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Water-management of Irrigation

A case study on the water-management of irrigation in the urban fringe of Dharwad-Hubli

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Preface

This research is a description of the water-management of irrigation, and how this water-management is arranged socio-economically in the urban fringe of Dharwad-Hubli. We have to see this water-management in the light of the Green Revolution. The Green Revolution is the term widely used to refer to the application of Western technologies to raising agricultural production in the developing world. This encompasses the breakthroughs in the 1960s in plant genetics, which produced high yielding varieties of grains such as rice and wheat, and the associated technological package required for their production, including fertilisers, pesticides and insecticides.
Part of the attraction for planners of the Green Revolution lay in the assumed scale-neutrality of the technologies and the power of the market to encourage and disseminate improvements in well-being. It was assumed that the biochemical technologies of seeds and fertilizers would be equally viable at all scales of operation, whether on small or large farms. It was therefore thought that the yields and incomes of all farmers could be enhanced without raising rural inequalities. In practice, however, the Green Revolution had extremely uneven regional and social impacts.
In India the Green Revolution is considered to have delivered national food self-sufficiency. But the per capita grain production actually fell in most of the major states to 1985, and was correlated strongly with the distribution of irrigation which enabled multiple cropping over the year. To ensure the conditions for cropping, new technologies were developed. These new technologies for irrigation can be seen in the light of the associated packages required for the production. But the question is how these new technologies for irrigation are distributed socio-economically in the present agrarian structure, and how these technologies will be used.

This research is a Master's Thesis, as assignment for the Department of Spatial Sciences on the Rijksuniversiteit Groningen, and has the aim to give insight in the water-management of irrigation in the urban-fringe of Dharwad-Hubli, which is a twin city in the north of the state Karnataka, India.
Thanks to the guidance of Dr. P. C. J. Druijven and Dr. S. R. Nidagundi, but also through my fieldwork in the form of inquiries and interviews, did I get a good insight in the water-management of irrigation in the urban-fringe of Darwad-Hubli.
And I like to thank everyone, who assisted me to come to this research report.

Theo de Boer

Summary

We defined in this research the water-management in agriculture as the process whereby water will be manipulated and used for the production of food and fibres (Abu-Zeid, 1980). In the context of water-management we distinguished physical features, social and governmental institutions which have its influence on the manipulation of irrigation water by farmer households. We tried to find out how water-management of irrigation is arranged socio-economically in the urban fringe area of Dharwad-Hubli. We described this on the hand of the operational properties in the context of water-management of irrigation. First we discussed the physical features. We described the characteristics of the climate and area features on the scale of India and Karnataka. We found that the climate around Dharwad-Hubli could be classified as semi-arid tropics. The crucial characteristics of the semi-arid tropics were, from an agricultural point of view, aridity for the major part of the year and an annual potential evapotranspiration which exceeded the annual precipitation. This was mainly due to the geographical location of Dharwad-Hubli in the Northern Maidan, which is characterised by its general lower altitude and rain-shadow location in relation to the Western Ghats. The Western Ghats exert considerable influence as a climatic barrier. This has also its influence on the monsoons. The South-West monsoon from June to September feeds normally the Rainy season crops and the Winter season crops are fed by the North-East monsoon from October to November, but rainfall is more rare during this monsoon. The largest part of the precipitation water from the monsoons will run-off the surface which along the watersheds of the main rivers. The plateau characteristics are mainly responsible for the drainage pattern of this precipitation. Dharwad district, and the twin city of Dharwad-Hubli is situated in between the northern and southern catchment tributaries of the river Krishna. Because of this location, the twin-city can not easily make use of the river basins for irrigation.

But a part of the precipitation from the monsoons will enter the soil. More than half of this amount is absorbed in the top layers and the remaining water percolates down into porous strata and represents the enrichment of groundwater. The amount of groundwater depends mainly on rainfall and geological factors. The characteristics of this resource are that it is dynamic and rechargeable, but in the arid and semi-arid tropical regions, the groundwater potential is extremely poor. Some of the aquifers are extremely saline and unsuitable for irrigation.

Irrigation by farmers became more important in the context of the Green Revolution. The means where the farmers became more depended on for a radical productivity growth were part of the Green Revolution ‘package’ which enclosed High Yielding Varieties (HYVs), chemical fertilizers, pesticides and irrigation. But these parts are interrelated, because these HYVs or crops in general, are characterised by high response to fertilizer inputs but are conditional upon adequate water and water-management.

But water for irrigation was scarce during a long drought in the area of Dharwad-Hubli. Because of the combination of insufficient water supply from the monsoons, the water use and evapotranspiration were most of the other water resources for irrigation dried up. But the deep groundwater aquifers did not suffer from water losses due to evapotranspiration. We found that groundwater became the most important water-resource for irrigation around Dharwad-Hubli. The result was that the farmer households became more dependent on bore-wells as irrigation facility, to get the water from these deep aquifers. These bore-wells are mostly private resources. And the landowners, who invested in the construction of bore-wells in their own land, make their own decisions

about the amount of water use. The role of social and governmental institutions is almost negligible for the water-management in bore-well irrigation.
The private investments in bore-wells could be more easily done by large landowners, because of their higher land property which can be seen as capital. Large landowners are more creditworthy for the bankloans for investments. This appeared also from the fact that the large landowner had on average the highest amount of bore-wells per household. And they also used the most of the water for irrigation. And because of their bigger scale of irrigation they could cultivate a more diverse cropping pattern than the other landowner categories, which were more specialised on water use efficient crops during the drought. Because of their higher yields with irrigation and their higher amount of irrigated ha, are the large landowners in a better position to make new investments in the long run. As result of this, there will be a growing socio-economic disparity between the irrigating farmers in the urban fringe of Dharwad-Hubli. To make the necessary investments in these irrigation facilities, all landowner categories used different strategies. One of the strategies is diversification of household members in non-agricultural jobs. The twin city of Dharwad-Hubli gives many alternative employment opportunities for diversification of agrarian households. The wages from these jobs can also be used for new investments.
But investments in new bore-wells will be a threat for the sustainable development of the irrigating agrarian system in the urban-fringe of Dharwad-Hubli. Because of the insufficient water supply from the monsoons during the long drought, decreased many bore-well yields and the groundwater level fell. This was mainly due to the high water use for irrigation, and these effects will not be corrected in the near future. The result was that new investments were made in deeper bore-wells and more powerful pumpsets. But this will give a sustainable problem in the long run. These new bore-wells enlarge the bore-well density in particular regions. And the result of this will be that more bore-wells will fall dry and a depletion of the water-resource.

Water-Management of Irrigation

1. Water-Management of Irrigation

1.1 Introduction

There is plenty of water on earth. Almost seventy percent of the globe is covered with water. Water is an important element for live on earth and has been for centuries regarded as an inexhaustible gift. This profusion has often led to complacency in the management of this invaluable resource (Kassas, 1980).

There is a remarkable paradox in this profusion of inexhaustible gift. Because estimates show that less than one percent of all the water on earth, is available as sweat water. The rest is salt-water, frozen water in the icecaps and glaciers or ground-water which is unreachable for us (Barlow & Clarke, 2002). The almost one percent of the earth's total available water should be enough for all the people. This looks strange but this small fraction seems to be continuously renewed through the hydrological cycle (Kassas, 1980).

In the hydrological cycle of water, rainwater falls from the clouds on the land, nourishes life, returns through rivers to the salty sea and evaporates as fresh water back into the clouds. Except for a few sources, like fossilized groundwater, water is infinitely renewable, but there are two big obstacles stand in the way of delivery water to the people. Water is not equally distributed geographically. Some places in the world, such as Canada and Ireland, have more water than they can possibly use; others, like northern China, and the Middle East have too little. And in many parts of the world, such as India and Bangladesh, rainfall is highly seasonal: almost all the year's supply may arrive within a few months (The economist, 2003).

The second, bigger difficulty with water is neither physical nor geographical, but man's extravagantly wasteful misuse of it. According to the Economist (2003), this cause is largely derived from a wilful refusal to treat water as an economic good, as a subject to the laws of supply and demand. Unlike most other natural resources, water does not have a substitute in its main use. It can be used more or less efficiently but it cannot be replaced. Because of its renewable characteristic and indispensability for human beings, water is believed to be the most precious of all gifts. But especially over the past century, it has been ill governed and above all, colossal under-priced and often given away for free. But this does ignore the huge costs of collecting, cleaning, storing and sometimes distributing and also the treating of waste-water and sewage (The economist, 2003).

The domestic consumers are hardly to blame for water shortages, because around 50% of the water in piped systems is lost through leakage. In the Western countries the industry and energy uses a large amount of water. But more important, wherever in the world water is scarcest, irrigation for agriculture takes up at least 75% and sometimes as much as 90% of the available water. This is most of the time the case in developing countries (The economist, 2003).

On the other hand the irrigated agriculture is the most effective manner to increase the production of crops, which is important to feed the populations. According to Abu-Zeid (1980) improvements in irrigation can result in a higher living-standard in developing countries. But in a lot of developing countries, where irrigation projects originally had the intention to increase and improve the food-production radically, and benefit all classes of farmers, failed to match these purposes because of a low production in contrast to its potential (Abu-Zeid, 1980).

Irrigation water is notwithstanding the main issue of this research. Irrigation disasters are of all times, but because of modern engineering there are irrigation disasters on a massive scale. The dams, canals, tunnels and pipes that are needed to supply the irrigation water can be the biggest and most costly infrastructure projects. The Indian subcontinent has plenty of water, but it is often at the wrong place or at the wrong time (The Economist, 2003). This maldistribution of water in major irrigation projects is believed to have affected adversely the environment, biological and social (Venkata Reddy, 1990). It appears that India had some bad experiences with the organisation of water. Sumita Dasgupta, of the Centre for Science and Environment in Delhi, said that the problem of India is not water scarcity, but the lack of good water-management (The economist, 2003).

Water-management in agriculture is the process whereby water will be manipulated and used for the production of food and fibres and include all the water that is used for that purpose, both rain and irrigation (Abu-Zeid, 1980). Water-management plays an important role in future perspectives, because good water-management can bring in a better allocation of irrigation water and the production can be much higher.

As we know, surface water (precipitation from the moment it falls on land surface until the moment it returns to the ocean or sea) and ground water provide most of man's water resources. According to Kassas (1980), these water supplies can be increased by improved management and the use of technological innovations. Resources from ground water can be increased; techniques of watershed management and harvesting of precipitation can increase the surface water resources and non-conventional sources (cloud seeding, desalination, re-use, etc.) can become important (Kassas, 1980).

Some processes, such as the movement of water over and through the soil, are reasonably well understood, but others such as the effect of water on soil loss and on nutrient availability, or how commodity prices might affect conservation practices, are less well known. Such factors as land tenure, food-pricing policies, availability of inputs, as well as social and cultural constraints, affect the practices for water-management a farmer will employ at any particular time (National Research Council (NRC), 1991).

1.2 Theory

A prediction for India supposes that within ten years India will have 250 million more residents. According to the Food and Agriculture Organisation of the United Nations (FAO), the agricultural production has to grow with fifty percent to feed the growing world population (Barlow & Clarke, 2002). Also during the 1960s, scientists and development organisations tried to increase the cereal-grain yields dramatically to feed the population. This was the basis of the Green Revolution. They implemented the Green Revolution 'package' which enclosed High Yielding Varieties (HYVs), chemical fertilizers and pesticides. These HYV, are characterised by high response to external inputs such as fertiliser, but are conditional upon adequate water and water management regimes. Irrigation development and the HYVs have spearheaded agricultural intensification strategies of the Green Revolution (van de Laar, 1993).

Irrigation and its management is an essential part of the Green Revolution 'package'. The idea is that irrigated agriculture is an effective manner to increase the production of crops. As we mentioned before water is a renewable resource. But the water use in agriculture increased in many developing countries since the Green Revolution, because the genetically improved or high yielding varieties (HYVs) required more water. To come up to these expectations, improved irrigation techniques are developed. These diverse techniques will be used by farmers in different ways and applied for alternative resources. But a condition for the use of irrigation in the long run, is that natural resources should be managed in a way that the process of exhausting is more slowly than substitution of renewable resources.

In this research I will try to find out how water-management is arranged socio-economically in the urban fringe of Dharwad-Hubli and how some aspects can be improved in a more sustainable way. The research questions on the basis of this research are in general how access to irrigation is arranged socio-economically and the distribution of the water use. For this reason we also have to define and describe the concept of water-management and the reason for water-management in the irrigation process. In this context it is important to know how water-management of irrigation is arranged socio-economically and what the role is of the farmer household. On the hand of the farmer household perceptions and strategies we try to find out the context of the decision making processes. And I like to know, in case of unequal distribution and environmental degradation of water-resources, what the consequences are and how water-management can be improved in the theoretical concept of sustainable development in agriculture.

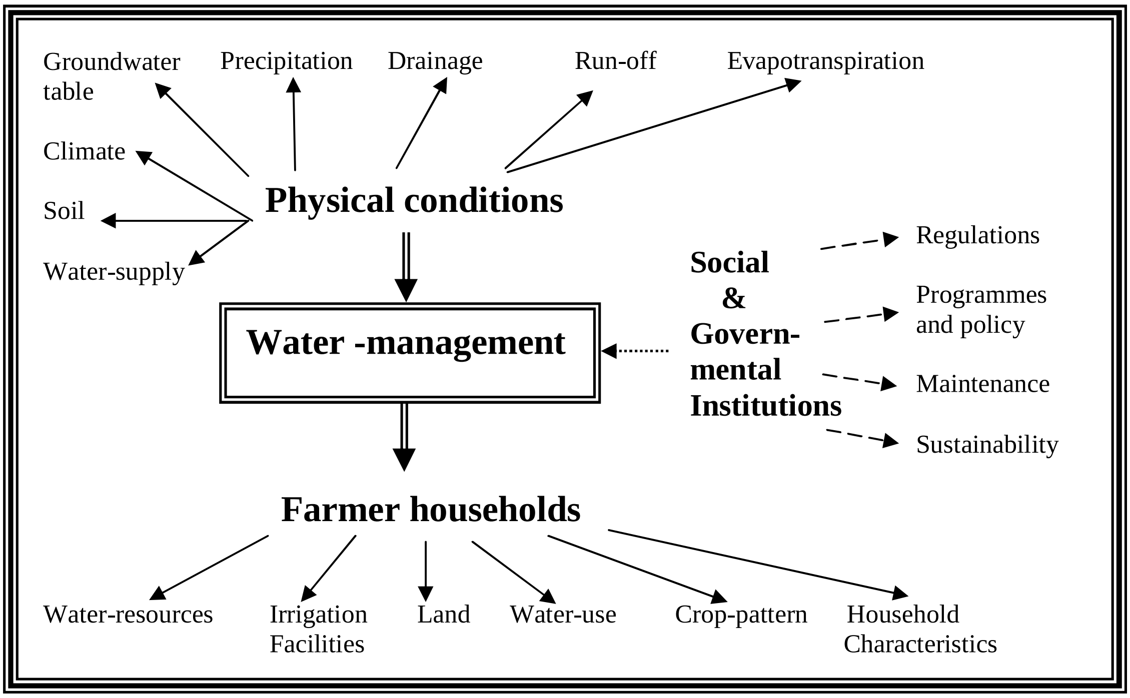
Water-Management

In this context we have to discuss the concept of water-management of irrigation. The management of irrigation encompasses many operations. There are many definitions for Irrigation water management. In the introduction we defined water-management in agriculture in a broad sense as the process whereby water will be manipulated and used for the production of food and fibres as described by Abu-Zeid (1980). It is focused on the use of the whole on water-resources, irrigation-facilities, drainage, silt-management, regulation, farmers, institutions, procedures, soil and cropping-systems to get water for the growth of crops, and include all the water that is used for that purpose, both rain and irrigation.

A more specific definition for irrigation management is used by Venkata Reddy (1990) which reads as 'the process in which institutions or individuals set objectives for irrigation systems; establish appropriate condition, and identify, mobilise and use resources, so as

to attain these objectives; while ensuring that these activities are performed without causing adverse effects' (Venkata Reddy, 1990, p.47). Within this definition there is also attention for sustainable development if we take into account the adverse effects within the environment. But in this research we will use a definition for the water-management of irrigation. Water-management in irrigation is the process whereby farmers manipulate the water within the context of physical conditions and social and governmental institutions to improve the production for food and fibres. This is definition is shown in figure 1.1.
As we mentioned before, rainfall in India is highly periodically and unpredictable. To arrange the access to water all over the year for crops, water should be manipulated and managed from the water-resources. Water-management is complex system of intervening factors which appears from figure 1.1 which is a broad schematic view of the system wherein a farmer household participates.

Fig 1.1 Schematic approach of Water-management of Irrigation



In this chapter and through the whole research we will discuss some of the factors which play an important role in the context of water-management of irrigation. First we will describe how water-management of irrigation is arranged empirically. Recent research responds to the criticism on the Green Revolution. The idea is that the Green Revolution depends on irrigation, fertilizers and pesticides that poor farmers cannot afford and may be ecologically harmful (Virmani, 1990). In this research we will compare the empirical results with the theoretical normative objectives within the paradigm of sustainable development and try to give sustainable improvements in the water-management of irrigation. In this context we have to know what the objectives are of sustainable development.

Sustainable development
The term sustainable development is the outcome of the field of tension between economic development of the developing countries and the new attention of the western

countries for environment protection after the alarming results of the Club of Rome and the Brundtland report. There is a tension between the decline of resources and environment, and the famine and extreme poverty which threatened the existence of millions of people, who need economic development. The main purpose to find a solution for this problem is to find a balance between the main dimensions of sustainable development; the natural or ecological dimension, the economical dimension and the social dimension. Another problem is that there are different fundamental tendencies to distinguish in managing this balance (Dam, 2004). In this report we will use the general theoretical approach of sustainable development whereby the exchange between the dimensions and resources is allowed as long as the whole stays in balance. The idea is that natural resources should be managed in a way that the process of exhausting is more slowly than substitution of renewable resources (Dam, 2004).

As part of the Green Revolution package, irrigated agriculture is an effective manner to increase the production of crops. The vision was that improvements in irrigation are important to create a higher living-standard in developing countries. Many irrigation projects in developing countries had the intention to increase and improve the food-production radically and benefit all classes of farmers. But a lot of these projects failed to match these purposes. In many cases the result was that there existed still a low production in contrast to its potential production (Abu-Zeid, 1980). And in many places in the developing world there is even decline in productivity visible.

Scientists are worried about the decline in productivity of many soil and water systems, especially in the high population growth regions in Asia. To achieve *sustainable* development in agriculture, the agricultural productivity must be enhanced while its resource base is conserved. Soil and water resources provide the resource base on which agriculture is based. But successful agricultural production on household level requires combination of physical features, technological, institutional and societal resources. To enhance the agricultural productivity sustainable means that water and new techniques must be managed to *intensify use of quality lands* while *minimising the environmental degradation* (NRC, 1991).

The nature of sustainability requires a *systems approach* which is interdisciplinary with a broad perspective as well as specific focuses. *Farmer participation* plays a role in recognition of problems and for the practical application. In the theoretical perspective of the system approach there are certain properties distinguished in sustainable agricultural systems. These properties can be labelled productivity, stability, equitability and diversity (NRC, 1991).

Productivity in the research will be described as the yield per hectare of a particular crop type per season or year.

Stability is a measure of the constancy of the productivity. It describes the degree to which productivity remains constant despite small-scale fluctuations in water supply and economic conditions of the farmer households.

Equitability is the term used to express how evenly or fairly water and access to water are distributed among the households on the regional level.

Diversity is a measure of the number of different types of strategies of the households. Diversity allows rural people to spread risks and maintain a minimum level of subsistence even when some activities fail (NRC, 1991).

In this research specific focus or emphasis will be on the needs and decisions of farmer households in specific socio-economic settings and actual farming situations. And the first step toward sustainability is the *matching of crops to the characteristics of the land*

and water environment, but also to the research preferences and the economic and cultural context of the users. The data of this research is partly based on the communication process with the local farmer households on the management of local soil and water resources. Recognition of the problems of farmer households and their involvement in the process would be necessary in realising the objectives of sustainable development.

1.3 Methodology

The research on the water-management of irrigation is based on a fieldwork in the urban fringe of Dharwad-Hubli. The data collection for this research is based on literature, inquiries and interviews. The literature is mainly used for the theories on this case and for the description of the physical features on the different scales, which play also a role in the water-management of irrigation in urban fringe of Dharwad-Hubli. The interviews and inquiries are held during my fieldwork in this area. The research population which was used for this research existed out of irrigating farmers within the borders of the Dharwad-Hubli municipality. It appeared that there were specific areas where many farmers used irrigation for their cultivation. The choice for the specific areas which were used for this research was based on a schematic overview of the two main soil types of the area. To get an equal distribution of the irrigating farmers over these soil types, I choose three villages on the red soil and three villages with typical black soils, and the area in between Dharwad and Hubli. After that did a rondom sample under the irrigating farmers, who were situated on the routes to these villages. These irrigating farmers were questioned about their water-management of irrigation on the hand of the inquiry, which is visible in the appendix. To get an overview of the total agricultural population and irrigated hectares of the village areas of the research population, I interviewed the particular village accountants. And for more specific information on the impact of some irrigation projects, I had an interview with a geologist.

On the basis of this information I tried to analyse how the water-management is arranged socio-economically in the urban-fringe of Dharwad-Hubli. First, I described the physical features and its operational properties on the hand of the literature, which had its influence on the water-management of the farmers households. Secondly I described the influence of the social and governmental institutions in the context of the farmer households, this information is mainly based on the literature and the interviews. To distinguish the socio-economic distribution on the access and use of irrigation water in the research, I divided the research population in landowner categories. And on the base of the information from the inquiries, I tried to find out the access to water-resources and irrigation facilities, and the use of irrigation water over the different cropping seasons. The sum and averages of these individual household inquiries on these subjects are counted per landowner category. And on the hand of these arrangements, the literature and the interviews, I tried to find out what the consequences are of this present water-management on the sustainable development of this irrigating agricultural system in the urban fringe area of Dharwad-Hubli.

2. Area description and watersheds

2.1 India

India is since historic times a well-defined physical geographical unit and embraces a major part of South-Asia. Its natural borders exist of the young-folded Himalayan mountain chain on its North-West to North-East and the Bay of Bengal, Indian Ocean and the Arabian Sea on the East, South and West border. The peninsular India is rimmed by ranges on the sides which are often cut through by streams which give them access through the Great Plains, the area of the Ganga and Brahmaputra basins, in the north to the Bay of Bengal in the east. From the mid to the South of India, the narrow coastal strip in the west with its backwaters and the wider coastal strip in the east are marked features with its sandy and deltaic plains are distinctive landscape features on the respective margins of the so called Peninsular Uplands which presents a landscape of detached hills, wide valleys and series of plateaus (Singh, 1995). In general these southern plateaus are called the Deccan Plateau. The term "Deccan" comes from the Sanskrit word dakshina, which means "the south". The Deccan Plateau encompasses the four states of Andhra Pradesh, Karnataka, Kerala and Tamil Nadu (http://www.kamat.com/kalranga/deccan/index.htm). These general landscape features and natural borders have also its influence on the climate of India. The climate of India shows typical periods of precipitation, which is responsible for the national water supply.

