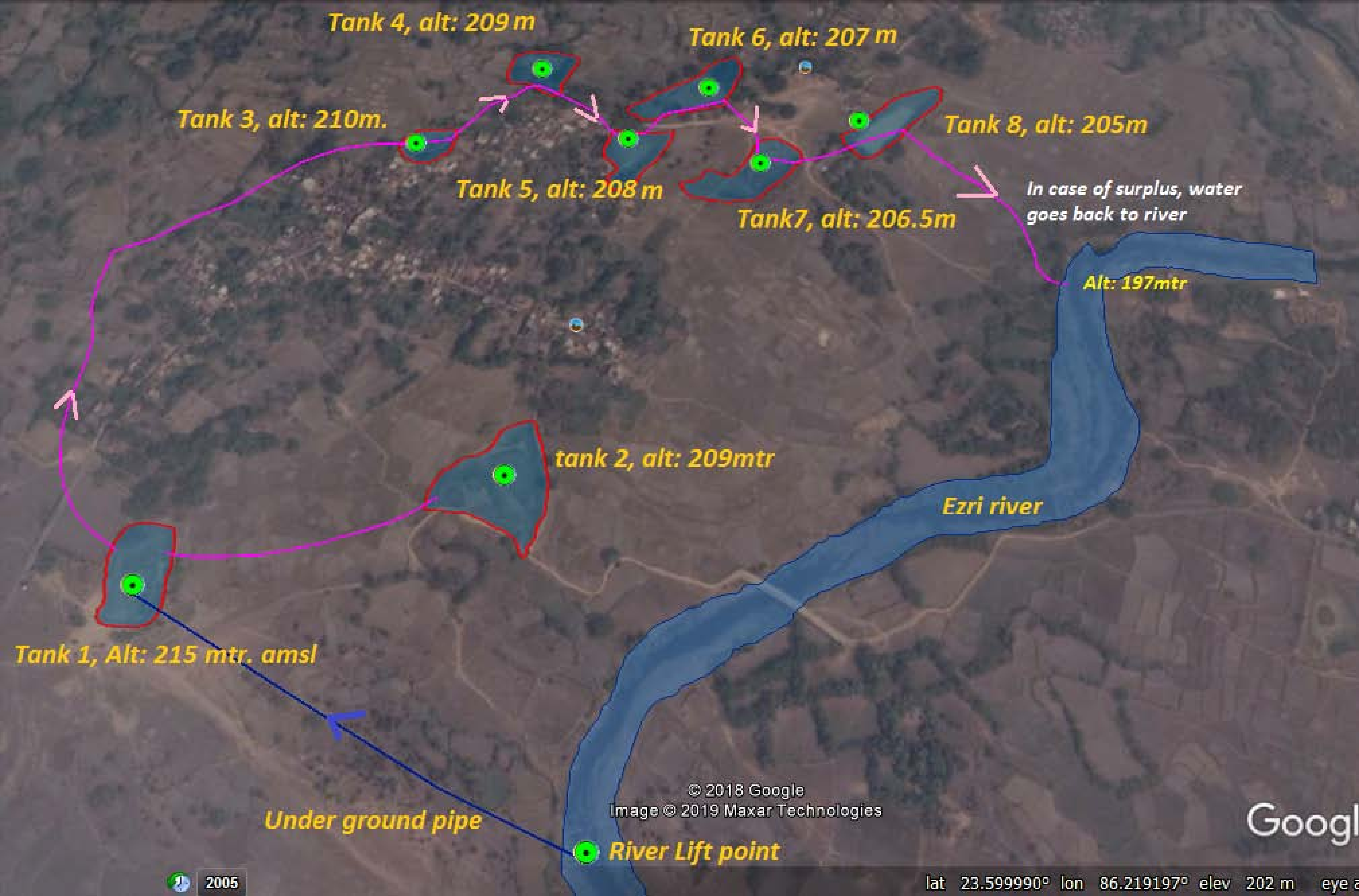
Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B938	0	180	0.6	0.5	1.6	0.8	0.3	0.8	0.0	0.0	0.3
B939	0	180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B94	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B940	140	320	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B941	340	540	0.6	0.3	1.7	0.4	0.1	0.9	0.6	0.2	0.1
B942	200	580	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B943	340	560	0.5	0.3	2.1	0.5	0.1	1.0	0.6	0.2	0.1
B944	140	360	0.7	0.8	1.4	1.1	0.5	0.7	0.4	0.1	0.4
B945	140	360	1.0	0.5	1.0	0.5	0.5	0.5	0.4	0.1	0.3
B946	200	440	0.1	0.3	7.7	1.9	0.0	3.8	0.5	0.0	0.1
B947	200	400	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B948	60	240	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
B949	100	260	0.3	0.3	4.0	1.0	0.1	2.0	0.4	0.0	0.1
B95	20	220	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B950	0	160	0.9	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B951	0	160	0.8	0.7	1.3	0.9	0.6	0.6	0.0	0.0	0.4
B952	0	160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B953	20	160	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B954	0	140	0.3	0.3	3.8	0.9	0.1	1.9	0.0	0.0	0.1
B955	0	140	0.9	0.5	1.1	0.5	0.5	0.5	0.0	0.0	0.3
B956	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B957	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B958	0	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B959	20	240	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B96	0	260	0.4	0.2	2.5	0.6	0.1	1.2	0.0	0.0	0.1
B960	0	220	0.5	0.3	1.9	0.5	0.1	0.9	0.0	0.0	0.1
B961	120	340	0.3	0.3	3.8	0.9	0.1	1.9	0.4	0.0	0.1
B962	40	260	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
B963	0	220	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B964	0	200	0.4	0.3	2.4	0.6	0.1	1.2	0.0	0.0	0.1
B965	0	200	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B966	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B967	0	200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B968	0	200	0.6	0.3	1.6	0.4	0.2	0.8	0.0	0.0	0.1
B969	0	200	0.6	0.3	1.8	0.5	0.1	0.9	0.0	0.0	0.1
B97	20	260	0.6	0.2	1.7	0.4	0.1	0.8	0.1	0.0	0.1
B970	0	180	0.3	0.5	2.9	1.5	0.2	1.5	0.0	0.0	0.3
B971	20	200	0.4	0.5	2.5	1.3	0.2	1.3	0.1	0.0	0.3
B972	0	180	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B973	0	180	0.9	0.5	1.1	0.6	0.5	0.6	0.0	0.0	0.3