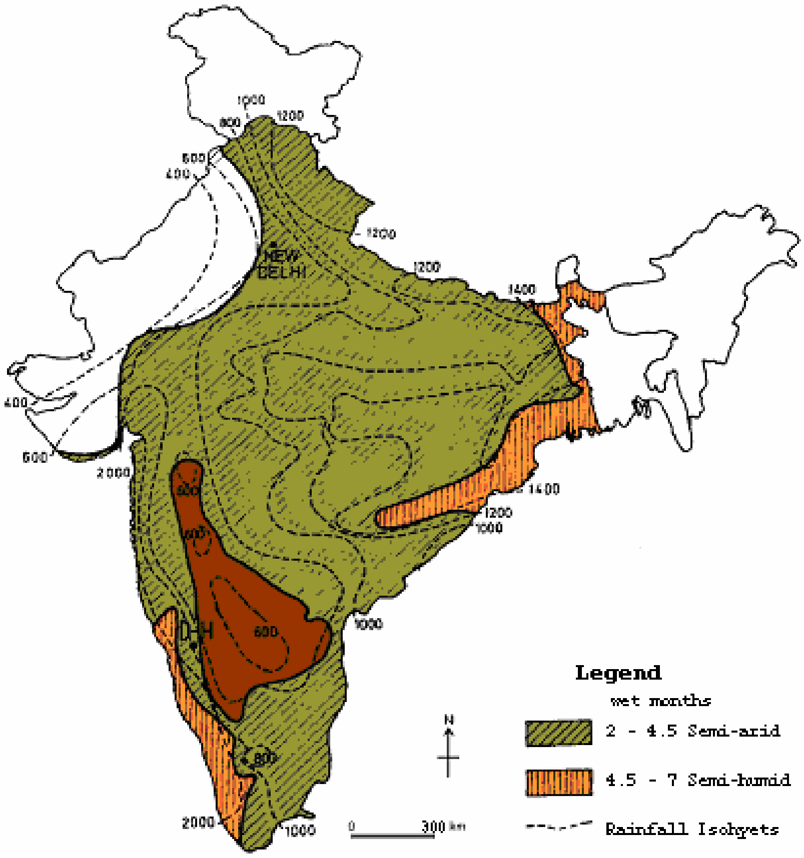
2.2 India Climate

The rainfall in India is highly seasonal. This seasonal rainfall (monsoons) is in general influenced by the Himalaya as meteorological barrier in the north and the marine influences. A considerable portion of the country belongs to the sub-tropical zone and shares the characteristics of a tropical monsoon climate (Singh, 1995). This monsoonal climate is characterised by the rhythm of the two main seasons, the summer and the winter season and their associated monsoonal regimes. The winter season is characterised by its lower temperature, its low humidity and scanty rainfall. The following dry summer is marked in general sharp rise in temperature and consequent decrease in relative humidity. The transition between the winter and summer season is essential as it sets the stage for the outburst of the summer monsoon. This outburst curbs the upward tendency of the temperature from the half of June. The wet summer or the Rainy season is characterised by high humidity and a fairly high temperature, which create sultry conditions. The summer season monsoons are controlled by the seasonal alternating low and high pressure conditions over the land and the sea. This instable weather condition prevails throughout the country till the seasonal low is replaced in the North-West by the end of May. The temperature occasionally fluctuates due to the pre-monsoon thunder-showers associated with the convectional movement in the form of storms (Singh, 1995).
A short transition span is also experienced between the change-over from the summer monsoon to the winter monsoon during October-November. The winter monsoon lasts from mid-October to February, associated with decrease in temperature and relative humidity. This period is responsible for a small amount of rain in the country.

The classification of sub-tropical zone is mainly based on the air temperature and precipitation. But temperature presents seldom an impediment to the agricultural economy. Crops require heat, and can be grown throughout the year if water is no

constraint. Disability of the agriculture is caused by moisture and precipitation. The availability of moisture is not only dependent on the amount of precipitation but also on the evapotranspiration. To indicate moisture availability, classification systems defined humidity or aridity. Based on these classifications, a considerable portion of India is classified as semi-arid tropics (Huibers, 1985).
The crucial characteristics of the semi-arid tropics are from an agricultural point of view, aridity for the major part of the year and the annual potential evapotranspiration which exceeds annual precipitation. With these characteristics it is assumed that the level of rainfall is only just sufficient for growing good crops. The technique for classifying the climatic areas, based on these characteristics, is described by Toll (1965). The climatic approach is based on the duration of the humid season. A month is defined as humid if the mean precipitation exceeds the mean potential evaporation. Figure 2.1 shows the outcome of this ratio. Using Troll's classification, the research is limited to the semi-arid areas experiencing 2 to 4.5 humid months, which is the case around Dharwad-Hubli (see figure 2.1). The areas with 4½ to 7 humid months can be classified as semi-humid (Huibers, 1985). These relative short humid periods makes the semi-arid tropics in India a special case in agricultural research and water management. These areas have specifically agricultural potentials and problems.

Fig. 2.1 Semi-arid tropical areas in India (striped areas), according to Troll's classification



Source: Huibers (1985), Rainfed Agriculture in a Semi-Arid Tropical Climate.

2.3 India water

As we have seen the climate characteristics influence the amount of water in India. Now it is interesting to know the potential amount of the water resources available. This water potential is one of the resource bases on which agriculture is based. India is endowed with abundant land and water resources. The average annual precipitation is about 1250 mm over the Indian land surface of 328 million hectares. The ratio which is mostly used for the national water potential is the million-hectare-meter (MHM). For India the average annual water potential from precipitation will be about 400 MHM.

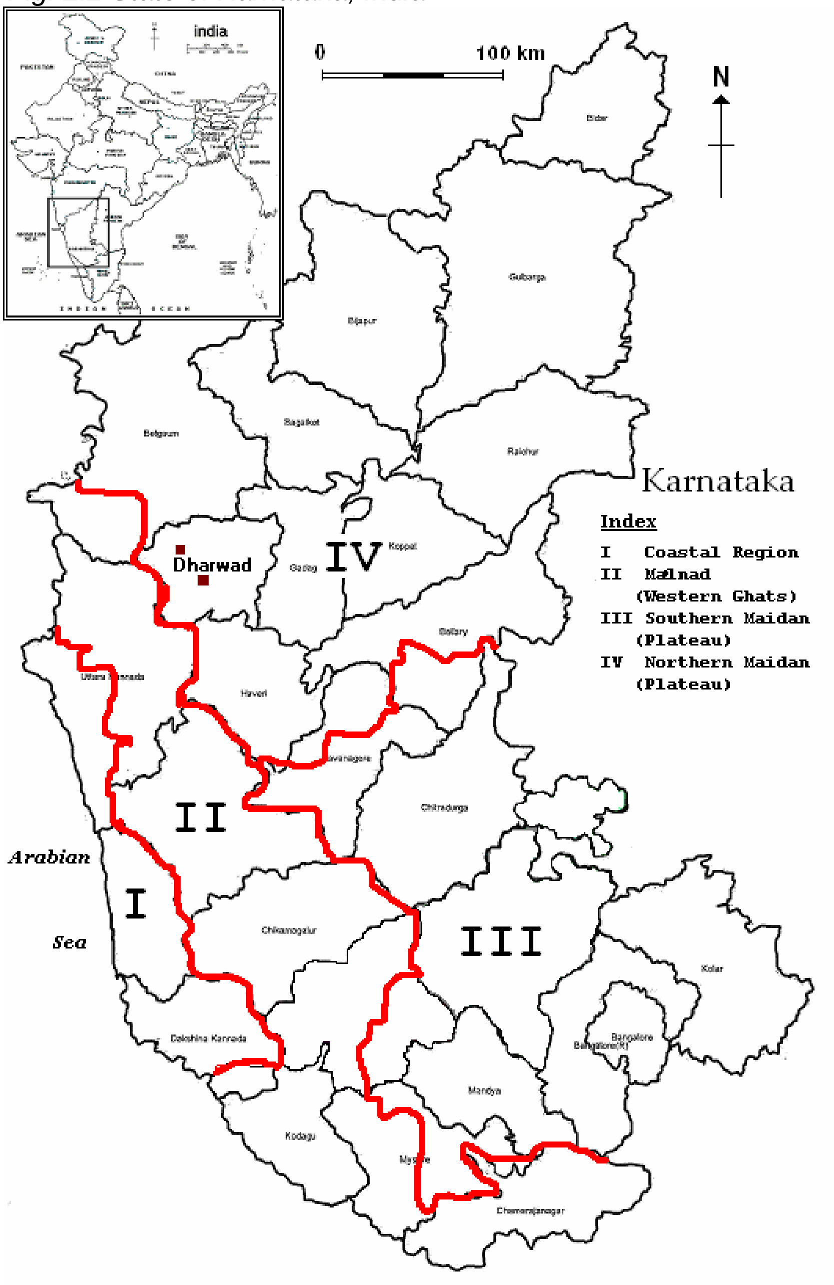
A part of this precipitation is running of the land surface as rivers to the seas. The annual water resource in the various river basins of the country is estimated at 187 MHM. In addition to this surface water resource, there is a dynamic rechargeable groundwater resource. This groundwater resource potential has been estimated as 43 MHM. This means that the total Indian water availability is about 230 MHM (Sivanappan, 2000).

To make visible what this amount means, we have to divide this amount over the population. The per capita availability of water is about 2300 m^3/year. But the Indian population is growing and when it reaches the level of 1.6 billion in 2050 according to U.N. agencies, the per capita water availability will be about 1400 m^3/year. This means, by the indicator of water scarcity accepted by the World Bank and other agencies, that the country will be water stressed (1700 m^3/year) but not water scarce (1000 m^3/year) in 2050 (Sivanappan, 2000).

2.4 Karnataka

The area of research is situated in the Indian state Karnataka. The geographical description of Karnataka will be discussed on the hand of four sub-regions with its typical landscape features. Every region has its significant landscape features and associated climatically characteristics on a lower scale. The State of Karnataka can be divided geographically in a coastal region, the Malnad or transition zone, the Southern Maidan (plateau) and Northern Maidan (fig. 2.2) (Deshpande, 1992).. The case study is situated in the twin-city Dharwad-Hubli. Dharwad-Hubli is situated in Dharwad District to the eastern border of the Malnad, in the Northern Maidan (fig. 2.2).

Fig. 2.2 State of Karnataka, India



Source: India, A regional interpretation, Deshpande, 1992

In the Malnad or Transitional Zone changes the elevation progressively into the Western Ghats. The Western Ghats is a mountain range from north to south along the cost in Karnataka and are featured by step-like scarps of the western edge. The topographic border of this Malnad, which is the heavy rainfall region of Karnataka, is based on the border with the Dharwar rock complex in the east where the precipitation appreciably declines eastwards. This Dharwar rock complex exist out of valley's which open out gently with progressive widening to the east (Deshpande, 1992).

The Dharwar rock complex is topographically situated in the Northern Maidan. The landscape presents a geographical transition. The high semi-deciduous forests, with tropical and sub-tropical evergreen strands, pass into teak-pole forests, with an increasing element of shrub, bamboo and grasses. On the border with the Malnad, the agricultural land is restricted to valley strips. Eastwards the region commands more land under agriculture with varied crops: some like sugarcane under irrigation and others like millets, pulses, chillies and cotton (Deshpande, 1992).

The 'Bail Seeme' which is another name for 'The open country' is part of the Northern Maidan and is geologically largely underlain by the archaen schists (Dharwars), with an overlay of rocks and later series. This North Karnataka plateau is a vast expanse of the peneplain surface drained by the Krishna River and its tributaries (Deshpande, 1992).

The Krishna basin in the Northern Maidan is covered with black soil; it has a low-level relief and a high concentration of arable lands (Sharma, 1999). These black soil plains exists of the typical lava recur with its features of friability, retentively and natural capacity to regain fertility (Deshpande, 1992). The moisture retentive black soils and a predominantly rural population with a medium density, provides that this region is a more favourable environment for agriculture compared to any other region in the state. Its low rainfall and poor irrigation development do not hinder the cultivation of at least the Rainy-season crops and the rugged relief poses only a serious hurdle in a few districts (Sharma, 1999).

About 80-90 percent of the reporting area is arable in large parts of the Northern Maidan including Dharwad District. Almost the entire region, except a few taluks, has an above state-average proportion of *net sown area**. An above state-average proportion is net sown in the Dharwad-Gadag plateau, under which the Hubli region and some other regions, and the Varada basin of the Dharwad district (Sharma, 1999).

2.5 Climate of Karnataka

The Karnataka region with its typical north-south position of major relief features responds differently to the monsoon currents and thus exhibits sub-regional climatic variations within the tropical monsoon zone. The Western Ghats exert considerable influence as a climatic barrier. It divides in the spatial distribution of climatic attributes, the temperature, rainfall and relative humidity etc. In clear accordance with the altitude the Malnad is the rainiest, (over 2,000 mm) while the North Maidan with its general lower altitude and rain-shadow location is the driest (below 700 mm). As we have mentioned, these dry circumstances in the Northern Maidan are categorized as semi-arid tropics. Due to this semi-arid climate of the North Maidan there is in general a savannah type of biotic cover (Deshpande, 1992). Even the South Maidan with a relatively higher altitude has a more equable climate with a moderate rainfall of 900 mm (Singh, 1995).

The North Maidan is situated in the rainfall shadow area of Western Ghats in Northern Karnataka and this has its influence on the monsoons.

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* *net sown area = landuse area – forest land – land not available for cultivation – other uncultivated land excluding current fallows – fallow lands* (Sharma, 1999).

The South-West monsoon from June to September feeds the Rainy season crops and the Winter season (from October to the half of February) crops are fed by the North-East monsoon from October to November. But in general the rainfall is rare and erratic (Venkata Reddy, 1990). The temperature generally starts rising from February and continues till May. Regionally it remains high in the North Maidan and the average May temperature varies around 30 °C in Dharwad.

Only occasionally the pre-monsoon showers (popular called the mango showers) lower the temperatures to some extent. With the outburst of the monsoon in June the temperature falls by about 4°C in the North and continues to fall till September gradually.

A relatively abrupt decline starts from November and continues till January, which is generally the coldest month (Singh, 1995).

2.6 Karnataka watersheds

The watersheds form the catchment areas of the precipitation during the monsoons. The plateau characteristics are mainly responsible for the drainage of this precipitation. As we mentioned, the Deccan Plateau covers a large part of Karnataka. To discuss the main watersheds of Karnataka the parts of this Deccan plateau in Karnataka are divided in the Northern, Southern and Central Karnataka Plateau. The Western Ghats form the main watershed in the Region between the Bay of Bengal and the Arabian Sea rivers. The structure and control is quite obvious in the evolution of different drainage systems and patterns.

As we discussed with the climate of Karnataka, the state receives rainfall from both the south-west and the north-east monsoons, though the rainfall from the former is much more than that of the latter. The Western Ghats form the barrier on this south-west monsoon. The rainfall decreases towards the east and is the highest along the coast and lowest in the north-east (Agarwal & Narain, 1997). Along the coast the rivers are flowing east-west to the Arabian Sea. But in the main share of the Deccan Plateau, the water will be drained by the west-east Rivers. The east-flowing rivers with 87 percent of the state's geographical area possess only 42 percent of the total yield, while the west-flowing rivers with only 13 percent of the state's drainage basin carry 58 percent (Sharma, 1999).

In general, the main west-east river systems of Karnataka can be distinguished as the Godhavari basin, the Krishna and the Cauvery basin. These river systems have its own secondary watersheds which divide the tributary streams (Singh, 1995).

The Northern Karnataka Plateau includes the present-day districts of Gulbarga, Bidar, Belgaum and Bijapur and has an elevation of 300-600 m. The Bidar district in the north-east of Karnataka confines mainly the less extensive catchment of the Ghodavari basin. The other districts of the Northern Karnataka Plateau define the northern catchment tributaries of the Krishna. The river plains of the Krishna and its tributaries flow across the eastward-tilting plateau before reaching the Bay of Bengal. These rivers break the northern treeless monotony area, where black cotton soil predominates.

The Southern Karnataka Plateau includes the districts of Bangalore, Tumkur, Kolar, Mysore, Hassan and Kodagu. It covers the Cauvery basin and has an elevation of 600-900 m (Agarwal & Narain, 1997). The Cauvery, though irregular in profile, has been the mainstream of the regional culture. It furnishes one of the best and oldest power and irrigational facilities in the southern region and a Power Station (Singh, 1995).

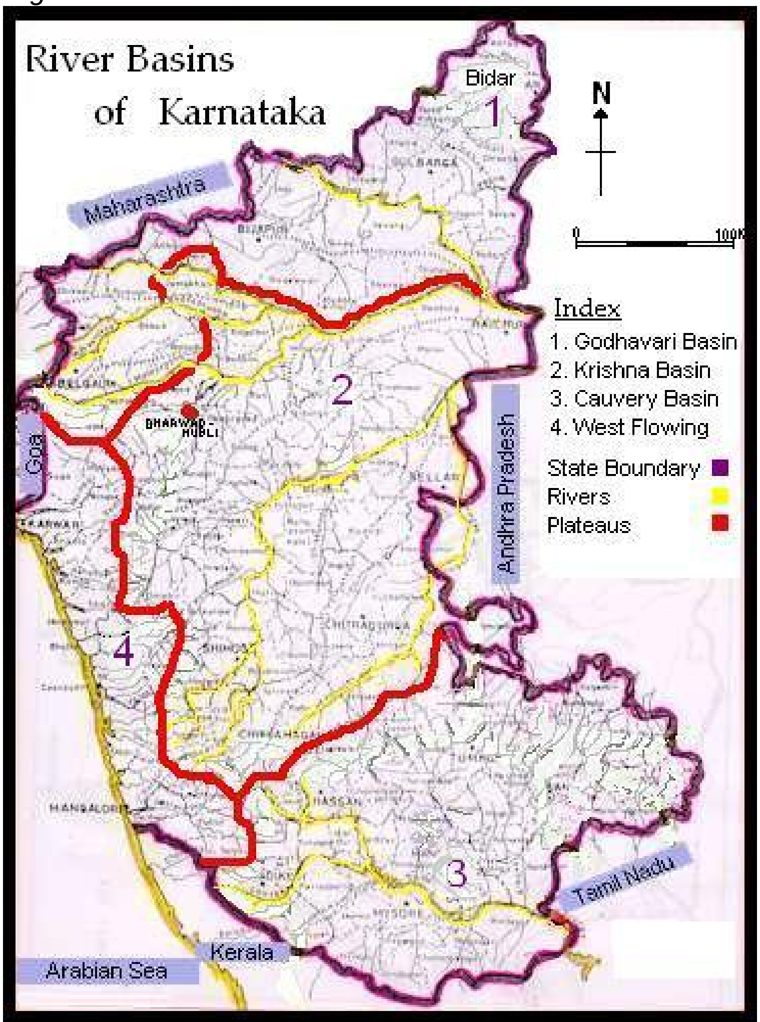
The Central Karnataka Plateau covers the districts of Bellary, Dharwad, Raichur, Shimoga, Chitradurga and Chikmagalur. The region marks the transition between the Northern Plateau and the relatively higher Southern Plateau. These districts define in general the southern catchment tributaries of the Krishna (see fig. 2.3). Dharwad district is situated in between the northern and southern catchment tributaries of the Krishna.

An important tributary of the Krishna for Dharwad-Hubli is the Malaprabha, which is the resource for the consumption water.

The Tungabhadra is the main tributary on the south of Dharwad-Hubli it receives water in its upper reaches from the Tunga and the Bhadra. Both rise from the Western Ghats very near to each other, but take different directions till they unite. The Tunga plays an important role as a location factor in the origin of towns and chains of religious centres. It is believed in South India that the Tunga water is perhaps the sweetest of al the river waters (Singh, 1995). The Bhadra is dammed in its upper reaches also for irrigational purposes while the combined river Tungabhadra is harnessed both for hydro-electricity and irrigational purposes in its lower reaches (Singh, 1995).

According to sharma (1999), there need to be made a correction in the imbalance of west and east flowing rivers in Karnataka. The west flowing rivers should be utilised for the development of the drought-prone eastern regions, where nearly 84 percent of the state's cropped area lies and more than three-fourths of its people live. Karnataka's water resources for irrigation and some other uses can be significantly increased, if the enormous volume now flowing as waste through the west-flowing rivers is diverted to the east-flowing rivers (Sharma, 1999).

Fig. 2.2 River Basins of Karnataka



(http://waterresources.kar.nic.in/river_systems.htm, 23rd February 2005)

2.6.1 Karnataka's water resources

Though Karnataka's water resources are not vast, these are most of the times adequate to provide protective irrigation. There is also substantial scope to significantly augment the temporary amount with suitable changes in the development strategy and irrigation techniques (Sharma, 1999).

Most of the water resources for irrigation are in the state's two major river basins, the Krishna and the Cauvery and the basin of the Godhavari contributes only a small proportion (Sharma, 1999).

The ultimate potential for irrigation in the state is considered adequate for 5.5 million hectares. (This includes the 3.5 million hectares from major and medium irrigation projects and one million hectares each for minor surface schemes and groundwater.) The state hopes to develop this potential fully by 2010 AD, when it will cover up to 50 percent of the cropped area. This will be around 11 million hectares. These estimates are based on the prevailing average irrigation requirement of about 0.8 hectare-meter per hectare. This 0.8 hectare-metre per hectare includes the significant losses in the case of surface irrigation, and excessive use in farms, which are likely to decrease in the future (Sharma, 1999).

2.6.2 Groundwater as resource

Groundwater is a significant water resource for irrigation around Dharwad-Hubli, which is located between the tributaries of the Krishna. Because of this location, the twin-city can not easily make use of the river basins for irrigation. It depends mainly on groundwater resources, which exists out of storage basins due to aquifers or inert underground drainage systems, within the Krishna basin.

The amount of groundwater depends on rainfall and geological factors. In the arid and semi-arid tropical regions, the groundwater potential is extremely poor. Some of the aquifers are extremely saline and unsuitable for irrigation. Over India we see that of the 80 million hectare metre (MHM) that seeps down the soil, more than 50 percent is absorbed into top layers. The remaining water percolates down into porous strata and represents the enrichment of groundwater (Lenka,1991).

A suitable groundwater aquifer may be visualised as a giant sponge that is buried underground, and does not suffer from water losses due to evapotranspiration as do reservoirs behind dams and conveyance losses in water transport to fields and root zones of crops. Where groundwater is available, accessible and of acceptable quality (non-saline), groundwater resources can in principle be combined to augment water resources available for agricultural production (van de Laar, 1993).

The groundwater recharge in the state Karnataka is estimated at 18.5 billion m^3 and is an utilisable resource at 9 billion m^3. As we see only about 50 percent of this potential is utilisable economically (Sharma, 1999).

Management of this natural resource should bear in mind the nature of this water which depends on renewability, soil and the stratigraphic position of water-bearing strata (Kassas, 1980). Environmental aspects of utilisation of groundwater resources relate to: contamination by salt water intrusions, pollution by domestic and industrial effluent, salinisation of land irrigated with ground water, depletion of non-renewable groundwater resources, etc. (Kassas, 1980).

Another important aspect of development and exploitation of groundwater resources is that aquifer formations often transcend political and farm land boundaries. They represent a form of shared resources. Management may need to be a regional level, or some regional machinery for coördination may need to be established (Kassas, 1980).

But according to sharma (1999), a conjunctive use of surface and groundwater would be essential for a judicious and balanced use of the irrigation resources. Well irrigation has been found to be more efficient and productive than any other source of irrigation. It has in fact played a key role in the ‘green revolution’ in several parts of India (Sharma, 1999).

3. Irrigation

3.1 History of irrigation

Because of the seasonal water supply in the semi-arid tropics, the residents had to find out systems to store water for a longer period. The long tradition of water harvesting in India reflects the reverence the people always had for water. Water was worshipped, saved and stored for use but never exploited. Karnataka had been a forerunner in managing water harvesting structures. There were numerous such structures, which varied in size from 36 km², the area occupied by the largest tank, to very small reservoirs. The basic purpose was to establish a chain of water storage structures (Agarwal & Narain, 1997)

Traditional water harnessing for irrigation in Karnataka used a number of systems: water was supplied directly from river channels; from tanks supplied by river channels; from a series of tanks situated in valleys of rivers or streams; and, by wells and springs. At the turn of the century, channel irrigation was restricted largely to the south of the erstwhile Mysore state (Agarwal & Narain, 1997).

Tanks formed till recently, an extremely important irrigation resource in the State. Most of them are believed to be made by the Vijayanagar or Anegudi Kings (1335-1570 AD), who were famous for their waterworks (Agarwal & Narain, 1997). Rulers, chieftains, rich merchants or religious men built most of the large tanks, as charity works in the distant past (Sharma, 1999). Temples also undertook work on water harvesting structures. In cases where farmers possessed lands close to the water supply, they provided the necessary labour for deepening the riverbeds or removing the silt (Agarwal & Narain, 1997).

Tanks were also the predominant traditional method of irrigation in the Central Karnataka Plateau, and were fed either by channels branching off from dykes or bunds built across streams in the valleys. The outflow of one tank supplied the next all the way down the course of the stream; the tanks were built in series, usually situated a few kilometres apart (Agarwal & Narain, 1997). Surplus water flowing from a tank fed the one below and the latter a third one down the valley in succession. Tanks in the upper course are much smaller and intended often only as a check dam to prevent soil erosion in the catchments above them and inflow of silt into the tanks below (Sharma, 1999).

Under the British, village authorities were responsible for the upkeep of these tanks. If not properly maintained, the repair work was carried out by *amildars*, and the cost recovered from the defaulters. But the reservoirs would gradually see a decrease in their storage capacity due to deposits of silt. However, by the 1880s, this management practice had ceased. In the latter half of the last century, the British carried out bigger repairs and left the repairs of catch water drains and water channels to the people. The distribution in the 19th century of water was managed by the community and the leading members of the villages, settled by the officers of the British irrigation department. As their water usually did not last throughout the year, the cultivators depended on wells sunk below the dam or on the rainstorms of March and April (Agarwal & Narain, 1997).

Dharwad was well supplied with water, but in the plains the rivers also tended to run dry, and the people had to depend on pond-water or dig holes in riverbeds. Most reservoirs and ponds in Dharwad were old and found largely in southwest Dharwad, where there was an abundance of suitable sites. The use of tanks decreased in the end of the twentieth century, as result of the decreasing storage capacities and its high maintaining costs. And the Green Revolution has stimulated the individual economic decision making processes and its new irrigation technology enabled farmers to irrigate more independently from the community managed tanks. In spite of a decline in the number of tanks in recent years, Karnataka still has about 36,000 tanks.

3.2 Irrigation in Karnataka

The need for irrigation is more acute in Karnataka than in most other parts of India. Over two-thirds of the state's cropped area receives an annual rainfall, which is too low (below 75 cm), which is seasonally concentrated and highly uncertain. Even during the Rainy-season is irrigation needed, to protect crops from dry spells. And over most of the state, a summer crop is almost impossible without irrigation (Sharma, 1999).

The interior plateau's of the state experiences 25 percent or more loss in crop production during droughts every fourth or fifth year. Only 13 percent of the net sown area in Karnataka is cropped more than once during the year, compared to 27 percent in the country as a whole. And only 21 percent of the cropped area is covered with irrigation in Karnataka, compared to 31 percent in India as a whole (Sharma, 1999). Karnataka's farmers have not benefited from the high yielding variety (HYV) technology to a significant extent. This is mainly due to the non-availability of adequate and timely supply of moisture, upon which the new HYV technology so critically depends. The area shifts on state level, from crops like jowar, ragi, and bajra to the HYV crops rice, sugarcane, maize, and hybrid cotton, whose yield returns are 2-3 times higher, are so far negligible. These changes per hectare value of gross cropped area in agriculture in the state, is only evident in small pockets in command areas of major/medium irrigation projects (Sharma, 1999).

Irrigation received an impetus in Karnataka with the advent of planning. Irrigation was accorded a high priority in each plan. A large number of major and medium projects have been undertaken since 1951. In the early nineties gigantic irrigation schemes are realised in the Upper Krishna, Ghataprabha and Malaprahba Rivers which realised an irrigation potential up to 29 percent of the net sown area (Sharma, 1999).

Though impressive in relative terms, the progress was not adequate from the point of view of the state's needs and still huge resources remained undeveloped. At the same time, nearly 60 percent of its water resources remained unexploited. With only about one-fifth of its cropped area covered with irrigation, Karnataka still remains one of the least irrigated states in India. And in spite of all the emphasis on the development of many major/medium irrigation projects, it has suffered from extreme cost escalation. And the water from completed projects has been often used by rich landlords near the main outlets, for raising high duty crops like paddy and sugarcane, because of the low costs (Sharma, 1999).

3.3 Minor Irrigation

In these cost escalated planning projects for irrigation development, minor irrigation is mainly neglected. Minor irrigation in India is defined as any irrigation project which involves a cultural command area of less than two ha (Pant, 1992). Minor irrigation includes small tanks, lift irrigation and groundwater use. Neglect of minor irrigation was a serious gap in the irrigation development strategy of Karnataka. This irrigation development strategy was putted stepwise in successive governmental Plans. Minor irrigation accounted for only 15 percent of the total public investment in irrigation up to the end of the Sixth Plan. And the allocation for minor irrigation, though increased substantially, was of the same proportion for the Seventh Plan (Sharma, 1999). While, according to Sharma (1999), minor irrigation is more cost-effective, can be developed within a short time, has a better spatial spread, involves little misuse and is more efficient. And the per hectare cost of development of minor irrigation, was only about one third of that for major/medium irrigation. The reason for this efficiency and little misuse of minor irrigation is that these small scale projects are mostly developed and controlled by the users themselves. This makes the users more responsible for their resources.

3.3.1 *Development in minor irrigation*

As we have seen in the history of irrigation, tanks were the prime source of irrigation in Karnataka till the 1950s, and tank irrigation is still quite important. Tanks served more than 40 percent of the net irrigated area and were the chief source of irrigation in the state till the 1950s. Shrinkage in tank irrigated area and massive growth in all the other sources, have reduced their share to about 14 percent and much lower than the area irrigated by canals and wells. The decline embraced the entire Malnad region and several districts in the North Maidan. The shrinkage was very sharp in Dharwad district, where tank irrigated area fell during the 1966-90 period by 56 percent. On the contrary, the green revolution period saw a growth in small tanks in several other Northern Maidan districts (Sharma, 1999).

The irrigation potential of tanks has been on a decline in Karnataka now for long; about 68 percent of the total tank capacity was irrigated in 1975-76. This proportion came down to only 50 percent in the state as a whole and to only 30 percent in the North Maidan by 1989-90 (Sharma, 1999). The decline in tank irrigation is also due to the rise of alternative sources. It cannot be denied that canals and bore-wells have become more popular. In most cases it was reduction in the storage capacity of tanks, which has led to the reduction in tank-irrigated area. Silting up of tank beds and continued disrepair of tank bunds, weirs, sluices and channels have reduced many tanks to a lamentable state of decay. According to Karnataka's Planning Department, nearly half of the total number in the state was in need of restoration by 1985, but almost nothing has been done so far. A condition for the control and management of the tanks, it is necessary that it is made purely a community asset (Sharma, 1999).

3.3.2 *Bore-wells*

Next to the reduction of the storage of tanks, the decline in tank irrigation was due to the rise of alternative sources. This appears from the fact that the Green Revolution period since 1966-1967 has seen more than a doubling of the well-irrigated area in the state. The rising trend of was also universal spatially and its extent phenomenal in several districts. The growth of well irrigated area was more than three times in Dharwad district (Sharma, 1999).

An open well is irrigating one to 1.5 hectares of land and there is an existing scope for 0.6-1.0 million wells. Most of the wells in the state at present are open wells with a depth of 12-15 metres. The number of open wells has grown sharply, due to several favourable factors. These favourable factors are the easy availability of loans from the government and financial institutions, subsidies on lift machines, mostly free power supply, and above all an acute urge with the farmer to have his own irrigation sources (Sharma, 1999). This has emerged as a key factor in the success of the modern agriculture technology as result of the Green Revolution. But also the frequent droughts have provided an additional compulsion.

Despite a rapid growth, the proportion of well-irrigated area has also fallen in several districts, due to higher growth in other sources like canals, lift-irrigation and in particular bore-wells. In the drier North Maidan with a poor irrigation development, the other sources are mainly in the form of diversion of river channels with low, temporary earthen bunds. Their contribution is especially important in parts of the Dharwad district, with 16 percent of the net irrigated area. The Ranebennur, Hirekerur and Mundargi taluks of Dharwad district have 10-15 percent of the net irrigated area under lift irrigation. Lift irrigation involves pumping of water of streams and reservoirs. The method is very successful in areas where extensive cropped area remains un-irrigated on high rivers banks up to 20 metres, as for example, in the case of the Krishna river valley (Sharma, 1999).

In particular bore-wells become popular, due to their greater reliability and moderate costs with virtually free power supply. This must have led to the reduction of tank-irrigated area in some cases. Because of the frequent droughts, the exploitation of groundwater has taken a quantum jump with the introduction of the bore-well technology in the recent years. The number of bore-wells is relative small, though it is increasing at a fast rate. Bore-wells tap water from deeper, basement aquifers and irrigate a larger area. These wells with a diameter of 10-20 cm, tap water from aquifers up to 45-100 m, and yield a much larger quantity of water than open-wells. A bore-well can perennially irrigate up to 5 hectares of land, depending on the richness of the tapped aquifers. A schematic view of a well and bore-well is shown in box 2.1.

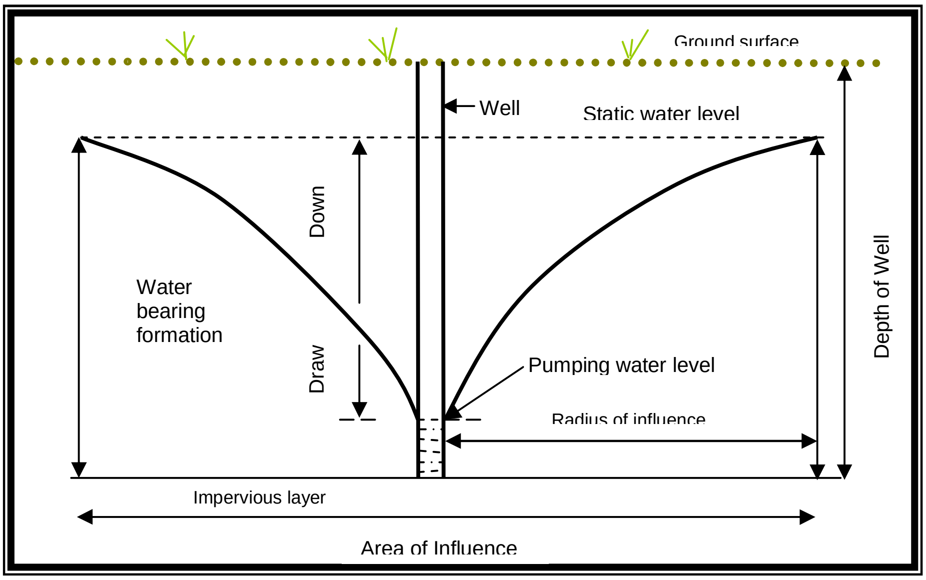
The total number of bore-wells in the entire state has gone up to 60,000 and the area irrigated by bore-wells to 129 thousand hectares. Bore-wells have also emerged as an important irrigation source in Dharwad district. The Byadgi, Ron and Savanur taluks of the Dharwad district have even more than 50 percent of the net irrigated area under bore-wells (Sharma, 1999).

Also around the twin city Dharwad-Hubli in Dharwad district only bore-wells could be used for irrigation, during the period of research. In the next chapter of this research we will pay special attention to the water-management of irrigation with the bore-well as a resource.

Box 2.1 Well and bore-well

A water well is a hydraulic hole down to the water strata, and are designed to supply a large volume of water for agricultural purposes. The efficient utilisation of ground water through wells depends on the design to suit the best characteristics of the water strata, their extent and capacity. The water in the well stands at a height equal to the atmospheric pressure, the so called static water level which is equal to the saturated soil around the well. When the water is drawn *out, the water level drops down. The water around the well starts percolates into to the well from all sides till the pressure differences become zero. The water level in the well before pumping is called static water level and the level after pumping is called pumping level. This pumping level is variable and changes with the rate of pumping and the instant difference between the static water level and the pumping water level is called draw down. The area which gets affected by the pumping of water is called the area of influence. This area of influence is an inverted imaginary cone with the static water level as the base and the pumping level as variable (Lenka, 1991).*

Fig 4.2 Schematic view of a Well



Source: Irrigation and Drainage (Lenka, 1991)

The yield of a well is the volume of water discharged per unit of time from it.

Bore-wells are the same type of wells as appears in the schematic view in figure 4.2, but are 15 to 75 cm diameter narrow wells, dug by special machinery up to the groundwater. There are different methods for boring mechanically like percussion boring, water jet boring and rotary boring. The choice for method is mainly governed by the size and depth of drilling. Percussion boring consist of equipments to break, crush and evacuate the formation materials in the bore hole and has the advantages over rotary boring of collecting more precise data, detection of water bearing zones and water yield at each zone as the drilling proceeds (Lenka, 1991).

3.4 Micro Irrigation

Micro-irrigation will be discussed on the scale of farmland or on the level of special cropping patterns. Micro-irrigation is the latest and most efficient method of water utilisation for crop growth. It has high water use efficiency and can be adopted on a large scale for various crops in India. Micro irrigation is the term used to describe the method of irrigation which is characterised by the following irrigation features:

1. water is applied at low rate
2. water is applied over a long period of time
3. water is applied at frequent intervals

4. water is applied directly into the plant root zone
5. water is applied via a low-pressure delivery system (Patel, 1999)

The advanced methods of micro-irrigation are known as sprinkler and drip (trickle) irrigation. In the case of sprinkler irrigation, water is applied once in the four to seven days. This reduces the moisture stress of the crop area to some extent. The water can be regulated in this Micro irrigation system. This advanced method of irrigation has an efficiency of up to 70 to 75 percent. Though it has even distribution, it consumes more energy and more labour (Patel, 1999).

The recent advanced method of drip or trickle irrigation is the most efficient method of irrigating the crops. Water is applied to the crop area near the root zone on a daily basis and as there is no water/moisture stress, the crop growth is not affected at all. Each plant is given water, based on evapotranspiration requirement. This method has an irrigation efficiency of up to 92 to 95 percent (Patel, 1999).

As we have seen, efficient water use becomes more important because of the increasing water scarcity as result of population growth along with greater industrialisation. Based on this scenario, we can expect that less water will be available for agriculture.

Drip or trickle irrigation in the urban fringe

3.4.1 *Ring method*

The ring method of irrigation is suitable for orchard crops like fruit trees and is generally circular in shape around the base of the trees. The depth of the ring depends on the quantity of irrigation. The thumb rule for the size of the rings is a distance equal to the radius of the crown but many local variations depend on the vertical and horizontal spread of the roots. The advantage of this method is that the whole field does need not to be irrigated (Lenka, 1991). But it is very difficult to show the amount of water utilisation per ha of the ring method irrigation separately. This is also the reason why we do not use this type of irrigation and the orchard characteristics further in the research. But we have to mention that the investments in orchard crops are typical for the urban fringe area, because of its higher expected yields on the nearby markets. These mainly rich farmers use the ring method for irrigation of these crops. Another difficult research point of these crops and its corresponding irrigation method would be the unknown yields. The yields of these crops are most of the time not known by the farmers because of contracting character. Prices are negotiated and the harvesting is done by intermediary merchants. But the main thing we have to know is that the ring method uses the water more economically. With an irrigation up to two third of the ring depth, is this method relative water use efficient.

4. The research Area

4.1 Cultural description

The main cultural aspect in whole India and which plays a significant role on every local scale within the Indian States is the caste system. According to the Indian law, the "discriminating" traditional caste hierarchy may not exist anymore. But the phenomenon caste plays since historical times an important role in the arrangement of the societal resources and expresses itself mainly in the more traditional villages. The phenomenon is hierarchical in structure. In short, most residents in the villages are caste Hindus and

relatively few of the caste Hindus are Brahmins, which is the highest caste in the hierarchical ladder. The majority of the residents belong to communities whose traditional occupation is farming. In the village, one can find many separate caste affiliations (Walker & Ryan, 1990).
Many rungs in the caste hierarchical ladder are occupied by a few service-caste families who are employed as carpenters, smiths, barbers, water-carriers, washer men etc. Measured by political power and wealth, only one or two castes are dominant in the village. But the caste hierarchy is dynamic, as some castes perceive themselves in ascendancy and others in decline. Material expectations loom large in the perceived hierarchy within the upper classes (Walker & Ryan, 1990).
Undeniably, caste strongly influences many aspects of human endeavour, like in who someone marries, where one lives in the village, with whom one eats and in some isolated places, where one fetches the water. These things are all conditioned by caste. Although almost all castes own some land, caste is a good marker of large landownership in the village. But it would be wrong to assign all variation in human behaviour exclusively to caste differences among village residents. Caste plays only a little part in who hires whom, who buys from and sells to whom (Walker & Ryan, 1990).

4.2 Economic description

In this research we will not pay specific attention on the phenomenon of caste within the society. For the arrangement of the societal resources we will discuss the socio-economic distribution, because the caste hierarchy may not be breaking down but it is eroding in all villages. One of the reasons for this eroding is that transactions are increasingly monetarized and more impersonal. Most members of the service-related castes, in the village, are now paid in cash or receive cash in addition to in-kind remuneration. Most members of these castes supplement their traditional occupation with earnings from farming and agricultural labour, and several migrated from the village (Walker & Ryan, 1990).
Another reason is that the stock of the traditional services offered to village residents is decreasing. The village is less autonomous and more interdependent within the broad network of villages and cities (Walker & Ryan, 1990). This interdependence manifests itself by larger farmers who have to attract labour households. Mainly in the urban-fringe area the village labour market has to compete continuously with other working opportunities in the cities.
This given plays also an important role in the villages of the research area. The research area for the fieldwork is situated in the urban-fringe of the twin town Dharwad-Hubli. The twin town Dharwad-Hubli is one of the commercial centres in the north of the Central Deccan plateau of Karnataka and is still a locally important collecting centre of agricultural produce. Hubli, about 20 kilometers south of Dharwad, is a historically evolved commercial centre, which acquired a great importance in the cotton prosperity about 60 years ago. Hubli commends a wide economic network, especially with the rich wheat- and cotton-growing tract of the eastern black soil plain, but also with routes going out to north Kannada towns. Cotton-textile weaver companies, oil mills and engineering units are the new expressions of its sprawling landscape, located in the urban-fringes (Deshpande, 1992). Dharwad, an old fort site, became important when the British made it their district headquarters on account of the hill and dale landscape and its comparatively cooler climate. The town soon became an educational Centre for North Karnataka (Deshpande, 1992).
Hubli is now mainly a centre of trade and commerce, industry and transport and Dharwad on the other hand, is now mainly a centre of administration and higher

education. Dharwad is the district headquarters and contains the Deputy Commissioner's Office and all other district-level offices (Hunshal & Nidagundi, 1998).

The urban progress is still going on and Dharwad is almost merged with Hubli, with industrial factories being located all along the national highway no. 4, in between the two cities (Deshpande, 1992). The towns still retain their identity both in landscape and public sentiment, though for municipal services, like water supply, a corporation is established. And the Hubli-Dharwad Municipal Corporation includes now both the twin cities of Dharwad and Hubli (Hunshal & Nidagundi, 1998).

The urban space between Hubli and Dharwad is the space where the features of a "dual-economy" can be seen very clearly. Enterprises are intensified and diversified in different places, and affect some villages quit differently from others. The differences between rich and poor household investment and survival patterns appear to widen, as the villages become more urban (Hunshal & Nidagundi, 1998).

4.3 Research population

The region between Dharwad and Hubli is only a part of the selected urban-fringe area. But this higher populated fringe-area is characterized by the competition for land between the different economic sectors. The original agricultural sector in these villages has to compete for the land with the growing urbanization of Dharwad as well as Hubli, and with their service and industry sectors. The area along the highway is a strategically settling place for companies for their transport and accessibility.

The research population is not equally spread over the surroundings of Dharwad-Hubli. The research population exists of a random sample of irrigating farmers in the urban-fringe of the Dharwad-Hubli municipality, based on two given. The first given for the selected regions was the supposed higher intensity of irrigating farmers compared to other regions in the urban-fringe. The second reason is based on the schematic overview of getting a research population, spread over the two main soil types of the city area.

The selected areas northwest of Dharwad exist of the more rural village-areas Narendra, Lokur, Kankur and Aminabhavi. The regions north and east of Hubli exist of the high intensively irrigated village-area of Devaragudihall and the less irrigated village-areas of Kusugal, Shiraguppi and Sulla.

The total area of all these villages together amount to 30,255 hectares. Of this total land surface, the selected area "between Dharwad-Hubli" takes the biggest share; by approach 8 thousand hectares, which is 26 % of the total research area, while this area carries more than half the population, around 54 %, of the total population of all the selected areas together. It also has relatively the lowest agricultural population, which include cultivators and agricultural labourers, lower than the average comparing to all the other areas which are above the average of around 15 %. This means probably that many inhabitants of these villages in the category "between Dharwad-Hubli" are employed in other sectors than agriculture. This is typical for the competing transition area of the urban-fringe area.