Grid Code	RR	AR	DD	SF	CCM	Dr. Int	Inf. No.	LOFL	Dis. index	Rug. No	D. Tex
B974	0	180	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B975	20	200	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
B976	0	180	0.6	0.3	1.8	0.4	0.1	0.9	0.0	0.0	0.1
B977	140	320	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B978	140	340	0.1	0.3	7.8	1.9	0.0	3.9	0.4	0.0	0.1
B979	280	480	0.4	0.3	2.3	0.6	0.1	1.1	0.6	0.1	0.1
B98	0	240	1.4	1.8	0.7	1.2	2.5	0.3	0.0	0.0	0.9
B980	160	400	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B981	140	380	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
B982	180	380	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
B983	60	240	0.6	0.3	1.6	0.4	0.2	0.8	0.3	0.0	0.1
B984	60	220	0.6	0.3	1.7	0.4	0.1	0.9	0.3	0.0	0.1
B985	20	180	0.7	0.3	1.5	0.4	0.2	0.8	0.1	0.0	0.1
B986	0	160	0.7	0.3	1.5	0.4	0.2	0.7	0.0	0.0	0.1
B987	0	160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B988	20	160	0.3	0.3	3.6	0.9	0.1	1.8	0.1	0.0	0.1
B989	0	140	0.8	0.8	1.3	1.0	0.6	0.6	0.0	0.0	0.4
B99	60	280	0.6	0.2	1.6	0.4	0.2	0.8	0.2	0.0	0.1
B990	0	140	0.6	0.8	1.6	1.2	0.5	0.8	0.0	0.0	0.4
B991	20	160	0.6	0.3	1.8	0.4	0.1	0.9	0.1	0.0	0.1
B992	0	240	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
B993	20	240	0.1	0.3	11.9	3.0	0.0	6.0	0.1	0.0	0.1
B994	0	220	0.8	0.7	1.2	0.9	0.6	0.6	0.0	0.0	0.4
B995	20	220	0.8	0.8	1.2	0.9	0.6	0.6	0.1	0.0	0.4
B996	0	200	0.6	0.3	1.7	0.4	0.1	0.9	0.0	0.0	0.1
B997	0	200	0.7	0.3	1.4	0.3	0.2	0.7	0.0	0.0	0.1
B998	0	200	0.8	0.5	1.2	0.6	0.4	0.6	0.0	0.0	0.3
B999	0	200	1.2	0.5	0.8	0.4	0.6	0.4	0.0	0.0	0.3