Fig. 4.1 Research area in the urban-fringe of Dharwad-Hubli

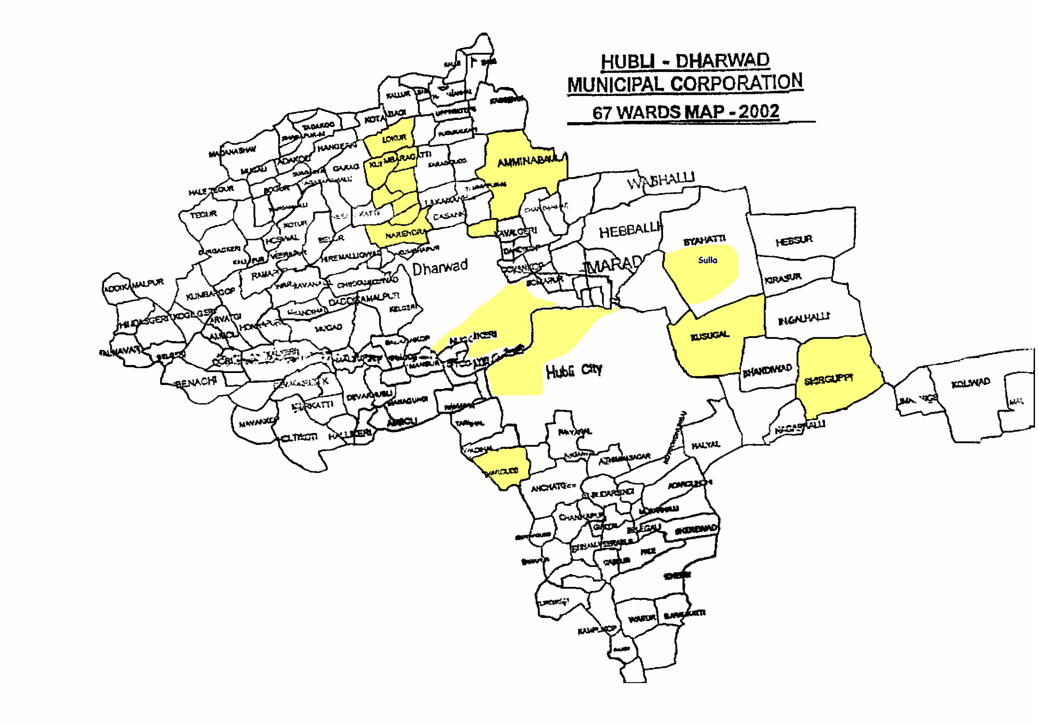


Table 4.1 Population and agricultural information of the research area

Selected Areas	**villages**	**Area of village (in ha)**	**total population**	**population density (pers/ha)**	**cultivators**	**% cultivators on total population**	**agrl. Labourers**	**% agrl. Labourers on total population**	**No. households**	**Births 2004 (first half year)**	**Deaths 2004 (first half year)**	**natural growth 2004 (first half year)**	**Net Sown Area (in ha)**	**agr. population density (agr.labourers and cultivators/ha)**	**% ha irrigated of Net sown area**
betw. D-H	Navalur	2276	15000	6,6	808	5,4	600	4		20	15	5	1887	0,75	3,2
	Unkal	3391	8534	2,5						30	22	8	1927		1,1
	Baridevarkoppa	866	9281	10,7						11	12	-1	762		1,3
	Amargol	1428	17000	11,9	671	3,9	300	1,8	1000	30	15	15	1161	0,84	1,0
Narendra (D)	Narendra	2961	8240	2,8	1017	12,3	675	8,2	1400	29	25	4	924	1,83	3,6
Lokur (D)	Mangalgatti	272	1646	6,0	139	8,4	250	15,2	360	3	1	2	235	1,66	4,3
	Kusabagatti	4244	2131	0,5	308	14,5	150	7,0	608	5	6	-1	584	0,78	2,3
Kankur (D)	Chandamatti	753	809	1,1	213	26,3	200	24,7	320	7	3	4	672	0,61	5,4
	Kavalgeri	984	1246	1,3	240	19,3	110	8,8	450	5	5	0	590	0,59	27,7
Aminabhavi (D)	Aminabhavi	4655	9831	2,1	1100	11,2	650	6,6	1598	149	89	60	4422	0,40	2,7
Devaragudihall (H)	Devaragudihall	1344	1362	1,0	192	14,1	207	15,2	223	2	3	-1	469	0,85	91,9
Kusugal (H)	Kusugal	3439	7229	2,1	1164	16,1	275	3,8	1625	24	20	4	3160	0,46	0,2
Shiraguppi (H)	Shiraguppi	3307	4618	1,4	830	18,0	520	11,3	780	15	10	5	3175	0,43	
Sulla (H)	Sulla	2097	5545	2,6	630	11,4	550	9,9		14	8	6	1966	0,60	1,1
	Total/average	32018	92472	4	7312	13	4487	10	8364	344	234	110	21935	0,82	11,2

Source: data based on information of the village-accountants

During the fieldwork, we tried to reach the irrigating landowners or landholders who decided about cropping and irrigation. The reason for this is, to find out the factors on the base of the decision making processes. But as consequence of this inquiry decision in the field we found less information about renters. It appeared that renters mainly do or can not invest in irrigation systems and because of this do not decide about irrigation. The only two percent renters of the irrigating farmers we found will now be taken together with the landowner categories. The reason for this is that further in the research we only use landowner categories, to compare the socio-economic distribution of the resources within the water-management system. The comparison of the socio-economic distribution on the hand of landownership is based on property. The land as property of a landowner plays an important role in the financial resources and makes the farmer credit worthy for bank-loans. And this has its influence on the decision making processes and the strategies in disappointing harvest periods.

To make the research data comparable with secondary data, the landowners are divided in three groups. The three groups which are used by Hunshal and Nidagundi (1998) are categorized into small, medium and large landowners. The definitions used by Hunshal and Nidagundi, are for small landowners less than 5 ha, for medium landowners 5 to 10 ha, and for large landowners over the 10 ha. It's interesting to see that Hunshal and Nidagundi found 45 % small, 37 % medium and 18 % large landowners on a research sample of 10,726 landowners in peri-urban villages of the city region Dharwad-Hubli. But when we take a look at the random research sample of the irrigating landowners in the urban-fringe of the city region Dharwad-Hubli with the same categories we will find another order as will appear in table 4.2. I have to command that the two percent renters with no possession of land and renting land smaller than 5 ha, are included in the small landowner category. Because of this small amount of renters with in general comparable agricultural interests. I will continue to do so in the following chapters.

Table 4.2 Distribution of agricultural households over landowner categories

	Absolute share	%
small landowners	49	**59.0**
medium landowners	15	**18.1**
large landowners	19	**22.9**
Total sample	83	100.0

4.4 Distribution over the soil

The second reason on which the research population is based was the simple schematic overview of the soil. The soil is a main element for agriculture and a restrictive for other activities. As we mentioned before, the city region Hubli-Dharwad is located in a predominantly rural region. Due to the productive nature of the soils, agriculture is the main economic activity. As a generalisation to the east of the city region, farming is more urban-orientated, which means that there has been a diversification from subsistence to commercial cropping, to satisfy the urban markets but also due to increased irrigation. To the west farming is more rural-oriented, where farming is still geared towards traditional subsistence crop production. (Hunshal, 1997) (http://www.ucl.ac.uk/dpu/pui/research/previous/consolidation/pdf%20consolidation/chap2.pdf).

This agricultural pattern follows the abstract pattern of the two distinguished soils around Dharwad-Hubli. The two main types of soil we distinguish, are black and red soil. The already mentioned black soil is a typical lava recur with its features of friability, retentively and natural capacity to regain fertility. The black soils occur to the east of Hubli-Dharwad, and are typified by their dark coloration, high clay content and high water retention. These black soils are fertile and can give good crop yields if rainfall is adequate. Crops which thrive on ‘heavy’ soils, such as sorghum, cotton, wheat and potato are predominant. The deeper soils permit cropping on residual soil moisture in the north-east monsoon and the dry Winter and Summer seasons (Hunshal & Nidagundi, 1998).

The soil type which occurs to the west of Dharwad-Hubli is called red soil. Its formation is a result of wide diffusion of iron in the rocks, and characterised by its less fertility by lack of nitrogenous, organic and phosphoric contents (http://www.schoolresult.com/geographyxii1998/qa2a.htm.). The red soils overlie acidic bedrocks such as granite and granite gneiss and are usually acidic in reaction. Their red coloration is derived from the presence of ferric oxides. The red soils vary in their sand and clay content and have good potential for irrigation and are suitable to crop rainfed rice. Where rainfall is adequate, particularly in the western areas, cropping is possible in both the heavy south-west monsoon (Rainy season) and the drier north-east monsoon in Winter season (Hunshal & Nidagundi, 1998).

For this research the urban-fringe area was divided geographically in nine research village regions as mentioned before (see fig. 4.1). This is partly based on this schematic overview on the occurrence of these soil types. The black soils are in general characteristic of the northern and eastern sides of Hubli-Dharwad, contrasting with the medium red soils in the south and west of the city region, with a transition zone in between the cities. Table 4.3 shows the share of irrigating farmers in the different village regions as percentage on the type of soil they are cropping. But the table also describes the total hectares farmers crop on a particular soil type in the region. For example from the table it appears that half the amount of farmers in the region ‘between D-H’ crops on red soil while the amount of cropping hectares is more on black soils. This means that 50 % of the interviewed farmers cropped on red soil, but are most of the time smaller farmers than the farmers who cropped on the black soil in this region. A potential declaration for this appears from Hunshal and Nidagundi (1998) that ‘urban’ development is concentrated in the red soil areas. The agricultural sector on the red soils in “between D-H” has to compete more with urban sectors, for land.

Another interesting point that appears from the table is that the village regions Narendra and Devaragudihall were typical red soil regions. And on the other hand the village regions Aminabhavi, Kusugal, Shiraguppi and Sulla were typical black soil regions.

Table 4.3 Research population and cropping area on Soil type

Region	soil	% of landowner households	Ha. Cropping
between D-H	Black Red Mixed	40 50 5	57.29 38.66 3.24
Narendra (D)	Black Red Mixed	 87.5 12.5	 43.32 2.63
Lokur (D)	Black Red Mixed	85.7 14.3	187.3 8.1
Kankur (D)	Black Red Mixed	80 20	36.44 12.15
Aminabhavi (D)	Black Red Mixed	92.9 7.1	88.26 4.55
Devaragudihal (H)	Black Red Mixed	 100	 30.97
Kusugal (H)	Black Red Mixed	100	29.55
Shiraguppi (H)	Black Red Mixed	100	102.2
Sulla (H)	Black Red Mixed	87.5 12.5	62.35 6.48
Total	**Black** **Red** **Mix**	**59.0** **32.5** **7.2**	**563.4** **121** **29.1**
		98.8	**714**

In the end of part 4.3 we made a distinction for the research population. The landowners households were divided over the landowner categories, small, medium and large landowners, to compare socio-economic differences. In table 4.4 we combined these landowner categories with the soil type on which the landowner households crop. It appears that the landowner categories were are not equally spread over the soil types. The small landowner households were relatively equally spread over the main soil types. But we see that most of the medium and large landowners crop on blacksoil. This can have its influence on the use of irrigation over these categories. As we mentioned before these blacksoils were typified by their high water retention. These black soils are in general fertile and can give good crop yields if rainfall is adequate. But during the drought the rainfall was insufficient and the landowners also had to irrigate.

Table 4.4 Percentage of landowners divided on soil

category	Soil type	% of the landowner households
Small landowners	Black	51
	Red	41
	Mixed	6
Medium landowners	Black	67
	Red	27
	Mixed	7
Large landowners	Black	74
	Red	16
	Mixed	11

It appeared from the fieldwork that the farmers in eastern village, Shiraguppi were dependent on canal irrigation in the first place, for their crops. But when this canal was closed because of insufficient water supply during the drought, the farmers could not choose for digging bore-wells, because of the features of the deep black soil on the east of Hubli. The slippery nature of that black soil made deep wells a risky investment, but more important the water from these deep wells was useless because of the brackish nature of the deep aquifers.

In the past the life-style of the regional community was adjusted to these natural hazards like drought. It was expected that, at least once, in three years, there would be scarcity of food. The traditional method to avoid shortages was to store the grain of surplus years in underground granaries. However, the introduction of commercial crops, as well as railways and roads destroyed this self-sufficiency, with the result that the impact of scarcities is felt more than before. The modern storage methods are costly and need better protection from rodents and pests as well as inclement weather, they also entail wider organisation of transport and distribution (Deshpande, 1992).

5. Institutions

5.1 Water institutions

In the theory we mentioned the definition of Venkata Reddy (1990), in this definition for *irrigation management,* play institutions an important role. Institutions are also part of the factors within the water-management definition of Abu-Zeid (1980). And in the schematic approach of the water-management system in agriculture (fig. 1.1) it is one of the environmental factors in the context of water-management of irrigation for the farmer household.

In this schematic approach we distinguished the institutions in social and governmental institutions. And in this chapter we will discuss the control and management of these institutions in the water-management of irrigation. For the institutional organisation of irrigation we can distinguish several phases, namely; the control of the water source, the delivery of water, and the actual application of water to crops and drainage. And each of these phases involve a number of distinct functions like facility construction, operation and maintenance, water allocation and conflict resolution. Water-management of irrigation encompasses all these phases and functions but can not be seen as a single entity. It has to be viewed in terms of arrangements for performing the various functions in each of the phases of irrigation and water control (Agarwal & Narain, 1997).

Most studies in the Asian context show water control and management institutions primary in terms of their relation to general political authority, while wide variations in the structures and processes of these institutions have been documented. A problem is that no attempts have been made to examine the significance and reasons for these variations (Agarwal & Narain, 1997). Also in India are such studies not available. But we will recognize in this research, that institutions for irrigation and agricultural water control have to be viewed in relation to physical conditions, farmer households, technology of water control, economic and other factors which define the context in which these institutions function and which to some extent condition their characteristics.

As we mentioned in the theory, the Green Revolution has brought about a strong growth in irrigation potential, due to innovations, programmes and policy. And many of these irrigation projects in developing countries had the intention to increase and improve the agricultural production radically and benefit all classes of farmers (Abu-Zeid, 1980). Also in India the government realised systems to benefit more farmers more equally. But this equitable distribution of water resources within the community and between settlements is likely to give rise to problems and conflicts. Both traditional and modern systems tend to be iniquitous in one form or another.

The delivery of water phase is a critical stadium for the allocation of water. By tank and canal irrigation systems raised in this phase problems of equity between the catchment and command areas. In terms of water distribution, the farmers in an advantageous position reaped the benefits of the irrigation system, like drawing more water for their crops. As a result there was a considerable area deprived of water at the tail end of the irrigation system. The need to protect catchments is reiterated but farmers in the catchment area are unlikely to reap any water benefits from catchment protection. It appeared that the systems, though suited to the ecology of the region, do not necessarily promote equitous distribution of water among the farmers (Agarwal & Narain, 1997).

5.2 Institutions in Dharwad District

The information about the amount and use of irrigation systems is collected by the local governments. According to Hunshal and Nidagundi (1998) there were 436 minor irrigation schemes in 1998 in the total Dharwad District. And this amount provided about 72 thousand ha each year. This information is calculated by the different levels within the governmental hierarchy. The district total is the multiplied amount of all talukas. The heads of each *taluka** record the information about the farmers, areas irrigated and crops grown. They use this information to gather the water tax for maintenance of the tank and the other sources. There is an Irrigation Committee in each taluka, which decide about the outlet of tank water after the Rainy Season, because all of the tanks are rainfed. An assistant executive engineer from the Minor Irrigation Department is secretary to the committee and is responsible for letting water from the tanks into the fields.

But in the Dharwad District there have been problems with getting sufficient water at the correct times. They also have the mentioned problems with the maintenance of structure and sharing the water fairly. In some cases excess use and misuse result in salinisation and other problems. The central and state government try to develop a solution to get farmers to share the water fairly by Participatory Irrigation Management (PIM). Karnataka amended its Irrigation Act of 1965 in 2000, empowering farmers to involve themselves in the water management. The users' institution would be formed at the primary level with water user cooperative societies (WUCs), and the project level federation and Apex body are at State level. With these amendments in the Irrigation Act the trend is shifted from water-resource control dependency on the State department, to self-reliance in addressing issues related to farmers in command areas through WUCs and federations (http://www.deccanherald.com/deccanherald/july04/spt2.asp).

The organised result of this social institution is that many farmers in India are united in Water Users Associations from each outlet. These registered cooperative societies' aim to work out a way to share the water between the farmers, who are billed through the organisation. The government subsidises the irrigation schemes at the beginning and fixes the rate which the association pays. But there are no such examples of Associations, which are more concerned with canals and tanks, known in the Dharwad-Hubli municipality region (Hunshal & Nidagundi, 1998).

5.3 Situation in Dharwad-Hubli

Governmental and social institutions on irrigation, are almost negligible in the municipality region of Dharwad-Hubli. As we have seen in chapter three, bore-wells became more popular in the nineties, due to their greater reliability and moderate costs and its virtually free power supply. In the Dharwad-Hubli municipality region only bore-wells could be used for irrigation during the period of research.

Only in Shiraguppi the farmers were dependent on canal irrigation and had their own social local institution on village level, to regulate the catchment and tail ender problem. Supervisors appointed by the collective of users, had to prevent that catchment farmers drew more water for their crops, to save water for the tail-enders. As we see, the allocation of water and its conflict resolution on local level in the delivery of the water phase were maintained by a social institution on village level. But the canal system as part of the control of water-source phase, was still constructed, operated and maintained by the government. The water in the canal came from the dammed Malaprabha, and the farmers had to pay tax per acre for the use of the canal water.

** taluka is an administrative devision below district*

But this system was closed by the government three years before because of the insufficient water in the capture areas during the drought. But the bore-well irrigation alternative was no option for Shiraguppi because of its brackish deep aquifers.

During the drought, irrigation without bore-well was almost impossible in the Dharwad-Hubli municipality region. As we have seen the resource of the bore-well is groundwater and this has some undefined legal features. This groundwater is not recorded in laws as public or state property and this is a reason for the negligible management and control of the water-source by governmental institutions. But as we have seen in chapter two the groundwater aquifer may be visualised as a giant sponge that is buried under ground and depends on rainfall and geological factors for its amount. We can imagine that these geological factors are not bound to the surface borders of the farmer land and the groundwater aquifers are not equally distributed in the underground. In this case it is surprising that there is no regulation or cooperation between farmer households about the irrigation with bore-wells. Farmers, who invested in the bore-wells in their own land, make their own decisions about the amount and frequency of irrigation. The farmers make their own decision to invest in the construction of a bore-well and claim all phases in the institutional organisation. The institution for the delivery of water is claimed by the investor of the bore-well also when neighbouring farmers make use of his bore-well. The use of neighbouring farmers is mostly based on unilateral trade agreements, but only takes in a few cases. Most of the time, the farmers invest in bore-wells for its own use.

The delivery of water phase as part of the decision making process of the bore-well owner, makes the access for other farmers more difficult. The access to make use of the groundwater potential is based on the socio-economic circumstances. Farmers need capital for the investment in a bore-well. This socio-economic exclusion also does not support the equitous distribution of water among all classes of farmers. This privatisation results in individual decisions by investors or bore-well holders, who do not have a significant interest by social cooperation within social institutions.

But the governmental institutions still play a role, merely based on supporting and stimulating. This appears from its role in the electricity supply. To pump up the water the farmers use electric pump-sets. The reason for this is that electricity used for agriculture was already subsidized by the government. But because of the water power based electricity supply, the supply was bad and unstable during the drought. The bore-well owning farmer protests formed obviously a strong lobby and the protests on this electricity supply were compensated by the government with free electricity for the farmers. And in a single case is known that farmers got subsidy for the investments in digging a bore-well.

It is possible to see this policy of subsidizing in the context of this highly privatised irrigation system. And with this policy the government tries to reclaim some influence in the use or misuse of this groundwater resource. But this subsidizing can have some adverse effects which became clear with the drought. Subsidizing electricity is subsidizing the use of the bore-well. The growing use of these large-scale water harvesting technologies, threatened the sustainability of the already over drafted groundwater basins, during the drought. The over drafted groundwater basins, had the result that bore-wells of some farmers fell dry.

5.4 *Policy reforms needed*

These consequences of the drought will repeat in the future. As we have mentioned before, water going to be a limited factor and constraint for increasing agricultural production in this century. Water-management is necessary to utilise water judiciously

and economically by various means such as conservation, development, storage, distribution, reclamation and re-use for sustainable food security.
According to Sivanappan (2000), the irrigated agriculture will face a number of challanges in the next few decades. On the one hand, it must raise its agricultural production by productivity growth. On the other hand it will be faced with increasing competition for decreasing water resources. The situation is made worse by dwindling financial resources and increasing cost of water (Sivanappan, 2000).
One of the solutions for these future constraints is to be found in the social and political environment. A crucial pre-condition would be a reform in water policy. Saving water depends on such activities and should be initiated in a big way to overcome the water problem, but it will not be easy to carry out.

6. Socio-economic distribution

Production growth is the logical economic aim of a farmer household. The way to do this with a fixed amount of land is increase the yield per ha. This productivity growth was also the aim of the Green Revolution. As we have seen, the means where the farmer depended on for a radical productivity growth were part of the Green Revolution 'package' which enclosed High Yielding Varieties (HYVs), chemical fertilizers, pesticides and irrigation. But these parts are interrelated, because these HYVs or crops in general, are characterised by high response to fertilizer inputs and are conditional upon adequate water and water-management. The farmer has to make a choice in cropping pattern and its response to external inputs for productivity growth. But when the external inputs become the limited factor, a farmer has to decide between changing the cropping pattern or try to find alternatives for the inputs.

In the chapter seven we will discuss the relation between the crops and its water requirement. But as we have seen the fieldwork on the base of this research took place in a period of three years drought. Water was the limited factor for cropping. Water is mainly the limited input factor for productivity growth in the semi-arid tropics. This appeared also from the conclusions of Walker and Ryan (1990) in other villages in the semi-arid tropics, that water is much scarcer than land, for all but the smallest irrigated farms. And sole ownership of more than one well is rare. The incentive to own wells is much stronger than the ambition to own land in villages. Among villagers, wealth is most readily communicated in the number of productive wells a household owns than how much land a household owns (Walker & Ryan, 1990).

Access to water resources for irrigation became essential for cropping, especially during the drought. But as we have seen before, the access to the drought protected groundwater potential is mainly based on financial circumstances to make private investments, with the introduction of bore-wells. These bore-wells are deciduous for the amount of irrigation water of the owner. But the possession of bore-wells is not the only factor for the available water amount. We will describe the factors which play a role in the available water, and its result on the cropping patterns. And we take the households together in landowner categories, to get insight in the socio-economic distribution of these phenomena.

6.1 Access to Irrigation Water

Land is a factor in the water-management scheme, which plays a role in the decision making process of the farmer household. But according to Walker and Ryan (1990), water is much scarcer than land, for all but the smallest irrigated farms, in semi-arid tropical villages. Land is not the limited factor; it exceeds the amount of water available for irrigation. Only the smallest irrigating farmers have probably more water than their crops or land require. But the main role of land for a farmer in the water-management is its possession. Land as property is capital, which plays an important role in the financial resources of the owner, and makes landowners more credit worthy for bank-loans. This has its influence on the decision making processes and strategies of a farmer household, and particularly on its access to irrigation.

This given makes it more interesting to look at landownership, to discuss the socio-economic measure of distribution of the particular factors responsible for the water access, availability, use, cropping patterns and differences in productivity. The research population will be divided as mentioned in chapter three, based on the socio-economic categorization and definition of Hunshal and Nidagundi (1998) for small, medium and large landowners.

The research data are based on the information of the fieldwork period, which was only a momentum, and not a process of monitoring. This made the research more complicated for making comparisons about dry, wet and good periods. But this research period was the end of a period of three years with insufficient rainfall and crop-failure, but also an awaiting and anticipating period for the release of a potential good monsoon. The collected data or based on the recent experiences of farmers on the Rainy (Kharif or Mungari), Winter (Rabi or Hyngari) and Summer season. The irrigation sources, like tanks and surface wells, were almost all dried up during my fieldwork, due to three years of drought. This is one of the reasons why farmers in the urban fringe of Dharwad-Hubli started to pay more attention on the use of bore-wells for minor irrigation, while bore-wells were formerly generally used for drinking purpose. The difference with the bore-wells for irrigation is that these have a bigger circumference, are deeper, and need a more powerful pump.

The recent attention for the bore-wells appears from the relative low age of the first bore-wells of the farmers. The average age of the first bore-well of a landowner is seven years and almost 50 percent of the first bore-wells are not older than three years. These are not older than three years, because this bore-well is merely an expensive alternative source. The first bore-wells are the first dug bore-wells per landowner household. Some landowners have second borewells, but these are almost all younger than three years and would give a misrepresentation. Other reasons for the growing popularity of the bore-well in the Dharwad-Hubli region are the environmental conditions for exploiting the groundwater potential, and the independence of the unreliability of the existing facilitated irrigation systems due to insufficient supply and the restrictions by the Irrigation Committee in periods of drought.

The environmental conditions for a bore-well are mainly geologically. The deeper layers in the area of Dharwad-Hubli are characteristic of the Dharwar rock complex. This means that the deeper layers of the soil are hard rocks as granite and granite gneiss, which come into move by temperature changes and forces in the earth. In this way there arise lots of fractures into the layers whereby exchange of groundwater can take place easily between different levels of altitude in the soil. This also means that heavy rainfall, after seeped into the soil, disperses and reaches very deep aquifers. These underground basins in deep aquifers offer an alternative water source. The bore-well is the ideal instrument to make use of this water potential, by its characteristics of depth and powerful pump sets.

The independence reason is essential in the use of these bore-wells. As we have seen in the chapter before, the total decision making process from construction to the use of a bore-well is reduced to the landowner household. This process of investment making for private purpose makes the landowners relatively independent from social and governmental institutions. The construction of the bore-well is on their property and on their own risk and they do not accept government intervention in the use of their bore-well water. In general are the landowners making their own decisions, sometimes democratically within the household, about the amount of irrigation water they need.

6.2 Socio-economic distribution of access

The consequences are generally believed that the ownership of private pumps tends to be skewed in favour of larger landowners. Theoretically, a landowner must have an adequate irrigable command area of his own land holding to earn an adequate return on his investment. Although there are possibilities of selling water, farmers with large land holdings have a natural advantage over small landowners. In addition, they are in a better position to finance the investment (Pant, 1992). This argument comes true in table 6.1 which reveals that the average bore-wells per landowner, is the highest for large landowners. The data supports that ownership of the bore-wells is skewed in favour of large landowners. Another circumstantial reason for this skewed distribution mentioned by Pant (1992) is that there is bribe, which is required to be paid to the officials of the state Electrical Board, for the electrical connection of private electrical pumpsets. Under these circumstances it is quite natural that the agricultural rich would have better access to satisfy these corrupt officials compared to poor landowners.

But the broad main reason, as we mentioned before and which follows the average amount of bore-wells per landowner household pattern over the categories in table 6.1, is the credit worthiness of landowners for investments. The table reflects that the large landowners have more bore-wells than the medium landowners etc. Table 6.1 gives the amount of bore-wells of the research population. It appears that the group of small farmers possesses 49% of the bore-wells. But because of the bigger share of small irrigating landowners it appears that they only have an average of 1.16 bore-wells per landowner compared to the large farmers with an average of 2.11 bore-wells per landowner.

Table 6.1 Amount of bore-wells of the research population

Landowner categories	% **of research population**	**Amount of bore-wells**	%	**Average amount of bore-wells per Landowner hh**
Small	59	57	49	1.16
Medium	18	19	16	1.26
large	23	40	34	2.11
Total/average	100	116	100	1.40

The investments for a private irrigation-system are very high. The investments for digging bore-wells are on average 114.3 Rs/m with an average depth of the first bore-well of 95.6 m. This means that the average costs of digging approaches 11,000 Rs. But these costs are only the costs of digging. The total investments for a farmer exist out of the sum of motor costs, pipelines, casing and field irrigation systems. This will bring their total average investments to an approach of 100 thousand Rupees. To overcome these high investments the government subsidized eight percent of the farmers for digging the first bore-well over the last two years, during the drought.

Digging of a bore-well

6.3 Distribution of Water use

The amount of bore-wells does not say anything about the real water use of the farmers. The environmental conditions for a good yield are not equally spread and differ over small distances. A good yield of a bore-well is related on depth, supply and especially fractures in the soil. These factors do have dependent effects. In this period of drought there was no supply from rainfall. The static water-level within the bore-well decreases with the use, and the difference between water-level and pumping water-level becomes smaller (see box 2.1). This reduced the draw-down effect. When the surrounding soil contains more fractures the groundwater supply for an intersecting deep bore-well remains high. In this way it appears that deeper bore-wells, in a dense irrigated area, attract the water from less deep bore-wells, which on their turn fall dry. This means that the depth of a bore-well is also important. In this period of drought it was still possible to get water from deeper layers. This also explains the growing investments in deeper bore-wells. The average depth of the first bore-well is about 95.6 m and 105 m for later bore-wells than the first.

The fractures in the soil layers are crucial for the localisation of the bore-well. The localisation process is complex and not without risk. To optimize the yield of the bore-well, geological research on presence of fractures is necessary. In most of the cases play geologists a part in the decision making process of landowners.

As we see, the actual water use of farmers also depends on the bore-well yield and not only on the amount of bore-wells. This yield depends on many external factors and is therefore highly unpredictable. After placing, the yield can be checked in inches on continues discharge scale in a 90 degrees funnel. This yield was known by the farmers, but decreases in drought periods. This inch yield is translated in the bore-well yield data chart (in the appendix), from inches to litres/second and litres/hour. Combining these yields with the time that farmers irrigate per day in Winter/Summer season, it is possible to find out the water use in the research period. The intermediate inches in the bore-well yield data chart are taken in equal distances to find out the approaching bore-well yields. This will give an impression of the water use, but will not stay constant in drought periods.

The length of time irrigating is dependent on the provision of electricity for the bore-well pump set in by approach 99 per cent of the cases. On average these times will be 7.6, 7.9 and 7.9 hours a day for the small, medium and large farmers respectively. This means that on average all farmers get almost the same low electricity supply in a drought period. This is due to network problems and restrictions of the electric service sector, which is based on water power stations. In the need of more water the farmers also start with night irrigation, because of the reason that electricity is more certain and regular during the night (Pant, 1992).

Landowner with bore-well and electricity service

In these circumstances the total daily bore-well water use of the research population is by approach 8.3 million litres. Though the use of water is highly unpredictable for the individual households, the averages on landowner category show us some characteristics. The extension of daily water use in table 6.2 is based on the average household yields (in inch) and the daily pump time per household, and translated with the intervening bore-well yield data chart. Further is this daily use multiplied by the amount of bore-wells of the separate households and corrected with the present quit bore-wells. After this process the farmers were taken together and divided over the socio- economic categories. The daily average litre/day in table 6.2 is based on the average litre/day per daily irrigated hectare. The reality is that not all the farmers are irrigating a whole ha per day, but this extension gives a comparable impression of the irrigating intensity over the categories. Table 5.2 shows the highest irrigation intensity for the large landowners. Compared to the average irrigation of 0.3 ha/day for medium landowners, which is almost equal to the small landowners, the average water use in litres for medium landowners per ha is much higher than the average use of a small landowner.

Table 6.2 Water use per landowner

Landowner categories	Average litre/day per household (WS/SS)	Daily average litre/ha per household (WS/SS)	Average Ha/day Irrigating (WS/SS)	irrigating hours/day (WS/SS)
small	57260	194618	0,29	7.61
medium	87710	332043	0,30	7.93
large	287356	532674	0,47	7.93
average use	110695 (over all hh)	289859 (over all hh)		7.74

In general blacksoil needs more water to keep it moisture, this is possibly the reason for the higher water use per ha of a medium landowner. Around 67 percent of the medium landowners are classified as typical blacksoil farmers against only 48 percent of the small landowners. The combination with the average low daily ha irrigation, suggests that on average a medium landowner needs 13 to 14 days to irrigate his total irrigation ha in Winter season, compared to a large landowner who needs only 10 to 11 days.
A significant phenomenon is that the average water use per day and per ha, by a large landowner is more than the average water use of a small and medium landowner household together.

6.4 Distribution of irrigation

From table 5.3 it appears that small landowners on average irrigate 63% of their total cropping hectares in Winter/Summer season. Compared to the average of the medium landowners and the large landowners this is much. But the average absolute total cropping hectares in Winter and Summer season is small compared to the medium, and very small compared to the large landowners. It appears that the small landowners did not even have enough water to irrigate their total land. There are two possible explanations for this; the first is that the farmers did not crop their land to avoid exhaustion of the soil. But the second more relevant reason is that during the drought, the water supply in the bore-wells was not sufficient to irrigate up to their total land. As we have seen before water was, in particular during the drought, the limiting factor and this is also the reason why landowners participate on the Winter-season and Summer-season to crop less hectares, because of shortage in water supply and risk of crop failure.
From table 6.3 it appears that the absolute average irrigating hectares of the medium landowners are almost two times as much as that of small landowners. While the difference between the average irrigating ha of the large landowners is compared to the medium landowners is only around a quarter more, though the average litre/day water use is more than double.

Table 6.3 Average ha. irrigated of the Cropping field in WS/SS

Landowner categories	**Average total ha Cropping**	**Average total ha irrigated in WS/SS**	**irrigated ha/ Cropping field** % (in WS/SS)
small	2.84*	1.8	63
medium	6.88*	3.4	49
large	24.9*	4.4	18

** total of all the croppers included non irrigating landowners*

It appears that the water use per day is not the only dependent factor on the amount of ha irrigating. The frequency and amount of irrigation is also influenced by the soil type, weather conditions, and crop conditions like depth of wetted soil, the depth and dispersion of roots of the crop, and age of a crop (http://www.ikisan.com/links/knt_chilliVarieties.shtml, 29/12/2004). The important factor is the cropping pattern of the farmers. The variety of crops plays the main role in the use and need of water. In general the local crop knowledge is mainly based on trial and error and the minimal information by the farmers on which crops require more water and which crops are so called “dry crops”. But detailed scientific based crop knowledge is scarce. It is the manifestation of the given that farmers in developing countries primarily rely on local, indigenous knowledge, though some new crops are regularly incorporated into existing systems. Nevertheless, the given that crops are mainly rely on the local, indigenous knowledge is one of the reasons why there is no scientific knowledge about efficient water use in irrigation by the farmers. For a better understanding of water use efficiency and the social distribution of water use and need, it is important to discuss the scientific characteristics on water requirement of the main Indian crops.

From this information about the access to water, it appears that the irrigating landowners do not have equal access. This undermines also the idea to benefit all classes of farmers within the sustainable development theory. It confirms also that the initial attraction for planners of the green revolution, the scale-neutrality of the technologies and the power of the market to encourage and disseminate improvements in well-being, is not achieved. It was assumed that the biochemical technologies of seeds and fertilizers would be equally viable at all scales of operation, whether on small or large farms. It was therefore thought that the yields and incomes of all farmers could be enhanced without raising rural inequalities (Potter e.a., 1999). But this is not new; even its extremely uneven regional and social impacts were already described by many critics of the Green Revolution. As we have seen, the reason for this uneven access is mainly based on the uneven land property. The consequences on this uneven access to irrigation facilities are translated to the cropping patterns of the landowners in the next chapter.

7. Socio-economic distribution in irrigation and production

From chapter six, it appeared that water was the limited factor for a radical productivity growth. Water for irrigation is the critical part of the Green Revolution package. The result is that cropping patterns of the farmers have to be adjusted to the water conditions. The possibility of two cropping cycles in a year is due to the Green Revolution. But the differences in water supply between the Winter/Summer season and the Rainy season reflects within the cropping patterns of the landowners. This is the result of the different crop responds. Every crop responds differently on droughts and irrigation. It depends on the crops in which measure they adjust to the climatic variations and the corresponding water supply from the monsoons.
First we have to describe how the crops respond to water stresses or a particular amount of irrigation. And Secondly, we try to find out the anticipation of the landowners to these seasons during the drought, with their available amount of irrigation. We try to describe this with the distribution of specific crops over the socio-economic categories. As we have seen in the chapter before, most of the water is available by large landowners for the relative small amount of irrigating hectares. This can have influence on the distribution of crops over these socio-economic categories. When the landowners got more water for irrigation at their disposal, they can crop more high yielding varieties, which require moisture conditions. Further we will discuss in this chapter what the influence is of irrigation on the yields per crop. The amount of water use can make substantial yield differences per crop within the semi-arid tropical conditions of the Dharwad-Hubli area. We will compare these yields with common yields or the average known yields of Karnataka over particular periods.

7.1 Crop Characteristics

Chapter six is a description on the water availability on the categories, but it is necessary to describe the impact of water on the crop growth. The explanation for the differences in intensity of water use (table 6.2) by the landowners, is based the differences in crops. The decision for specific cropping patterns is made on the availability or predicted availability of water by a farmer. Further makes a specific cropping pattern the farmer dependent. The farmer has to irrigate up to the requirement of the cropping pattern, to get good yields. The crops become decisive for the water use. For good yields each crop needs certain quantities of water. But data on the best combination of crops and irrigation regime are actually meagre. Maximum water use economics can not alone be the goal always. This economics of obtaining high yields mostly dominates the scene. But it appears that yield increases from irrigation and plant population follows some kind of decreasing increment function after a stage. This means that each successive unit of input produces less yield profit than its predecessor. In general, the tendency is to over-irrigate, especially if the water potential of the farmer is more than he already used. This tendency can be avoided only if information is available on the most efficient way to use water (http://www.ikisan.com/links/knt_irrigation.shtml, 29/12/2004). The most efficient way to use the water for specific crops is described by Lenka (1991) on the hand of critical stages. For full growth and development each crop needs certain quantities of nutrients including water at particular stages of growth. If that nutrient remains deficient than the requirement, the crop growth suffers irreversibly during other stages (Lenka, 1991). For a better understanding of the effects of the water supply, we have to discuss these critical stages of the main Indian crops, which are cropped by most of the landowners in the research population. Each crop may have one or more critical periods for a particular nutrient during its life cycle, but it is not necessarily the peak period of maximum requirement. Water requirement and critical stages of the most important crops for the research population are given in Table 7.1.

Table 7.1 Water requirement and Critical Stage

Crop	Duration (days)	Water requirement (cm)	Critical stage
Wheat	95-110	35-40	Crown root initiation, tillering, flowering
Maize	95-120	50-60	Silking, Cob development
Jowar	110-125	55-65	Flowering and Grain filling
Greengram (Winter season) (Summer season)	 75 70	 15 25	Flowering and development
Blackgram	90	20	Flowering and pod development
Groundnut (Rainy season) (Summer season)	 110 120	 48 55	Arrowing and peg development

Source: Irrigation and Drainage (Lenka, 1991)

We will describe in short the main Indian crop characteristics, based on the research of Lenka (1991), which shows the scientific water requirement for a high yield per crop. We will only mention here the crops that play an important role further in the research. The characteristics of the other main Indian crops are described in the appendix.

The second most important crop of India is *wheat* and is a typical Winter/Summer season crop for the irrigating farmers around Dharwad-Hubli. Wheat is also a typical grain cereal, like rice (the most important crop of India), which is modified in the context of the Green Revolution, to achieve higher yields. Its water requirement is much less than rice. In the local varieties 3 to 5 irrigations were generally necessary. For these tall local varieties tillering, flowering and grain development are considered as critical stages of irrigation. Lack of moisture during these growth phases seriously affects growth and yield. The water use efficiency is also more than that of rice. With an average yield of 3.5 ton per ha with a water requirement of 45 cm, the efficiency rate becomes around 78 kg/ha/cm, this is more than twice the efficiency of rice.

Jowar (Sorghum or great millet) on the contrary is a crop mainly of the non-irrigated areas. This is the reason why Jowar is cropped in general in Winter and Summer season. Even though considered as a drought resistant crop, stress during the boot to flowering stage results in pollination failure and reduces the yield. But heavy rainfall during grain development stage causes charcoal rot. The Rainy season crop does not need any water but under unfavourable conditions one irrigation of 4 to 6 cm may be necessary. For the Winter season and Summer season crop four to six irrigations are necessary. This depends on soil type, because for black soils five irrigations in Winter season are found adequate. The water requirement during the Rainy season varies from 35 to 45 cm and during Winter season from 48 to 62 cm.

Greengram, blackgram, horsegram and Bengalgram are part of the so called pulse crops. Most of the pulse crops are grown as mixed crops with cereals and no special attention was paid to their cultivation. Duration of the pulse crops varies from 65-100 days. Because of their partial indeterminateness no critical stage can be specified. But in all cases flowering and pod development periods are susceptible to moisture stress and four irrigations in Summer season are required.

More specific research on good yields of greengram at Dharwad in Rainy season supposes that irrigation at 75% depletion of the available soil moisture from 0-30 cm layer is required. The crop requires two irrigations in addition to 7 cm rainfall.

Chillies, is the main crop of the spices and is grown throughout the year. For a high yield it requires around 40 cm irrigation (Lenka, 1991).

The most important fibre crop is *cotton* and is grown over 8 million ha in India. *Cotton* is more sensitive to soil-water conditions. The root system of the cotton plant develops rapidly and in black soils roots penetrate to depths of 1.8 m before flowering. Irrigation and fertilisation influence the indeterminateness why the crop is more complicated. But keeping the growth characteristics in view, irrigation should be low and fixed during early stages, than the rapid growth rate is encouraged and it will mature almost uniformly, and the boll load becomes optimum. The flowering is the most rapid growing stage of cotton. More than 50% of the total water use is required during this stage. Fibre and seeds develop during the post flowering stage. Boll size, maturity time, seed weight, fibre strength and texture are affected by the time and quantity of irrigation but also the strength and yarn characteristics are affected by irrigation. This is the reason why irrigation in cotton is more complex than in other crops. In general, soil water stress reduces boll size, seed and lint. During the monsoon irrigation may not be required but in light soils and low rainfall areas as in the dry and black soils of the Tungabahdra, 2 – 3 irrigations with a 15 days interval are adequate. The water requirement is 106 cm in Karnataka based on ratios and a satisfactory crop of 2.6-3.2 ton cotton/ha (Lenka, 1991).

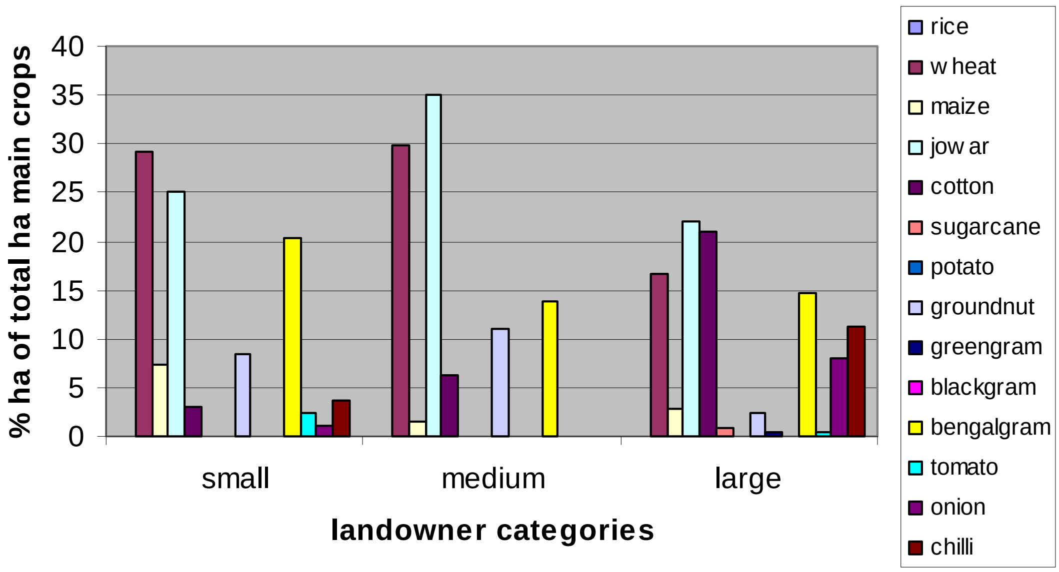
Groundnut can be grown with irrigation throughout the year. The crop continues to flower for long time. During pegging and peg development the soil should remain moist. Moisture stress during this stage reduces the pod yield. Groundnut is mainly cultivated during Rainy season, but when irrigation is available it can be grown throughout the year. After pollination the flower stalk bends down and enters into the soil and develops. During pod development the soil should also remain moist. Moisture stress during pegging and pod development reduces the pod yield, but there is not a clear critical stage. Irrigation 15-20 days after sowing ensures good pod development. Water requirement of the crop is about 55-60 cm. During Summer season, from February to the end of May, the crop needs 61 cm with a production of 22.5 quintal pods. For a good yield of groundnut the water table should be around 1 m below the surface.

Maize is also a product of the Green Revolution and was mostly grown in Rainy season. But with the increase in irrigation facilities its cultivation is increasing in Winter and Summer seasons. In Rainy season the crop normally does not need any irrigation when most of the water requirement is met from rainfall, but in cases of failure of rainfall one to two irrigations are required. In fertile and porous soils the roots penetrate on to 1.5 meter depth and the depth of extraction extends up to 1.5 m at flowering. Like many other crops, this crop stops extracting water if the soil moisture potential falls below wilting point. Maize displays appreciable tolerance to moisture stress except during the period from tassel emergence to completion of pollination. Moderate stress that results in significant wilting during these phases reduces the grain yield heavily. On the other hand, maize is very sensitive to excess soil moisture and is grown on ridges areas with poor drainage or heavy rain in black soils (Lenka, 1991). The daily requirement of Maize in Winter to Summer season is 2.5 to 4.5 mm, this means that maize requires a continues moist soil and that overall water demand is relative high.

7.2 Winter/Summer season cropping

As we mentioned before the water use is dependent on the cropping patterns of the landowners. To find out the water use for the crops we have to find out which crops are cultivated during the different cropping seasons. We try to describe this with the distribution in amount of hectares of specific crops over the socio-economic categories. Further we will take a look at the measure of irrigation to these specific crops. To do this we had to make a selection, as mentioned in the crop characteristics, of the main Indian crops. Most of these crops were cropped by all irrigating landowners in the urban fringe of Dharwad-Hubli. Some of these crops characteristics, and its responds to irrigation, were discussed before. Now we try to find out which crops are cropped the most by the different socio-economic landowner categories in a particular season. For this we took all cropped hectares of these main crops together per landowner category, these are 100 percent. The total cropping amount of ha of the other crops is almost negligible. After that, we counted the relative amount of cropped hectares for each crop separately. The result of this for the Winter/Summer Season is visible in fig. 7.1.

Fig. 7.1 % ha cropping of total ha main crops per category Winter and Summer Season



As we can see in figure 7.1, most of the hectares are cropped with jowar and wheat in the Winter/Summer season of 2004. But this share is not equally distributed over the socio-economic categories. For the small landowners covers wheat the main share of the cropping hectares. And for the medium landowners wheat takes up the second main share, after jowar. By the large landowners plays wheat also a smaller role than jowar. Bengalgram is a crop which covers a large part of the cropping hectares by all categories. The fourth main crop of the small and medium landowners is groundnut, while groundnut takes only a very small part of the large landowners. The Winter/Summer season distribution of the cropped ha is more spread over the large landowners. Jowar takes the main share of the large landowners, followed by cotton. This is a remarkable feature, because cotton covers only a small part of the other categories. Another interesting point in the distribution of crops by the large landowners

in figure 7.1 is the relative high amount of chilli ha. The medium landowners do not crop chilli in Winter/Summer season and the small landowner households only a fraction.
This gives an overview of the main crops cultivated by the landowners in the urban-fringe area in Winter/Summer season. The main crops can be distinguished in fig. 7.1 and will be discussed per crop. In this context we can give the relative amount of ha, which are irrigated by the different socio-economic categories.

7.2.1 Jowar/ Sorghum

The first crop we have to discuss is jowar or sorghum. Jowar is one of the crops which is most sown for Winter/Summer season in Dharwad-Hubli. The reason why this crop is mainly cropped in Winter/Summer season, is because jowar is considered as a drought resistant crop, and is a crop mainly of the non-irrigated areas. But it appears that in Winter/Summer season irrigation was more vital, because of strong yield differences. From the farmer experiences in Dharwad-Hubli (2004) there was less difference between the yields of jowar, but still the irrigated yield of Winter/Summer season crop was about 1.1 t/ha and the rainfed yield was 0.7 t/ha. From figure 7.1 we will find that, of the small landowner households, 25% of the hectares were cropped with jowar in Winter/Summer season. And almost 59% of these hectares were specifically irrigated by the small landowners. This is a relative a high percentage of irrigation compared to the proportion of the medium landowners. It appears that the medium landowner category cropped about 35% of the ha with jowar in this season. But only 11% of these ha were specifically irrigated by the medium landowner households. While the relative amount of cropping ha of jowar is more, compared to that of the small landowners, the medium landowners do not spend much water on this crop.
The relative amount of ha cropped with Jowar was also the highest of the main crops for the large landowner households. Though only 22% of the ha are cropped with jowar by the large landowners, about 15% of this was specifically irrigated. This is a bit higher than that of the medium landowners, but also the large landowners do not spend much water on this crop. But this relative overview does not say anything about the absolute amount of irrigated ha. This is important for an impression of the water use. We know the average amount of water/ha over the landowner categories from chapter six. When we like to have an impression of the absolute amount of the irrigated ha of jowar socio-economically we need to use table 6.3. By approach, the cropped ha of jowar are 22% of the average total ha cropping of large landowners. The irrigated ha by large landowners are 15% of this outcome. Then we will find that large landowners irrigated on average about 0.8 ha. When we do the same with the small and medium landowners, we will find that small landowners irrigated on average 0.4 ha and medium landowners 0.3 ha. But it is still possible that the medium landowners use more water for jowar, because of their higher daily average litre/ha. This gives another distribution on the amount of ha which are irrigated by the socio-economic classes. The large landowners irrigated on average the highest amount of jowar cropped ha. While jowar is known as a crop for the non-irrigated areas, the relative amount of irrigation is considerable. This is mainly due to the drought in the research period.