Compomnents of a Tank Irrigation System

Source : Modified after Dhan Foundataion (2006) https://www.dhan.org/vayalagam/


Tank 4, alt: 209 m
Tank 6, alt: 207 m
Tank 3, alt: 210m.
Tank 8, alt: 205m
Tank 5, alt: 208 m
In case of surplus, water goes back to river
Tank7, alt: 206.5m
Alt: 197mtr
tank 2, alt: 209mtr
Ezri river
Tank 1, Alt: 215 mtr. amsl
© 2018 Google
Image © 2019 Maxar Technologies
Under ground pipe
River Lift point
2005
lat 23.599990° lon 86.219197° elev 202 m

"GEO-ENVIRONMENTAL ASSESSMENT OF WATER RESOURCES IN ONG BASIN, ODISHA"

Interview Schedule for the Farmers (for Ph. D. Research)

Center for the Study of the Regional Development, (CSRD), **JNU, New Delhi.**

(Information provided in this interview schedule will be used *only for research* purpose)

1. **Location:**	**Serial No:**	
2. State:	3. District:	4. Block:
5. GP:	5. Village:	6. Hamlet/ *Para*:

2. Household characteristics

2.1. Name of Head of Household (HoH):					
2.2.	Name of Informant:		**Ph No.**		
2.3	Social group (Put √)	ST: 1	SC: 2	OBC:3	Gen: 4

3. Demographic and other particulars of household members:

Sl. No	NAMES of members (in CAPITAL letters)	Sex M=1, F=2	Age **(years)**	Education* **(code)**	Occupation# **(code)**
	a	b	c	d	e
1. **HoH**					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

*** Col.d:**	Iliterate-1	Below primary-2	Primary-3	Secondary-4	H. secondary-5	Graduate-6	PG-7	Diploma/certificate course-8

#Col e: (Occupation: choose codes from below)

Cultivation-1	Agr. Labour-2	Non-Agr. Labour-3	Salaried-4	Self- employed based on agriculture and allied activities-5	
Self-employed in **petty trade and business**-6			Collection of **fodder and cutting woods** from jungle and selling-7		
Unemployed-8	Student-10	Only domestic work- 11	Retired and very old-12	Disabled/handicapped/sick-13	Too young to work-14
Others- 15 **(Specify):**					

4. Land holding of the household

4. 1 **.**Types in acres:	a.Bahal:	b.Berna:	c.Maal:	d.Aat:
4. 2. Land Holding: (acres): a.Irrigated:		b.Unirrigated:	c.**Total**:	

4.3. Types of land ownership		**Irrigated** (in Acre)						**Unirrigated** (In Acre)
		Tank/MIP flow	Tank/MIP+ pump	Canal	Open-well	Bore-well	Others	
		a	b	c	d	e	f	g
1	Owned							
2	Leased-in							
3	Leased-out							
4	Operational holding (**1+2- 3**)							

5. Particulars of the tank	5.a.**Name of tank/MI Project** under which the farm is located:	
5.1	Location of the field: (**code**) **Head**-Reach: **H**, **Middle**: **M**, **Tail**-end: **T**	
5.2	How much of Farmer's land is under this tank (acre)[5.2.a+b+c+d]	
5.2.a. How much is irrigated with the *tank /project flow* water (acre)		
5.2.b How much land is irrigated with *pumping of tank/project* water (acre)		
5.2.c How much is irrigated with the *well* water (acre)		
5.2.d How much of land under the tank is *current fallow(Not cultivated)* (acre)		