Productivity on Jowar/Sorghum

Another important point is the productivity of the landowners. We have to know what the impact is on the yields of jowar with irrigation. These yields are known with the harvests, with its specific methods, and its characteristics of processing. For jowar there are in general two methods of harvesting i.e. stalk-cut or cutting of earheads by sickles. In case of the stock cut method, the plants are cut from near the ground level; the stalks are tied into bundles and removed from plants. By the earhead cutting method are the earheads, after their removal from the standing crop, piled up on the threshing floor and after few days they are threshed. Threshing of earheds is done by beating them with sticks or by trampling them under bullock's feet. The later method is quicker and is practiced by majority of farmers who use to grow the crop on larger scale. With the harvest of jowar, we can distinguish two types of products, the grains and hay. In general, the grain yield of improved varieties under assured water supply ranges between 2.5-3.5 t/ha and that of hay or karvi between 15.0-17.0 t/ha (http://indiaagronet.com/indiaagronet/crop%20info/wheat.htm#harvest, 21/12/2004). But the other yields are restricted to the grains which play the main role on the market.

Given the statistics of Karnataka it appears that in the period 1970-73 the average irrigated yield of Jowar was about 1.3 t/ha against an unirrigated yield of 720 kg/ha. But also in the periods of 1979-82 and 1986-89 the irrigation yields were only about 1.1 and 2.7 t/ha respectively. The average rainfed yields over the periods 1979-82 and 1986-89 are 876 and 1100 kg/ha, and lower than the irrigated yields (http://www.ifpri.org/divs/eptd/dp/papers/eptdp20.pdf, 14/12/2004).

But more specifically over Winter and Summer season it also appears that irrigation is more vital in Karnataka. The irrigated yield in Winter season in 1981-82 was about 1.1 t/ha against an unirrigated yield of 573 kg/ha and for the Summer season the average irrigated yield is known as 1.6 t/ha against an unirrigated yield of only 590 kg/ha (http://wgbis.ces.iisc.ernet.in/energy/agriculture/table18.html, 13/12/2004).

On the given of the landowners around Dharwad-Hubli (2004), it appears also that the irrigation of jowar plays a role. In Winter/Summer season the irrigated yield was about 1.1 t/ha and the rainfed yield was about 0.7 t/ha. The drought made irrigation more vital. Jowar is considered as a drought resistant crop, and is a crop mainly of the non-irrigated areas. But the crops still require a particular amount of water which can make strong yield differences in Winter/Summer season. When we take into account that a large landowner household irrigated on average 0.8 ha, they will get an irrigated yield of about 880 kg jowar. This is two times the yield of the small landowners with an average yield of 440 kg. As we see, the scale advantage of the large landowner results in higher yields with assumed corresponding profits.

As we have seen in the crop characteristics, the Winter and Summer season crop requires, dependent on soil type, four to six irrigations. And black soil requires in general more water, but five irrigations for black soil are found adequate (Lenka, 1991). Partly due to its longer duration the efficient water requirement is more than the requirement of wheat. The high yielding varieties mature in about 100-120 days duration and than will be harvested. Though jowar requires more water than wheat it is still one of the water use efficient crops. This is the reason for its popularity by all the landowner households for the Winter/Summer season.

But given the higher average yields in Karnataka and its potential yield improvement with irrigation, the productivity of jowar can still grow around Dharwad-Hubli. More than half of jowar cropping ha of the small landowners were irrigated, while the relative many ha of the medium landowners were not irrigated during Winter/Summer season. The drought resistant crop got a high degree of stability but the measure of constancy of yields can be put on a higher level.

7.2.2 Wheat

The other main crop, which appears from fig. 7.1, is wheat. Wheat is with jowar the main crop, sown by the small and medium landowners in Winter/Summer season around Dharwad-Hubli. Its share is also considerable for the large landowners. Wheat is a typical Winter season crop and is almost negligible for Rainy Season. The reason why this crop is mainly cropped in Winter season, is its relative low water requirement.

According to Lenka (1991) the water use efficiency of wheat is very high. But wheat is compared to jowar more vulnerable to water stresses. As we have seen by the crop characteristics, lack of moisture during the typical growth phases in many varieties of wheat, seriously effects the growth and yield. Figure 7.1 shows that wheat is cropped on 29% of the ha cropped by small landowner households. This percentage is almost comparable with the share cropped by the medium landowners. But the irrigation proportions are comparable with that of jowar. The small landowners irrigate up to 59% of the ha cropped with wheat and medium landowners only 11%. The large landowner households crop only 17% of the total ha main crops with wheat but irrigate up to 33% of these ha. This is the relative highest proportion of irrigating ha for the large landowners.
But what does this mean in absolute numbers. To give an impression of the amount we will give an estimation of the average ha irrigated wheat. By approach, when we take 17% of the average total ha cropping of large landowners (table 6.3) and 33% of this outcome, we will find an average of about 1.4 ha irrigation. While the same calculation for the small landowner household gives about a half ha irrigated wheat. By approach irrigated a medium landowner household on average 0.2 ha of wheat, which is the smallest amount for wheat compared to the other categories. It appears that the large landowners spend the largest amount of water, of the categories, on wheat in Winter/Summer season.

Productivity on wheat

What is the impact of the irrigation on wheat is the main question which follows. In this context it is interesting to mention that there was a strong growth in wheat yields from 1950 to 1992, which was mainly the result of improved irrigation systems as part of the Green Revolution. The total wheat production in India showed an 843 percent increase, from 1950 to 1992. From 1950 with a production of nearly 6.5 million tons, the production increased to 54.5 million tons in 1990 and to 56.7 million tons in 1992. The improved wheat production resulted from an increase in the area planted from nearly 9.8 million hectares in 1950 to 24.0 million hectares in 1990. But most of this greater production was the result of an increase in yields that went from 663 kg/ha in 1950 to almost 2.2 t/ha in 1990 (http://www.indianchild.com/indian_crops.htm, 13/12/2004).
This growth in yields is the result of improved irrigation systems and its use by the farmers. This appears also from the differences between irrigated and unirrigated yields. Over the years 1981-1982 the average yield of irrigated wheat in Karnataka was about 1.0 t/ha against 444 kg/ha for unirrigated wheat (http://wgbis.ces.iisc.ernet.in/energy/agriculture/table18.html, 13/12/2004). Another difference is that the rainfed wheat crop reaches the harvest stage much earlier than the irrigated crop. The crop is harvested when the grains become hard and the straw becomes dry and brittle. The harvesting is mostly done by sickle. The crop is threshed by treading with cattle on the threshing-flour or by a power driven thresher (http://indiaagronet.com/indiaagronet/crop%20info/wheat.htm#harvest, 21/12/2004).
The result of the research in Dharwad-Hubli gives a more recent overview. The total average yield of the landowners in Winter/Summer season was about 2.1 t/ha. Divided over the categories it appears that small landowners by approach got an irrigated yield of 2.2 t/ha against an unirrigated yield of 1.2 t/ha. For medium landowners the irrigated yield counted 2.6 t/ha, and an unirrigated yield of 1.0 t/ha. The yields were even higher by large landowners and approached an average irrigated yield of 3.0 t/ha and an unirrigated yield of 1.4 t/ha wheat. When we take into account that large landowners also crop most of the ha, this results in an average irrigated yield of 4.2 ton wheat for a large landowner household. The average irrigated yield for a small landowner household is only 1.1 ton wheat. As command I have to mention that these yields are based on

scatters and experiences of farmers and not on the physical facts. It only gives an impression of a potential ongoing productivity development over the last decennia. And it probably gives an impression of the differences of advance between the socio-economic categories. And it appears that large landowners use their scale advantages also with the cropping and irrigation of wheat.

It can be assumed that the cropping patterns did not change much over the last four years, but during droughts it is highly predictable that there will be a growth of the wheat cropping hectares instead of cropping more inefficient water using crops. The local varieties of wheat generally need three to five irrigations. But the average irrigated yield of 3.5 t/ha, described by Lenka was not reached by one of the landowners categories in Dharwad-Hubli. In general wheat does not need much water but it requires almost 45 cm in the critical phases to get this average yield. The relative insufficient water supply during the drought is assumed to be the main cause of this lower average yields. To use the available water supply in these typical critical stages it would be possible to get higher and more stable yields over the years.

7.2.3 Bengalgram

Another important Winter/Summer season crop in the urban fringe of Dharwad-Hubli is Bengalgram. Bengalgram is part of the so called pulse crops and most of the pulse crops are grown as mixed crops with cereals and no special attention was paid to their cultivation. But moisture stress has also little influence on the yields of the pulse crops and that is the reason why four irrigations in Summer season are required. Bengalgram is relatively the most cropped by the small landowners. Bengalgram covers 20% of the main crop hectares of the small landowners in Winter/summer season. This is comparable to almost 17 ha over all small landowners (appendix). The small landowners irrigated 41% of these hectares. Compared to the small landowners, the medium landowners cropped 14% of their hectares with Bengalgram, but only 9% of the ha were irrigated. The large landowners cropped almost the same percentage their ha as the medium landowners but irrigated this up to 19%. But these cropping ha of Bengalgram differ strong between the medium and large landowners. The total ha cropped with Bengalgram by the medium landowners is almost 9 against 37 ha by the large landowners.

To get the absolute proportions between the irrigating ha of the landowner categories, we will use the same calculation as used by jowar. By approach can we say that the small landowners irrigate on average 0.2 ha, while the average ha irrigated by medium landowners is negligible. And the average irrigated ha by the large landowners is by approach 0.7. As we see, the large landowners use not only the most daily average litre/ha for irrigation but also irrigate the highest amount ha of Bengalgram.

Productivity on Bengalgram

Because of its relative stable yield, it is not clear if irrigation would make a significant difference in yield. This is mainly due to soil moisture of the cereals. That is the reason why no special attention should be paid on irrigation to improve the yields of Bengal-gram, which is mainly characterised as mixed crop. Gram in general, matures within 130-140 days, and after maturity the plants are pulled out. But when it is cut with a sickle, leaves become reddish brown, dry up and start shedding. The harvested plants are spread on the threshing-floor, dried for about a week and will be threshed by bullocks or by sticks. A good pure crop of gram gives about 1.5-2.0 t/ha in case of Desi varieties but the Kabuli varieties give about 25-30 t/ha yield. The yield in case of mixed or intercrop depends upon the plant population of gram
(http://indiaagronet.com/indiaagronet/crop%20info/wheat.htm#harvest, 21/12/2004)

In the period 1970-73 the average irrigated yield of gram in Karnataka was 348 kg/ha and a rainfed yield in the same period of 123 kg/ha. The period 1979-82 shows a productivity growth, the average irrigated yield was grown to 588 kg/ha and the rainfed yield was grown to 438 kg/ha. After this period the productivity growth of gram in Karnataka stagnated. In the period of 1986-89 the average irrigated yield was only 512 kg/ha and lower than the average of 1979 to 1982. The average rainfed yield over the period 1986-89 was 429 kg/ha and comparable with the period 1979-82 (http://www.ifpri.org/divs/eptd/dp/papers/eptdp20.pdf, 14/12/2004).
The yields in the fringe area of Dharwad-Hubli varied much between the households who cropped Bengalgram in Winter/Summer season. But we try to give an impression of the yields which were almost produced in the period of research. Based on the experiences of the landowner households, yields were known from 0.7-2.0 t/ha for a specific irrigated crop. The unirrigated crops over the categories got a yield in Winter/Summer season which varied from 0.8 to 1.6 t/ha. But as we have mentioned before, it is difficult to make a distinction between the irrigated and unirrigated yields. The various yield experiences of the landowners were also due to the different cropping patterns of the crop. It can be cropped as a single crop or as intercrop with its corresponding irrigation and yield differences. To compare the yields between the categories we will use the average irrigated yield of 1.35 t/ha. A large landowner household irrigated on average 0.7 ha, this results in an average yield of 0.9 ton. Small landowners have only an average irrigated yield of about 0.3 ton Bengalgram. It appears that the small yield advantage for Bengalgram with irrigation is benefited by the large landowners. But the water use intensity for Bengalgram will be relative low.

7.2.4 Cotton

The last crop we will discuss for the Winter/Summer season crop is cotton. Cotton is the only fibre crop in this row. Cotton is very sensitive to soil-water conditions. As we see in figure 7.1, cotton takes up the biggest share of the cropped ha of the large landowners. The small landowners only cropped 2.9% of their ha with cotton and the medium landowners 6.3%. But even 21% of the ha of the large landowners were cropped with cotton. This follows in general the pattern of the share of black soil over the categories. As we have seen in chapter four, the commercial cotton tracts are found east of Hubli and are cropped mainly on the black soils. And the large landowners are merely found on the blacksoils, as we have seen in table 4.4. The small landowners irrigated all the ha cropped with cotton and the medium landowners irrigated half their ha, which they cropped with cotton. This is a substantial contrast with the large landowners, who only irrigated 7.5% of the ha.
But before we will discuss this it is interesting to see what the absolute approach will be of the ha irrigated. We will use the same calculation for this, as we used by the other crops. The small landowner households irrigated on average only 0.08 ha of the cotton cropped ha. This is due to the low percentage of cotton cropping ha by the small landowners. A medium landowner household irrigated on average 0.2 ha of cotton and a large landowner household irrigated by approach 0.4 ha. It appears that in absolute numbers the large landowners irrigate a bit more hectares of cotton. This irrigation is relative low compared to the other crops, as we take into account that cotton is mostly cultivated as single crop. But cotton takes a long time to mature and only at the particular critical stages it needs more water. According to Lenka (1991) the irrigation in should be low and fixed during the early stages. A rapid growth rate than will be encouraged and it will mature almost uniformly. The flowering is the most rapid growing stage of cotton and requires more than 50% of the total water use. While cotton is a relative stable crop, soil and water stress during these critical stages reduces boll size,

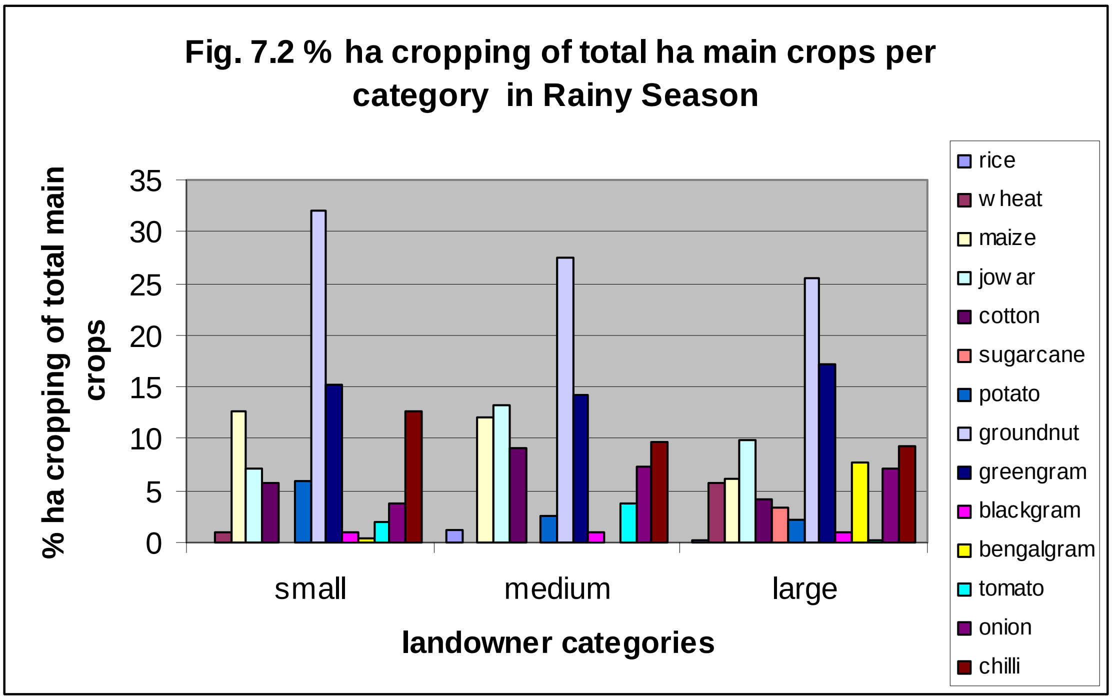
seed and lint. This will reduce the overall yield of cotton. The relative low share of irrigation on cotton by the large landowners is remarkable. But it is still the highest in absolute numbers over the categories. As we mentioned before, cotton is mainly cropped on the blacksoils, but the blacksoils need overall more water. This effect is maybe cancelled out by the higher water use intensity (litre/day in WS/SS, table 6.2) of the large landowners and the better soil conditions for cotton.

Productivity on Cotton
For the effect of irrigation on cotton, we have to look at the yields. Cotton is harvested by picking the fully opened bolls. The first picking of cotton will be done early in the morning, when 30-35% of the cotton-bolls are open. It should be picked separately over the different varieties. The second picking will be done 15-20 days after first picking. After picking, the cotton should be dried in 3-4 days in sun with due care. After that the cotton should be stored at a clean and dry place. During the monsoon irrigation may not be required but in light soils and low rainfall areas as in the dry and black soils two to three irrigations with a 15 days interval are adequate. The total water requirement is about 106 cm in Karnataka based on a satisfactory crop of 2.6-3.2 ton cotton/ha. But it is unknown on which product of the cotton crop these yields are based. In general, the effect of irrigation differs between irrigated and rainfed treated cotton but it depends also on the varieties. Investigated by the Agricultural Resource Centre the average irrigated yields for the improved and hybrid varieties vary between 2.0 and 3.0 t/ha and the rainfed yields over the different varieties vary between 0.8 t/ha and 1.5 t/ha. More specifically, the rainfed yields of the Desi varieties will be around 0.8 to 1.0 t/ha, the American variety yields will be 1.1 to 1.2 t/ha and the hybrid varieties around 1.2 to 1.5 t/ha. (http://indiaagronet.com/indiaagronet/crop%20info/wheat.htm#harvest, 21/12/2004). But compared to the average yields mentioned for the different varieties, the yields in Karnataka are very low. The recent yields of productivity in Karnataka over the nineties based on 25th Edition of the Indian Agriculture in Brief, and the Fertilizer Statistics show a fluctuating growth around 0.2 t/ha in the period 1990-91 to 1999-2000 with the highest average yield of around 0.3 t/ha in 1997-98 (http://www.ppi-ppic.org/far/farguide.nsf, homepage). To give an impression of the difference between the irrigated and rainfed yields of Karnataka, we have to look at the eighties. The average yields of Karnataka in over this period, differ also between the irrigated and rainfed treated cotton. The Irrigated yield of Karnataka over the period 1970-73 was 134 kg/ha and rainfed 23 kg/ha. For the period 1979-82 the average irrigated yield was grown to about 310 kg/ha against a rainfed yield of 83 kg/ha. Over the period of 1986-89 the average yield for cotton in Karnataka increased to an average irrigated yield of 419 kg/h and a rainfed yield of 122 kg (http://www.ifpri.org/divs/eptd/dp/papers/eptdp20.pdf, 14/12/2004).
The yields for Dharwad-Hubli over the year 2004, according to the Revised Crop Report 2003/2004, for cotton varied between 11 to 54 kg/ha. But according to the experiences of the landowners in the research period, the yields would vary between 0.2 to almost 0.5 t/ha. It appears from this information that the yields were not clear, but it will give an impression of the extremely low yields of cotton over these periods. Because of the fact that irrigation can make yield differences, it can be assumed that these low yields are mainly the result of the insufficient water supply during the drought. Many of the large landowners of the research population were reliable on canal irrigation. Almost 29% of the Winter/summer season cotton cropping landowners was reliable on this irrigation source, which was stopped by the government during the drought. This declares a part of these low cotton yields over these seasons. But because of their cropping and irrigation scale, the large landowners would benefit the most of this water use efficient commercial fibre crop.

7.3 Rainy Season

All the irrigating landowners cropped two seasons. Most of them cultivated different crops over the seasons. The distribution of cropping patterns differs between the Winter/Summer season and the Rainy season. In the part before we discussed the crops which were mainly cultivated in the Winter/Summer season. In this part we will discuss the most cultivated crops by the landowner categories in the Rainy season before. We will use again, the amount of ha which were cultivated with a specific crop, to make it comparable with the patterns of Winter/Summer season.

We will use the same selection of the main Indian crops, as mentioned in the crop characteristics, because these crops were cultivated the most by all irrigating landowners in the urban fringe of Dharwad-Hubli. Now, we will try to find out which crops are cultivated the most by the different socio-economic categories in Rainy season. As we did for the Winter/Summer season, we take all cropped hectares of these main crops together per landowner category, this will be 100 percent. Further we count the relative amount of cropped hectares for each crop separately over the socio-economic categories. The result of this for the Rainy Season is made visible in fig. 7.2.



Now it is possible to see which crops are cropped the most in Rainy season by each landowner category. From figure 7.2 it appears that groundnut is cropped on most of the hectares, by all landowner categories. Another relative big share of the cropping ha is seized by greengram. The other crops which take a relative big share in Rainy season by all landowner categories are chilli, jowar and maize. An interesting crop is Bengalgram which almost only cropped by the large landowners in Rainy Season. The main crops for the Rainy season will be discussed separately. In the context of the crops we can give the relative amount of ha irrigated by the socio-economic categories. And we will discuss effects of this irrigation on the yields.

7.3.1 Groundnut

The first crop we have to discuss is groundnut. Groundnut can be grown throughout the year when irrigation is available, but it is mainly cultivated during Rainy season. This appears also from figure 7.2, groundnut is relatively the most cultivated crop by all landowner categories in Rainy Season. Of the ha cropped by the small landowners in Rainy Season is 32% cropped with groundnut. The medium landowners cropped 27% of the ha with groundnut and the large landowners 25%. The relative shares of irrigation of these ha differ much. The small landowners irrigated 53% of their groundnut cropped ha and the medium landowners irrigated 31% of their groundnut ha. This is a much bigger share than the 2.9% of the large landowners. The large landowners irrigated a very small part of their groundnut ha in Rainy season. But if we like to get an impression of the average amount of ha irrigated by the landowner households in absolute terms we have to make the calculation we used for the main crops of the Winter/Summer season.
The average total ha cropping is over the seasons almost equal. Most of the landowners use their total land for cultivation in Rainy and Winter/summer seasons. The average irrigated ha of groundnut in Rainy season for a small landowner household can be found by approach with the average total ha cropping (table 6.3) multiplied by the 32% groundnut cropped ha and the 53% irrigated. For a small landowner household this will be about half a ha. The average ha irrigated by a medium landowner household is about 0.6 and the average ha irrigated by a large landowner is only 0.2. The large landowners do not spend much water on the groundnut crop in Rainy season compared to the other landowners. It appears that a medium landowner spend more water on groundnut than a small landowner. The relative high water use in the wet season is a result of the drought. The water supply from the monsoon would not be sufficient during the Rainy season and farmers had to irrigate for a relative good yield.