6. Particulars of **costs of cultivation** of crops grown by the farmer (crop-wise) — **Production**

	Crop Name **Type: short/Long** **Breed:**	Area cultivated In acres	Irrig, Source $ **(See Code below)**	Season, **Kharif-1, Rabi-2, Zaid-3**	Seeds **in Rs.** Own	Seeds **in Rs.** Purchased	Manure (Cow-dung) in Rs. Own	Manure (Cow-dung) in Rs. Purchased	**Chem. Fertilizer** in Rs.	Pesticides in Rs.	Machinery Cost in Rs. Hired Tractors	Machinery Cost in Rs. Hired Thresher	Machinery Cost in Rs. Other machinery	Pumping Cost from Tank **@**	Cost of Diesel/ electricity for Well *	Family Labour Person-Days	Family Labour **Daily** Wage rate	Hired Labour Person-Days	Hired Labour **Daily** Wage rate	Other costs	Production (in units)	Price per unit	By Product (UxV) (in Rs. terms)
	a	b	c	d	e	f	g	h	i	j	K	l	m	n	o	p	q	r	s	t	u	v	w
1																							
2																							
3																							
4																							
5																							

$ Col C. None=**0**, Tank flow=**1**, Tank with pump= **2**, Bore Well=**3**, Open Well= **4**

Col n**@** Give details:	**Pump (on Tank)** was run: ………….. hours / day	Avg No of Days: Sept: , Oct: Nov.	Hiring Charges per day: Rs.	Diesel/kerosene: Rs. /day	Total: Rs.
Col O* Give details:	bore **well** / Open **well** Pump was run:………….. hours / day	Avg No of Days: Sept: , Oct: Nov.	BW Electric charge Rs. /Month Open well pump hiring charge Rs. /day	Op.Well: Diesel Rs. /day	Total: Rs.

7. Tank dependent farmer

(For exclusively well-dependent farmers turn over to table 12, page No.5)

7. Information regarding the tank institution

1	Whether the farmer's land is being irrigated by the tank water: (**code**) Yes-1, No-2	
2	**If Yes,** whether there is farmers' collective management of the tank: (**code**) Yes-1, No-2	
3	**If Yes,** Is it Pani Panchayat =1, Panchayat body= 2, Informal farmers committee=3, (**code**)	
4	If, Pani Panachayat (PP), ***NAME*** of the PP**:**	
5	Do they meet regularly to discuss regarding the use of tank water, (**code**)Yes=1, No-2	
6	**If Yes,** Place of meetings held: (**code**) at Panchayat building-1, School building-2, Other common meeting place-3, other-4 (specify……………………………………………………..…).	
7	Number of meetings held in a year on average (No.s)	
8	Number of meetings held **last** year (No.s)	
9	Number of meetings the farmer attended (No.s)	
10	If the farmer did NOT attend any of the meetings**, REASON(S)**for that: (**code**) there was *No significant issue* in the meeting to be discussed-**1**, it does *Not make any difference*-**2**, *Nobody listens* to you-3, was *busy* in some other activity-4, *Not informed*-5, other-6 (specify)..........	
11	Who decides the agenda for meetings: (**code**) Farmers together-1, by socially/economically *dominant farmers*-2, mostly by the *large farmers*-3, other-4 (specify).............	
12	Did you raise any issue in the meetings: (**code**) Yes-1, No-2	
13	**if Yes,** what was that:	
14	Were you asked about your opinion in the meetings: (**code**) Yes-1, No-2	
15	Who informs the farmer about meetings: (**code**) WUA/committee president-1, other farmer-2, other-3 (specify)……..	
16	Whether the farmer is member of SHG/JFM group/any other CPR management group:(**code**)Yes-1, No-2	

8. Rule enforcement

1	Who enforces the rules: (**code**) WUA appointed person-1, farmers themselves-2, other-3(specify.....)	
2	Who distributes water: (**code**) WUA appointed person-1, farmers themselves-2, other-3(specify..........)	
3	If the answer to Q8.2 is 1, how much do they pay him? **Rs…………………/ acre. /day or month**	
4	What is the criterion for water distribution: (**code**) landholding size-1, Per Farmer=2, other-2 (specify)........	
5	Was there any time when the water distributed other than established criterion: (**code**) Yes-1, No-2	
6	Whether the farmer is satisfied with the WUA's performance: (**code**) Yes-1, No-2	