Productivity on Groundnut

Groundnut is sensitive to soil moisture, moisture stress during pegging and pod development reduces the pod yield. So, when we want to find the effect of irrigation on groundnut we have to take a look at the yield differences. The prominent symptoms of the maturity of groundnut are the yellowing of leaves and the shedding of the older leaves, but also a dark tint inside the shell. When there is adequate moisture in the soil, the bunch and semi-spreading varieties are usually harvested by hand. The spreading types are harvested by digging, ploughing or working a blade harrow. The pulled out plants are stocked a few days for drying and are stripped afterwards (http://indiaagronet.com/indiaagronet/crop%20info/wheat.htm#harvest).
Around 1998 the productivity of groundnut in India was about a ton per ha. The productivity level fifteen years before was about 0.7 t/ha, this is comparing to other countries deplorably low. The main reason for this is that about 80 percent of the crop is grown under rainfed conditions. The average productivity under rainfed conditions is only about 0.8 t/ha, due to droughts, pests and diseases. On the other hand, the Winter/Summer season groundnut, grown under irrigating conditions or residual soil moisture gives almost double yields (S. Talawar, Peanut in India: History, Production, and Utilization, University of Georgia, http://lanra.anthro.uga.edu/peanut/download/india.pdf, 9/12/2004).
The average Karnataka yields of groundnut over the nineties show a growth and decrease. The yields from 1990 to 1994 based on 25th Edition of the Indian Agriculture in Brief show an increase from 0.7 t/ha to about 1.0 t/ha. From 1995 to 2000 the yields based on Fertilizers Statistics of the Fertilizer Association of India, show a decline in the yields from about 1.0 t/ha to 0.7 t/ha in the period 1999-2000 (http://www.ppi-ppic.org/far/farguide.nsf, home site).

As we have seen, groundnut in the urban-fringe of Dharwad-Hubli, is mainly cropped in Rainy season. The average yield of groundnut in Rainy season, according to the Revised Crop Report 2003/2004 of Dharwad-Hubli, was about 0.8 t/ha. This is relative comparable with the average Karnataka yields. The numbers about the differences in irrigated and unirrigated groundnut are unfortunately not known.
The distribution of these yields for groundnut is not in favour of the large landowners. As we have seen before, a large landowner irrigated only 0.2 ha, while even a small landowner household irrigated on average 0.5 ha. The landowner households who benefit the most of the assumed higher yields with irrigation are the medium landowners, who irrigated on average 0.6 ha. As we mentioned, groundnut is sensitive to soil moisture, but even when water is applied are the yields relative instable. The given above tells us something about the instability of the yields. As we have seen, the yields are in general low, with high fluctuations over the years.

7.3.2 Greengram

Greengram is the second main Rainy season crop in the urban fringe of Dharwad-Hubli. Greengram is like Bengalgram also one of the so called pulse crops. We mentioned already that most of the pulse crops are grown as mixed crops with cereals and no special attention was paid to their cultivation. But as we have seen by the crop characteristics the flowering and pod development periods are susceptible to moisture stress. Some water in these periods is required. From figure 7.2 it appears that in Rainy season 15% of the ha cultivated by the small landowners, were cropped with Greengram. This share is comparable with that of the medium landowners who crop 14% of their ha with greengram. Greengram takes up a bigger share of the ha of the large landowners. The large landowners crop 17% of their land with greengram in Rainy season. The relative irrigated shares differ more over the categories. The small landowner specifically irrigated 35% of their ha cropped with greengram. This is relatively more than double of that of the medium landowners, who irrigate 14% of the ha. And the large landowners irrigate only 8.2% of the ha cropped with greengram. For the approach on the absolute numbers of ha, does this mean that a small landowner household irrigated on average 0.1 ha of greengram. A medium landowner household irrigated, despite of its relative share, by approach the same. Because of their cropping scale, irrigated a large landowner household the most of the ha of greengram, about 0.3 ha. It appears from figure 7.2 and this information that greengram is an important (mixed)crop for the large landowners in the Rainy season, with a high percentage of specific irrigation. This is remarkable as we take into account from table 7.1, that greengram does not require much water in Winter and Summer season. The amount of additional irrigation water will be even lower for the Rainy season. We may assume that because of its relative high amount of cropping hectares, it is not a typical mixed crop around Dharwad-Hubli. The landowners cropped this pulse crop mainly because of the drought. And because of its high amount of ha cropping, more attention is paid on its growth and irrigation.

Productivity on greengram

Greengram is harvested before it is dead ripe. To avoid loss because of the shattering of pods there are one or two rounds of the picking. The plants are uprooted or cut with a sickle, and will be dried on the threshing-floor for a week or ten days. After drying it will be threshed by sticks and winnowed with baskets. The average yield of the grain from a pure crop varies from 0.5-0.6 t/ha, but potentially yields up to 1.0-1.5 t/ha. The yield in case of mixed or intercrop, which is mostly the case, depends upon the plant population (http://indiaagronet.com/indiaagronet/crop%20info/green_gram.htm, 21/12/2004).

The yields of gram in general always staid relative stable. In the period 1970-73 the average irrigated yield of gram in Karnataka was about 0.3 t/ha and a rainfed yield in the same period of 0.1 t/ha. The period 1979-82 shows a productivity growth, the average irrigated yield was grown to 0.6 t/ha and the rainfed yield was grown to 0.4 t/ha. After this period the productivity growth of gram in Karnataka stagnated. In the period of 1986-89 the average irrigated yield was only 0.5 t/ha and lower than the average of 1979 to 1982. And the average rainfed yield over the period 1986-89 staid the same as in the period 1979-82 (http://www.ifpri.org/divs/eptd/dp/papers/eptdp20.pdf, 14/12/2004).
The average yields around Dharwad-Hubli did not differ much between irrigated and rainfed treated greengram in Rainy season. Given the yield indication on the experience of the farmers, the average rainfed yields and the irrigated yields are almost equal around 0.8 t/ha. The large landowners cropped and irrigated on average the most of the ha. But there are no specific yield differences in the irrigated or unirrigated greengram crop. Irrigation will only give some more stability and certainty for a good crop growth, but the relative irrigation intensity will be low. The average yield was lower than the potential yield for Dharwad described in the crop characteristics found by Lenka (1991). These lower yields are mainly the result of the insufficient required additional rainfall in Rainy season. With only two required additional irrigations during the periods of flowering and pod development, is greengram a water use efficient crop. Because of the small yield difference between irrigated and rainfed greengram, it can be assumed as a relative stable crop even in drought periods.

7.3.3 Chilli

Chilli is an important crop for both seasons, but will be mainly found in Rainy season. But the main crop of the spices can grown throughout the year. As we see in figure 7.2, chilli is relatively equally distributed over the categories in Rainy season. The small landowners cropped over 13% of the ha, whereby 61% was irrigated even in Rainy season. The medium landowners cropped 10% of their land with chilli in this season. And the large landowners cropped about the same relative amount of ha as the medium landowners, which was 9%. But the large landowners irrigated relatively more of these ha than the medium landowners. The large landowners irrigated 49% of the ha cropped with chilli in Rainy season. And on the other hand the medium landowners irrigated 44%, the relative smallest amount of irrigated ha. But as we take a look at the absolute average of ha irrigated by the landowner households, we will get another distribution again. The ha of chilli which are irrigated on average by a small landowner household are by approach 0.2 ha. Compared to a medium landowner household, who irrigated by approach 0.3 ha, is this the smallest amount. Because of their cropping scale irrigated a large landowner household, on average a substantial amount of 1.1 ha. This is much more than the impression we get from the medium and small landowner categories. In general is the chilli crop mostly raised as rainfed crop, but annual rainfall should be around 80-100 cm and well distributed. In Northern parts of Karnataka where the rainfall is around 80 cm (total over the two monsoon peaks), it is extensively cultivated as a rainfed crop during Rainy season. But the insufficient water supply from rain during the drought made the crop dependent on additional irrigation. This is the reason for the relative high shares of irrigated ha over the categories. But for the irrigation of chilli it is interesting to mention how it is irrigated in the field. According to Lenka (1991), a high yield of chilli requires around 40 cm irrigation (Lenka, 1991). In general 50% of the already irrigating landowners are using the furrow irrigation technique to irrigate their chilli fields in Winter/Summer season these are mainly small landowners, the large landowners in this case are using sparkler installations. Alternate and widely spaced furrow irrigation with 20 mm depth of water per irrigation required about 40% less irrigation water as compared to every furrow irrigation with 40 mm depth of water. This water use efficiency did not have significant reduction in yield levels. The magnitude of water savings with this method according to Ikisan, would be an application for much of the semi arid regions of India, especially on soils with good lateral movement of water (http://www.ikisan.com/links/knt_chilliVarieties.shtml, 29/12/2004).

Productivity on chilli

For the effect of irrigation on chilli we have to take look at the yields. Chilli gives very good growth if the plants are pruned after complete harvest of red ripe fruits or green fruits in sweet pepper. The ripe chillies are harvested and heaped over night on the threshing yard. Half ripe red chillies colour even out during this night heaping. The next morning the chillies are spread over the cement of the threshing yard for sun drying. The chillies of the Rainy season harvesting commences after October around the cessation of monsoon. It appeared that during the Rainy season in Dharwad-Hubli, two protective irrigations gave a significantly higher fruit set and a yield of about 2.3 t/ha as compared to an unirrigated yield of 0.9 t/ha for red ripe chillies on sandy loam soils (http://www.ikisan.com/links/knt_chilliVarieties.shtml, 29/12/2004). But there are also more varieties which can be distinguished of chillies. Another important chilli variety is the sweet chilli or pepper. This crop has also its particular characteristics and corresponding yields, but has to be irrigated. Sweet pepper is an important vegetable grown under irrigated conditions. The crop is more sensitive to soil moisture, which is one of the predominant factors influencing its productivity. Irrigation reduces the yield of first picking but increases the second and subsequent pickings. The pigment content was reduced by irrigation but compensated by increased weight of the dry fruit. Excessive irrigation is to be avoided on heavy soils where drainage is slow. Soil moisture does not affect the fruit set but affects the fruit drop. At Dharwad, the fruit set is higher with about 41 percent with two protective irrigations at 40 and 60 days after transplanting whereas it is hardly about 11 percent under rainfed conditions (http://www.ikisan.com/links/knt_chilliVarieties.shtml, 29/12/2004). It was difficult to find a particular range of yields in the urban fringe of Dharwad-Hubli for chilli. This was mainly due because of some daily and weekly market harvests. According to the Revised Crop Report 2003/2004, the Rainy season yield was about 0.6 t/ha. These yields are deplorable low in contrast to the yields discussed before. But when we ignore the daily and weekly harvests, we found some average irrigated yields based on the experiences of the landowners. The average irrigated yield of the medium landowners was the lowest, with 1.5 t/ha. The average irrigated yield of the small landowner in Rainy season was 1.6 t/ha. The large landowner households had besides the highest average irrigating ha as result of scale, also the highest average yield. The yield of the large landowners for chilli in the Rainy season was even 2.1 t/ha. This bigger scale of chilli cropping and its irrigation, results in higher yields with assumed corresponding profits for especially the large landowners.

7.3.4 Maize

The last main crop we describe here is maize. It is not the most important crop for the Rainy season but it has to be mentioned. The cultivation of maize in India is mainly due to the Green Revolution. Maize was mostly grown in Rainy season but with the increased irrigation facilities its cultivation is also increasing in Winter and Summer seasons. The Rainy season crop normally does not need any irrigation when most of the water requirement is met from rainfall, but because of the three years drought the research population had to use irrigation. Maize displays an appreciable tolerance to moisture stress. But during the critical growth phases additional irrigation was necessary. Maize is more sensitive to excess soil moisture and is mostly grown on ridge areas with poor drainage or heavy rain in black soils, for a good root penetration (Lenka, 1991). But in general maize requires continues light soil moisture and the overall water demand is relative high. Maize was cropped on 13% of the land of the small landowners. This is comparable with the share of the medium landowners, who cropped 12% of their ha with maize in Rainy season. Maize plays a relatively smaller role for the large landowners. But maize is still cropped on about 6% of the ha of the large landowners in this season. But the shares which are irrigated are more interesting. The small landowners irrigated 65% of the ha cropped with maize. This is relatively more than the medium landowners who irrigated only 36% of the maize. But the large landowners with the smallest share of cropping, irrigated 86% of the maize. This means that irrigation of maize was more important for the large landowners. The average absolute numbers of ha irrigated by a small landowner household will be 0.2. This is even lower than the average ha irrigated by a medium landowner household. A medium landowner household irrigated almost 0.3 ha, which is mainly due to the higher average total ha cropping. This average total ha cropping of the large landowners will give also a higher amount of ha irrigated maize for the large landowners. It appears that by approach a large landowner household irrigated almost 1.3 ha of maize. The high amount of ha irrigated by the large landowners reflect the relative high overall water use of maize. Despite of its tolerance to moisture stress, maize is because of its high overall water demand not an economical crop.

Productivity on maize

Maize with its different varieties can be also sown for different aims. Maize grown for fodder should be harvested at the milk to early dough stage, the earlier harvested crop is likely to yield less and have lower protein content. But the maize crop sown for grain is harvested when the grains are nearly dry and do not contain more than 20 per cent moisture. The maize stalks are used as cattle feed or fuel. No part of the maize plant is mostly left unused.

There are a lot of restrictions for the farmers who crop the high yielding varieties. The farmers who crop this hybrid maize can not easily save their own seed for their next crop, because the advanced generation of hybrid seeds is likely to yield a reduction of 25-30 per cent. But they are able to save seed from composites and open pollinated varieties, when it is grown in isolation. The seeds from the best yielding and normally spaced plants, resistant to prevalent diseases and pests, should be bulked. The ears should be dried, shelled and treated with an insecticide. Untreated seeds on ears are at times badly attacked by stored grain pests and the germination is markedly reduced (http://indiaagronet.com/indiaagronet/crop%20info/wheat.htm#harvest, 21/12/2004).

Considerable variation in grain yield is observed. The yield levels depend mainly upon the variety, the amount of the fertilizer used, and the rainfall or irrigation pattern etc. Under irrigated conditions and these cultural practices, an average yield of 4.0 t/ha in the Indo-Gangetic Plains is not uncommon. In the Indian peninsular at higher elevations, a mean yield of 5-7.0 t/ha has frequently been obtained. But under low fertility and rainfed conditions with poor yielding varieties, a grain yield of about 2.0 t/ha is obtained (http://indiaagronet.com/indiaagronet/crop%20info/wheat.htm#harvest, 21/12/2004).

In 1997 produced India about 9.4 million tons of maize and the average yield over India was about 1.6 t/ha. There is a large difference in the yields in various states. The average yield for Karnataka in 1997 presents a yield of 3.6 t/ha and was one of the highest yields of the country (http://www3.interscience.wiley.com/cgi-bin/fulltext/55003746/PDFSTART, 14/12/2004). Also over the period 1980-1988 had Karnataka a constant high yield for maize of around 2.6 t/ha per year compared to the average of India with a yield of 1.2 t/ha per year (http://wgbis.ces.iisc.ernet.in/energy/agriculture/table9.html, 14/12/2004). However, the area under maize in Karnataka is small, only 5.5 percent of the total cropped area (http://www3.interscience.wiley.com/cgi-bin/fulltext/55003746/PDFSTART, 14/12/2004). Based on the Fertilizer statistics of the Fertilizer Association of India, the recent productivity yields are known for the years 1994 to 2000. For the year 1993-94 the average productivity in Karnataka of maize was still high, about 2.8 t/ha, with almost the same yield over the year 1999-2000 (http://www.ppi-ppic.org/far/farguide.nsf).

The total average yield around Dharwad-Hubli in Rainy season, based on the experiences of the landowners, was about 3.6 t/ha. But these yields are a bit dubious in the context of the drought. But according to the Revised Crop Report 2003/2004, the average yield was still about 3.0 t/ha. A possible reason for these high yields has to be the relative high share of irrigated maize. The small landowners crop relatively the biggest share of ha with maize and irrigated a substantial amount. But only 0.2 ha was irrigated by a small landowner household. The biggest share of irrigated ha, because of their bigger cropping scale, benefits especially the large landowners, with these good yields of maize. Beside the crops' appreciable tolerance to moisture stress, the landowners pay obviously much attention on the irrigation of maize, especially the large landowner households.

7.4 Crops, irrigation and socio-economic consequences

The categories responded with different cropping patterns over the seasons, though the relative water use efficient crops dominated in both seasons. All these crops we discussed here are relative resistant to drought circumstances. Maize requires most of the water, while jowar, wheat and the pulse crops are very water use efficient. From the interviews it appeared that the farmers cropped in general the same crops before the drought, but we may assume that during the three years of drought there was a shift in the amount of cropping hectares to more water use efficient and stable yield crops, to avoid yield reductions and to minimize the risk of bad harvests. This shift is mainly due to the reduction in water supply from rainfall and the decreasing groundwater level. On the other hand, the shift in cropping pattern possibly minimized the economic yields, but these cropping patterns were more water use efficient and resistant to the drought. In this case it is also interesting to mention that in a research about sole cropping and intercropping it appeared that economic and by-product yields of each crop were grown to maximum as sole crop, but reduced when grown as intercrop. On the other hand the value of irrigation water use of any intercropping system was less than the summation of the use of crops grown as a sole crop. Deep percolation loss of water was more in sole crops than in intercrops. This means that intercropping increased the water use efficiency (Lenka, 1991). This declares possibly the relative high share of the pulse crops in both seasons, which are in general grown as mixed crops with cereals. As we mentioned before, no special attention is normally paid to their cultivation, but a low amount of irrigation was needed in both seasons during the drought. The additional residual irrigation water of the cereals was possibly sufficient for good yields of the pulse crops in both seasons.

As we have seen, the socio-economic distribution of irrigation water, which we discussed in the chapter before, had its empirical impact on the production in both seasons. The relative distribution of the main crops (fig. 7.1 and 7.2) was comparable over all the categories. Only the share of cotton was relatively high for the large landowners in Winter/Summer season. The relative cropping shares of the main crops were overall lower by the large landowners. This is mainly due to the relative high share of other main crops cultivated by the large landowners. With the discussion of the main crops and its responds to irrigation we found that in general the large landowners are better off. This is mainly the result of their bigger scale of cropping and irrigation. The water use costs were for all landowner categories low, and the electricity costs for the bore-wells were even negligible during the period of research. It appears that the large landowners benefit the most of this. The large landowners are over almost all the crops we discussed, more productive than the other landowners. For some crops, like wheat (W/S season) and chilli (Rainy season), we found that even the average productivity was specifically higher for the large landowners. Only groundnut is a remarkable exception on this given. Groundnut is relatively the main crop for all landowner categories in Rainy season and is relatively sensitive to soil moisture. This would mean that more ha should be irrigated, but the most of the ha were irrigated by the medium landowners followed by the small landowner households. When we look at the yields of groundnut, it appears that the yields for groundnut were still low and did not differ much between the irrigated and unirrigated crop. Though groundnut is the least irrigated main crop for large landowners, it appears that there is still a limited loss. For all the other crops have large landowners a scale advantage. The high production gives the large landowners a corresponding better profit, compared to the other landowner categories. The result is that these large scale profits enable large landowners to make new investments, which gives the large landowners a cumulative advance. New investments in irrigation facilities enable large landowners to improve the water conditions for their crops. This can be investments in more bore-wells or new technologies. There are new technologies which enables farmers to irrigate more crops more efficiently. Investments in these technologies give large landowners an opportunity to increase their yields. These cumulative effects are, because of their smaller cropping and irrigation scale and their less creditability, much lower for the small and medium landowners. As we can imagine, there will be a growing socio-economic disparity between the irrigating farmers.

7.5 Diversification in crops

It appeared from the figures 7.1 and 7.2 in this chapter, that the cropping patterns were different over the seasons but comparable over the categories. As we mentioned before, the relative distribution of the main crops was lower by the large landowners. This was mainly due to the relative high share of ha cultivated with the other main crops by the large landowners. We did not discuss these crops specifically, but we may assume (according to the description in the appendix) that crops like sugarcane, potato, tomato and onion require in general more water than the crops we discussed in this chapter. It appears from the figures that the large landowners cultivated relatively more ha with sugarcane and onion (in Winter/Summer season), than the medium and small landowners. In this case it is interesting to know if the large landowner households also cultivated on average a more diverse cropping pattern in both seasons. We found that a large landowner household cultivated on average 3.2 types of the main crops, while the small landowners cultivated on average only 1.8 different types in Winter/Summer season. A medium landowner household is situated in between and cultivated on average 2.5 types of the main crops. In Rainy season cultivated a large landowner household on average 4.2 different types, a medium landowner household 4.1 and a small landowner household 2.4 different types of the main crops, mentioned in the figures 7.1 and 7.2. It appears that large landowners cultivate a more diverse cropping pattern in both seasons.

Crop failure and fall of market prices can be usually a reason for farmers to cultivate a more diverse cropping pattern, to spread these risks. Risk minimizing brings in a divers cropping pattern, with a lot of intercropped crops. As the economic law play also a role on the agricultural market in Dharwad-Hubli, the more supply of the same crops the lower the prices and the less negotiable power of the farmers. It can be assumed that the small landowners should be more vulnerable for these risks, because their investments and repayments are more dependent on their yields. To avoid total crop failure or fall of market prices, the small landowners should have a more diverse cropping pattern. But this risk minimizing by diversification would be based on the cultivation of more water demanding high yielding commercial crops, in combination with water use efficient and stable yield crops. This is actually not the case here. As we see the diversification is the lowest by small landowners and the highest by the large landowners in both seasons. The main reason for this higher crop diversity by large landowners is based on the farmers' responds to the drought. As we have seen, these stable yield and more water use efficient crops were the main cultivated crops during the drought. This is mainly due to the insufficient water supply. Crop failure was a common phenomenon during the drought. To avoid crop failure, the farmers had to respond with changes in their seasonal cropping patterns. The availability of water decided the cropping patterns of the landowners. And because of the fewer amounts of water resources available by the small landowners, they specialized more on the cultivation of more water use efficient and stable yield crops. The higher amount of bore-wells gives the large landowners a particular security to crop more ha with other varieties, which fetch good prices in a particular season. The cropping diversification of the large landowners with high economic yield crops like sugarcane, onion and particular chilli varieties, is typical for the urban fringe area of Dharwad-Hubli. The costs and problems of storage for these products are relative low because of the nearby markets and the profits are high.

8. Strategies and Perspectives of the irrigating Agrarian Households

In the chapters before the information about crops, yields and water use were divided over three socio-economic categories. As we mentioned in chapter four these categories were defined by Hunshal and Nidagundi (1998) in small, medium and large landowners. The idea about using categories of landowners, instead of farmers, was based on their property. We have also seen that because of a drought during the fieldwork, more than 90% of the landowners relied on bore-wells for their irrigation. The possession of a bore-well is in most of the cases based on private investments. These private investments can be made more easily when the households have capital. The easy way was to define land as capital.

In the chapter before we have seen that the amount of land plays a role in the scale of cropping. But this does not mean that large landowners had in general higher yields per ha. The growth of yields is mainly dependent on the investments they make on productivity improving facilities. Large landowners can get more easily credit for investments they make, because they are more credit worthy. The reason for this is that land can serve as a pledge for this credit, but possessors can also sell it or a part of it. This includes that the credit worthy declines with less property of land. This was the main reason for the average higher amount of bore-wells per landowner for large landowners in table 6.1. The pattern over the landowner categories of the average amount of bore-wells per landowner follows the credit worthy patterns as described. As almost logical result, it appears that the average litre/day water use per landowner in Winter/Summer season follows the same pattern over the landowner categories.

But it appeared from chapter seven that the bigger scale of irrigated production, more diverse crops and the low costs led to more profit for especially the large landowners. This enables them to make new investments on productivity improvement. From chapter seven it appeared that irrigation improved the productivity for the majority of the crops. The way to improve the productivity of farmers is to invest in new technologies of irrigation systems. This is what happened with the investments in the new bore-well technologies.