9. Rule violation

1	Was there any rule violation by the farmer: (**code**) Yes-1, No-2	
2	**If Yes,** What rule was violated: (**code**) water theft-1, other-2(specify....... ……………………………………………..)	
3	If the farmers indulged in water thefts reason for that: (**code**) due to water scarcity-1, farmer felt that there is discrimination in water sharing against him-2, since others too violated-3, do not care-4, other-5(specify..)	

Investigator's comments/observations:

1.

2.

3.

4.

10. Particulars of WUA / PP (Pani Panchayat)

1	Whether there exists a WUA / **PP**: (**code**) Yes-1, No-2	
	If Yes, fill up the following rows, otherwise skip it	
2	Whether the farmers is aware of it: (**code**) Yes-1, No-2	
3	How the representatives of the WUA**/ PP** were elected: (**code**) through *election* process-1, Socially/economically dominant persons-2, *Nominated by JE*-3, other-4 (specify)………	
3	Do you know the name of your PP President **(code)** Yes-1, No-2	
4	How was the PP election/selection process: **(code)** Fair=1, unfair =2, Don't know=3	
5	Did you participate in the election of President/ Chak members: **(code)** Yes-1, No-2	
6	Did you participate in the Joint survey of the PP related to work of the Tank? **(code)** Yes-1, No-2	
7	Did you participate in Repairing and Restoration work of the tanks? **(code)** Yes-1, No-2	
8	How much grant does the WUA**/ PP** receive in a year? Rs………………………	
9	Whether meetings were held after formation of WUA **/ PP**: (**code**) Yes-1, No-2	
10	Who chaired the meeting: (code) President of WUA **/ PP** -1, others-2	
11	How many General Body (GB) meetings have been held in your PP **(No.s)**	
12	Were you informed about the GB meetings and did you attend: **(code)** Informed & attended=1, Informed but did Not attend=2, Not informed=3	
13	Is there any political interference in the functioning of WUA**/ PP**: (**code**) Yes-1, No-2	
14	Has there been re-election into the WUA**/ PP**?	
15	If Yes, Were you happy with the ex-President ? If No why?	
16	There is **growth in Area** irrigated after PP formation: **(code)** Yes-1, No-2	
17	There is **growth in Per acre yield** of rice after PP formation: **(code)** Yes-1, No-2	
18	Have you been paying water tax/dues as per: **(code)**Old rate=1, Revised rate=2, Not Paying=3	
19	Whether woman should involve in PP activities **(code)** Yes-1, No-2	
20	What is the farmer's opinion about performance of the WUA**/ PP** (Put √)	
	1.Very high satisfaction ☐ 2. High satisfaction ☐ 3. Moderate satisfaction ☐ 4. No satisfaction ☐	
21	**If Not satisfied with PP work,** its due to what all changes that happened and what are those	
A		
B		
C		
22	For Tank maintenance, your preference is for: **(code)** PP=1, Irrigation Dept. Personnel =2, Traditional Irrig. Institution=3, Indifferent/ No preference= 4	
23	Opinion on PP maintenance work: **(code)** *Same* as before=1, much *Better*=2, *Worse*=3	
24	If answer is 3 (worse), reasons: **(code)** No progress in work=1, Lack of improvement of the system=2, President/Secretary/Treasurer has become contractor=3	
25	Does the farmer think that there really is a need for WUA: (**code**) Yes-1, the *informal system* is better-2, others-3 (specify……………………………………..)	
	If answer to Q25 above is "2" reasons for that	
A		
B		
26	**If answer to Q25 above is "1"** Does farmer has any suggestion to make the WUA work better	
A		
B		
C		

11. Cost and performance of tank irrigation

1	Criterion of sharing expenditure for tank/MIP maintenance: (**code**) On the basis of ***area*** of farm-**1**, *Per -farmers* basis-**2**, other-**3** (specify)………			
2	Has the farmers paid for maintenance of the Tank: (**code**) Yes-1, No-2			
	If Yes, amount paid *last year/ annually*	Kharif (K)	Rabi	Zaid
3	Amount paid in ***cash*** in Rs.			
4	Amount paid ***in kind***(in what ways:)in money term Rs.			
5	Contribution through supply of ***labour***(**code**) Yes-1, No-2			
5.a	Number of ***labour-days*** worked			
5.b	***Daily*** wage rate (**in Rs.**)[*write even if they are not actually paid*]			
6	Does the farmer get sufficient water from tank: (**code**) Yes-1, No-2			
7	If No, what are the reasons for it: (**Code)** Reduced capacity due to siltation=1, Damaged Sluice=2, No proper/strong canals= 3, canals exist but damaged=4, Improper water distribution-5, Others= 6 (specify…………………………..……………….)			
8	Is the farmers ready to pay for Operation & Maintenance costs: (**code**) Yes-1, No-2			
9	If he has not paid, why? **(Code)** Nobody asked Me=1, Not contributed due to lack of Money=2, Not contributed because others have Not contributed=3, Others=4(specify………………………..)			

12. Well-dependent farmers

1	Does the farmer *own* the well? (**code**) Yes-1, No-2	
2	If Yes, how many *functional wells* does he own? **(No.s)**	
3	Number of *failed wells* (that are Not being used) **(No.s)**	
4	Does he *share* his own well with neighbouring farmers**?** (**code**) Yes-1, No-2	
5	**If Yes,** with *how many* farmers does he share his well **(No.s)**	
6	Does the farmer get water from well ***owned by others***? (**code**) Yes-1, No-2	
7	**If Yes,** How many farmers share this well? **(No.s)**	

13. Reason for shifting to well-irrigation (Provide **ranks** in case of multiple reasons)

	Reasons	**Reason(A)** (Put √)	**Rank(B)**
1	Reliable supply of water		
2	Adequate water		
3	Control on water supply		
4	Productivity increase		
5	Free electricity		
6	Reduction of cost of well digging		
7	Reduction of cost of pumpsets		
8	BKVY subsidy		

14. Particulars regarding the wells of the farmer

14.a. Well dug through BKVY subsidy ☐ b. Privately dug ☐

Well No.	*Year* of digging	Pumpset (**code**)	Pumset capacity **in HP**	Digging Cost Rs.	Pumpset Cost Rs.	Cost on pipes & poles Rs.	*Depth* of the well in *feet*	*Hours* of yield in a day during Kharif	*Hours* of yield in a day during Rabi
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1									
2									
3									
4									
5									

Col. 2. Pumpset (code): Borewell pumpset-1, Openwell pumpset-2, Diesel pumpset-3, by Manual/bullocks-4

15	O&M costs of **1st well**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**
1	How much deep it was dug (in ft.)							
2	Cost incurred to deepen it (in Rs)							
3	Pumpset Renovation cost (in Rs.)							

16	O&M costs of **2nd well**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**
1	How much deep it was dug (in ft.)							
2	Cost incurred to deepen it (in Rs)							
3	Pumpset Renovation cost (in Rs.)							
17	O&M costs of **3rd well**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**
1	How much deep it was dug (in ft.)							
2	Cost incurred to deepen it (in Rs)							
3	Pumpset Renovation cost (in Rs.)							

18. Particulars of the FAILED wells

Serial No. of the well	***Year*** of digging (Y)	Digging ***cost*** (C):in Rs.	Depth of the well (D) in ***feet***
1			
2			
3			
4			
5			

19. Willingness of well-dependent farmers to contribute for tank revival

1	Does the farmer get adequate water from well: (**code**) Yes-1, No-2	
2	Does the farmer know that tank water increases the ground water: (**code**) Yes-1, No-2	
3	Did the farmer attend any of the meetings conducted by the tank-farmers: **(code**) Yes-1, No-2	
3a	**If No, why: (code)** he doesn't depend on tank-water any more=1**,** Others=2(write): Others=3(write):	
4	Is the farmer ready to contribute to the revival of tank: (**code**) Yes-1, No-2	

20. Any relevant information

21. Remarks of the researcher

Name of the Investigator	Ph No.										