As we have seen in chapter seven, the small landowners did not have the scale advantage and crop diversity, and lack the cumulative effects of this. They have on their turn less capital, and are hardly in the position to make investments to improve the productivity. Because of their scale of production are these potential investments relative high to their profits. But it is interesting to mention that the investment in one bore-well system with an average capacity will have a bigger impact on the relative irrigated land as part of their whole for small landowners. This is also shown in table 6.3, where the percentage irrigated hectares per cropping ha for small landowners is the highest. Because of this relative bigger impact for especially the small landowners, it makes the investments still attractive. The majority of the small landowners of the research population already made investments in at least one irrigation system. But in most of these cases were the investments high and the yields for repayment low during the drought. On the other hand became the bore-well a necessary instrument for irrigation during the critical stages of the crops, to avoid total crop failure. A small landowner household had more problems to make the necessary investments or struggled with the repayment. In this chapter we will discuss some of the household strategies, which were used by the landowner households in the urban fringe of Dharwad-Hubli. The means that enabled the households to make the necessary investments will be discussed as strategies.

An interesting strategy to keep the financial means within the family is the joint family. It is common in India to keep bigger agrarian households together within joint families. The main reason for this is that the families do not have to divide their land over the sons who would be the traditional heirs. This would keep the capital together within the family. Of all the households we interviewed, 61% were part of joint families. Divided over the socio-economic categories we find that almost 49% of the small landowner households were part of a joint family. Of the medium landowner households 93% were part of a joint family and of the large landowners 68% were joint families. A logical reason for this distribution over the socio-economic categories is that after dividing the heritage of land under more sons, land becomes smaller. After this partition a household becomes nuclear, probably with private land smaller than five hectares. This declares that a bigger share of 51% of the small landowners is a nuclear household. The traditional dividence of land declares also the high percentage of joint families under the medium landowners. If the medium landowners decided to divide the land traditionally, most of the heirs become nuclear small landowner household, which gives them less common capital to make necessary investments.

Another important strategy of the landowner households is diversification. In the chapter before we mentioned the diversification in cropping pattern, to avoid the risk of crop failure and price fall. But in this case we will discuss the diversification in jobs within the agrarian households, as risk minimizing strategy. Micro-studies make the point that all-India generalisations are bound to misleading, but what can be stated with some confidence is that there is a tendency that dependence on 'self-employment' of farmer households, has declined in importance through the 1980's, in favour of dependence on casual daily paid wage employment, which has become more significant. For India the National Sample Survey data showed also a significant and sustained tendency towards the diversification of rural occupations (Harriss, 1992). A condition for diversification of a household is the availability of jobs. According to Harriss (1992), the extent and nature of rural non-agriculture in this case is often of crucial importance. The Levels of livelihood almost certainly depend significantly upon the availability of productive non-agricultural employment.

This condition is easily met for the farmers in the urban fringe of Dharwad-Hubli. The twin city gives many alternative employment opportunities for agrarian household members. In almost 33% of the households in the research population, there was at least one member with a non-agricultural job. Seen over the socio-economic categories it seems that in all landowner categories this diversification has taken place. These jobs could vary between government servant, teacher, factory worker, merchant, construction worker etc. All these jobs were mainly jobs in the city and are mainly based on contracts. The ICRISAT researchers already concluded that in rainfall unassured villages in the semi-arid tropics changes in off-farm employment will play a larger role in conditioning wage levels and contractual relations than opportunities for agricultural employment within the village (Harriss, 1992). But it can not be confirmed from my research, that the landowner households were totally dependent on the conditional wage levels of the family member with the non-agricultural job. It depends on the contractual relations of the job if the households are dependent on their wage. But the wages of other non-agricultural jobs are at least responsible for particular investments by the family.

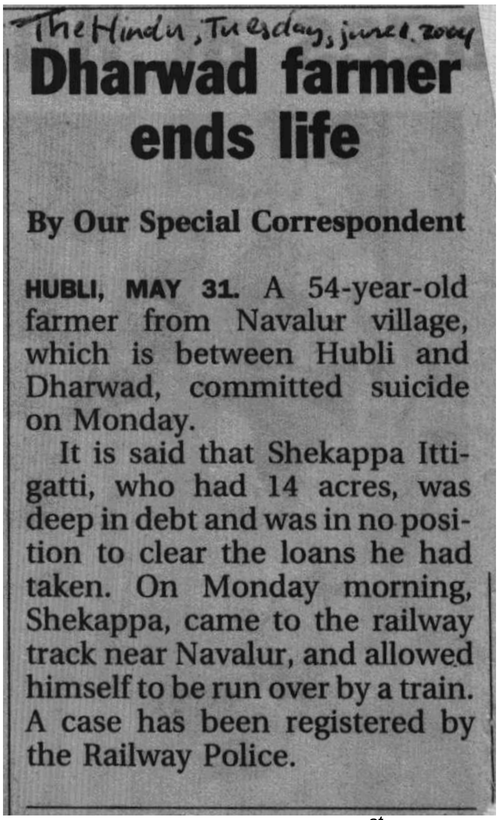
This strategy of diversification is complementary with the existence of joint families. It appeared that in most of the joint families there is diversification in jobs. Combined with the knowledge about family types in the fringe area of Dharwad-Hubli, it appeared that 71% of the diversified households concerned a joint family. A potential reason for this is there are sufficient agricultural labourers within the family. And more important with common capital it is possible to invest in education for one or more members.

Some other strategies of the landowners in the urban fringe of Dharwad-Hubli are sponsoring, contracting and trade of land. Sponsoring is defined in this research as external finance from relatives outside the household and acquaintances. But this did happen only in some cases, mainly from relatives outside the household. Contracting on the other hand is more used by the farmers. With contracting it is in the interest of the merchant or agency that a farmer does not want to store their crops, which gives the merchant or agency a better negotiable position. The merchant or agency on their turn, stocks the crops. Prices are mostly fixed before. The merchant or agency benefits if the crops have a good quality or when demand appears high, and can sell the product for a higher price. The farmer also benefits, even if the market prices fall, he still gets a relative good price. The agencies on their turn control the supply to keep market prices high. In some cases it is possible that the merchant provides the input, and the farmer get only paid for its labour to raise the crops. The advantage of the farmer is that he gets more stable future prospects and does not have many costs. But in most of the cases of contracting it only concerns the option of the merchant or agency on the crops. The strategy of contracting is almost relatively equally applied by the farmers over the three socio-economic categories.
There are also more small initiative strategies of farmer households to identify. Some rich farmers had a tractor to plough the land, and do threshing of his wheat, and rent these out for ploughing, threshing etc. and earn a good deal of amount.
One interviewed landowner started a brick production, and used the clay soil layer of one acre of his land as raw material. In some cases a household member started to sell their own crops directly to the market, to require better prices. And some mainly poorer households from lower castes seasonally worked on other farms. Even during hard periods or droughts higher castes do not make use of this strategy, because of their status and proud within the village.
And some farmers started to sell water to neighbouring farmers, when their bore-well worked well. The most common price which was paid by the neighbouring farmers is half the yield of the crops from the irrigated acres. In one case a farmer sold the water for 2500 Rs/acre.

The strategy of changes in land is two sided. It concerns the selling or rent out but also the purchase or rent in of land. In all cases it can be an advantage for the landowner household. The selling of land is seen as an option in later stages of repayment problems, by many landowners. Only in a few cases, a part of the land was sold within the recent four years, because of the causes of drought. But in most of the cases where land changes took place it concerned land dividing within the family.
In some cases farmers stopped renting in, because of disappointing yields. But in many cases rented the farmers more land within the four years. Renting of more land by many farmers indicated expected good yields. We have to make the command that the research population was based on irrigating and mostly more advantaged farmers. Reasons for renting more land were for example compensating the small residual land after family dividing, or more work for the household members. In one case it appeared that a landowner sold 1.6 ha to get the assets for investment in a bore-well, and rented the 1.6 ha again for half of the yield.

There is also another important application of farmer households to keep their farm running during the drought. Because of crop failure during the drought, many farmers

took bankloans, a credit which is comparable to their financial yields. In some cases farmers took more bankloans to finance the investment in one or more bore-wells.
According to Nair (1999), the fact remained that farmers, who were exposed to the market, particularly in the wake of globalisation, were in general not protected against the losses they suffered on account of poor harvest. The farmers, particularly small and marginal farmers, grow cash crops that promise higher open market prices. But when the crops failed to yield returns, farmers faced serious problems, particularly in the matter of repayment of loans they have taken at heavy interest rates. In the absence of good insurance facilities available to tackle such an eventuality, farmers turned to drastic steps like suicide (Nair, 1999).
These drastic steps became more common in the newspapers in the third year of the drought. Crops failed and bankloans were grown to exceptional amounts. Partly because of disinvestments in failing bore-wells or which felt dry after too much use.


The Hindu, Tuesday, june 1, 2004

Dharwad farmer ends life

By Our Special Correspondent

HUBLI, MAY 31. A 54-year-old farmer from Navalur village, which is between Hubli and Dharwad, committed suicide on Monday.

It is said that Shekappa Ittigatti, who had 14 acres, was deep in debt and was in no position to clear the loans he had taken. On Monday morning, Shekappa, came to the railway track near Navalur, and allowed himself to be run over by a train. A case has been registered by the Railway Police.

Source: The Hindu, june 1st 2004

9. More sustainable use of irrigation water

The Green Revolution-led growth in food production and the population increases have led to an over-use of water. Nationwide withdrawals of groundwater are estimated to be double the rate of recharge and water tables are falling by one to three metres per year. With the population projected to increase to 1.3 to 1.4 billion by 2020, the per capita farm land availability will decrease. According to Virmani (1999), we seem to be headed towards a scenario of distress which may be filled with food, water and energy famines.
Mentioned already in the theory, scientists are particularly worried about the decline in productivity of many soil and water systems, especially in high population growth regions. Meeting the increasing needs of food and fibres, the resource base for food production should be preserved. The fundamental problem is that water almost everywhere involves abuse, waste and even tragedy, especially in urban growth regions, where the balance between population, soil and water is more vulnerable for especially farmers. This has its impact on the sustainability of these agricultural systems.
Within the theory of sustainable development, which we discussed in the theory, there has to be an improved balance between its main dimensions. The three main dimensions of sustainable development are the economic, ecological and the social dimension. The combination of these dimensions on sustainable development in agriculture led to the concrete idea that the agricultural productivity must be enhanced while its resource base is conserved. And the resource base on which agricultural production is based, are the resources soil and water (NRC. 1991).
In the context of water-management in agriculture, as we mentioned in the theory, we showed that the agricultural production on household level depended on a total combination of physical features which included soil, technology, social and governmental institutions. To enhance the agricultural productivity in a sustainable way, water and new techniques has to be managed in this context, to intensify the use of quality lands while minimising the environmental degradation (NRC, 1991).
As we mentioned before, water is a renewable resource, but it appeared from the research in the urban fringe of Dharwad-Hubli, that there was actually no water supply, because of a long during drought of three years. Water became the main constraint, and the availability of water the main condition for agricultural production. In this chapter we try to describe the problems and the consequences of this water constraint. And further we will discuss the impact of this water constraint on the sustainable development in agriculture around Dharwad-Hubli. We will do this on the hand of the operational properties of sustainable development in agriculture, which we distinguished in the theory. The operational properties for the measure of sustainable development in an agricultural system are productivity, stability, equitability and diversity.

9.1 Irrigation with bore-wells

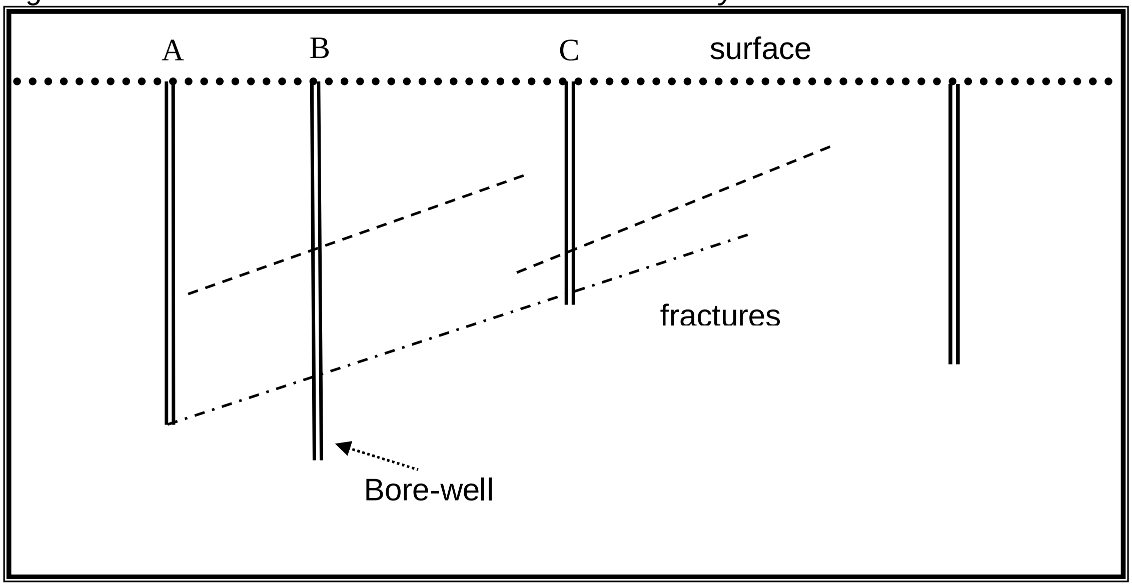
Because of the insufficient water supply, the farmers were dependent on irrigation. But most of the irrigation sources were all dried up during the three years of drought. This is one of the reasons why farmers around Dharwad-Hubli started to pay more attention on use of the underground groundwater storage and on the use of bore-wells. This recent attention appeared from the fact that almost 50 percent of the first bore-wells of the farmers in the research population were not older than three years.
As we mentioned in chapter six, the environmental conditions for a bore-well were mainly geologically. The deeper layers were hard rocks as granite and granite gneiss, with lots of fractures, which run slope through raised sides of the Dharwar plateau. The fractures regulate the exchange of groundwater between different levels of altitude in the

soil. The fractures in the soil layers are crucial for the localisation of the bore-well. The localisation process is complex and not without risk. To optimize the yield of the bore-well, geological research on presence of fractures is necessary. In most of the cases play geologists a part in the decision making process of landowners.
An important inessential reason in the use of bore-wells by a farmer, is their relatively independence. The total decision making process of digging a bore-well is reduced to the landowner household. This process of investment making for private purpose makes the farmers relatively independent of government intervention in water use. Landowners make their own decisions, sometimes democratically within the household, on the amount of irrigation water they need. There are no regulations on the amount of water they fetch.
As we mentioned in chapter six, the investments for a private irrigation-system are very high. The total investments in a bore-well for a farmer exist out of the sum of digging, motor costs, pipelines, casing and field irrigation systems. This will bring their total average initial investments to an approach of 100 thousand Rupees. These investments can be high for a lot of landowner households and vicious circles of depth are common as we have seen in chapter eight. But these costs will be lower for the purchase of more bore-wells, because of the existence of pipelines and field irrigation systems.

9.2 Sustainability problems

In arid and semi-arid regions is this groundwater potential extremely poor. According to Virmani (2000), are the semi-arid areas of India populated beyond their current carrying capacity and are already facing acute food and water shortages. The water-use in particular far exceeds its regeneration capacity. There is a strong decrease in the balance between the utilisable ground water recharge and the net draft, groundwater is being extracted or pumped out at faster rates by installing high powered pumps (Virmani, 2000). The consequences of this high extraction were visible during the drought around Dharwad-Hulbi. The impact of the drought and water use was mainly visible in change of the bore-well yields. It appeared from the interviews that by almost 21% of the households who were irrigating with bore-well, the bore-well yields (in inches) were decreased within 3 years. For example changes from 4.5 inch to only one inch were the case, which involves an approached decrease in yield from 6.3 to only 0.18 litre/second. This yield decrease during the drought was mainly due to the fall in water level due to the use of groundwater and partly caused by insufficient supply from rainfall.
The amount of bore-wells including type of pump set, becomes decisive for the amount of irrigation water used in the region. An important sustainability problem is playing a role, because when there are more bore-wells for a particular amount of water, the yield per bore-well will decrease. We may assume that in the future this bore-well density will increase, with the population growth and because of lower the investment costs for more bore-wells by a farmer household.
A predictable reaction of an irrigating farmer household, on the lower water level, is to invest in a second bore-well which has to be deeper. These deeper bore-wells will cross deeper fractures and aquifers in the lower water level. In the short run will these bore-wells pump water from these sources, and it will have a good yield. But the digging of more bore-wells has also its effect on the bore-well density in the area. On the hand of figure 9.1 we will discuss the effects of the higher bore-well density in a particular area.

Fig. 9.1 Schematic view of fractures and bore-well density



The higher density of bore-wells will have effects on the water supply from particular fractures in the underground. When we assume that bore-well B in this schematic view is dug after A, it appears that bore-well A does not get any water anymore. The water from the fractures which supplied bore-well A will be pumped up by bore-well B. Bore-well C will get water from two fractures. But when the groundwater level decreases the water supply from the highest fracture of C will fall dry. Bore-well C becomes dependent on the lowest fracture. But when bore-well B, which also depends now on this fracture for its water supply, has a more powerful pump, the draw-down effects will play a role. B will pump the water from the lowest fracture, and bore-well C will fall dry in a short period of time.

The reaction to dig deeper bore-wells and the use of more powerful pump-sets, appeared also from the research population. It appeared that 73% of the bore-wells, deeper than 152 meter (500 ft) were younger than 1.5 years. The more powerful pump-sets on their turn keep the pumping water level low. The consequences are that the radius of influence is more extensive. This can have influence on other smaller bore-wells in the area, but also on the water supply in the longer run. The farmer with a good bore-well yield can decide to irrigate more land or more intensively, and decides to adjust his cropping pattern. In both cases the use of water will be more. But when the source is not supplied by rainfall, the consequences are crop failure and no water for irrigation in the near future.

The problem which would reinforce this water demand is the under-pricing of water. According to the Economist (2003), free water or the under-pricing of water for the important agricultural sector in developing countries, leads to overuse of water for the wrong things, especially for highly water-intensive crops. We found in chapter seven that most of ha cultivated by the landowners around Dharwad-Hubli were not cropped with specifically high water demanding crops. But the free or under-pricing of water plays also a role in the urban-fringe of Dharwad-Hubli.

Almost all well owners pumped water with an electrical pump-set. These electrical pump-sets were preferred by almost all well owners, because electricity was more subsidised than diesel fuel (Walker & Ryan, 1990). It appeared that during the drought electricity was even free. According to The Economist (2003), this water policy fails in the pricing, trading and cost-benefit analysis. The farmers get their irrigation water for free and benefit also from free electricity. This was mostly due to the pressure of the farmers, who did not want to pay for insufficient electricity during the drought. According to the Economist (2003), around 60 to 70% of mostly free rural electricity is used to power hundreds of millions of inefficient pumps, which are used to deplete India's scarce groundwater. Electricity is the responsibility of the state governments. In this situation the states bear the blame for India's fiscal deficits. And the main beneficiaries of this system are inevitably the richer farmers, and not the poor peasants (The economist, 2003).

This does not appear directly from the research population which can be biased because of its random composition of irrigating farmers. When we assume that poor peasants do not use irrigation systems it is possible that only richer farmers provide. But from the research it even appears that of all the bore-wells in the small landowner category the average horsepower of the electric motor is 5.87. The average horsepower of the electric motors in the medium landowner category is only 5.57 and 5.77 hp for the motors in the large landowner category. This is remarkable because we have seen in chapter seven that the large landowners are able to make higher investments. The reason why large landowners use less powerful motors is supposed to be because of higher average amount of bore-wells per landowner. The investments for a motor are relative high, the average cost of a motor will be around 16 thousand Rupees, which is comparable with 16% of the average total investment for one bore-well.

The average depth of all the bore-wells over the categories shows also a remarkable pattern. It looks that not the large landowners are the problem with the most powerful motors and the deepest bore-wells. As we see the average depth of all the bore-wells over the categories are not equal. The average depth of a bore-well of a small landowner is by approach 106 meter. A medium landowner has on average a bore-well depth of 112 meters, and a large landowner on average only 103 meters. The reason for this lower average bore-well depth for the large landowners is that these are in general older, and dug before the drought. But when we compare the average pumping impact of the motor per meter, we can use the ratio hp/m. We see that this ratio is the highest for an average large landowner with 0.056 followed by an average small landowner with 0.055 hp/m. The medium landowner bore-wells have, because of their depth, on average a ratio 0.050 hp/m.

This pattern of ratios over the landowner categories can partly be found in the daily shortage over the irrigated ha. If the farmers would like to irrigate their total irrigated land daily during the drought period, we would find a shortage in capacity of the bore-wells. The information about the total irrigated hectares minus the irrigating ha/day makes this shortage visible. The average daily shortage over the socio-economic categories would be 1.8 ha for small landowners, for medium landowners 3.7 ha and for large landowners even 4.4 ha. This shows that almost all farmers had a daily shortage. As percentage of the total average irrigated ha per landowner in Winter/Summer season (table 6.2), this would mean that small farmers have a daily shortage of 84%, medium landowners a shortage of around 93% and large landowners have a daily shortage of almost 90%. This means that small landowners have a less daily water shortage and irrigate in fewer days its total irrigated land. The medium farmers have the highest daily water shortage and lowest ratio of hp/m.

This daily shortage is given in ha, but it appeared also from table 6.2 that small landowners had the lowest water use intensity in litre/ha of the categories. The first reason for this is that more small landowners were cropping on red soil, which needs

overall less water. The second reason for this is that the small landowners were more specialised in water use efficient crops. This is what we have seen in chapter seven.
The large landowners have the highest ratio, but less deep bore-wells. It appears that their pump-set is more powerful in combination with the depth of the bore-well than the deep bore-wells and less powerful pumpsets of the medium landowners. Because of the higher amount of bore-wells per large landowner household, we found a less daily shortage, than the medium landowners. As result of these factors we found that large landowners have more water per ha at their disposal.
A consequence of a higher water availability of a landowner household is that it would be used for more water demanding crops. This reaction is visible in the extreme inter-crop disparity over Karnataka. According to Sharma (1999) have rice, sugarcane and maize 45 percent of the states' irrigated area with only 15 percent of the total cropped area. The high yields and economic returns from these crops provide the incentive, which induces farmers to pay exclusive attention to the cultivation of these crops, often at the expense of all the others. But these crops consume an enormous quantity of moisture, almost 3-4 times of the amount required of jowar, ragi or groundnut.
We did not find this measure of inter-crop disparity by the research population. We mentioned in chapter seven that large landowners cropped a more diverse cropping pattern than small landowners. But the cultivation of rice was negligible during the drought and sugarcane was only cropped on a relative small amount of ha by the large landowners. But when we take a look at the cultivation of maize in the figures 7.1 and 7.2 we find that this crop is relatively equally distributed over the landowner categories in both seasons. We may assume that the higher amount of water availability by the large landowners was not an incentive to crop more ha with this crop. But it is possible that the large landowners irrigated their maize crop more intensively than the other landowners would be able to do. The diversification of the large landowners existed more of onion and chilli varieties which were less cultivated by the medium and small landowners in that particular season.

9.3 Discussion on sustainable development

This information gives us a more complete view of the socio-economic distribution of the available irrigation water, the water use and the adjustment of crops, the irrigation problems and potential problems. With the operational properties of sustainable development we will discuss now the effects of the present water-management of irrigation in the urban fringe of Dharwad-Hubli, as we described in the research. We try to find out what the effects are of this water management system on the productivity, stability, equitability and diversity of the agrarian system in the urban fringe of Dharwad-Hubli.
Productivity in the research was described as the yield per ha. As we have seen these were different for a particular crop. But we may assume that the yields were in general higher with irrigation. We have seen that the responds of especially the high yielding varieties were conditional upon adequate water, which was only possible with irrigation during the drought. Groundwater was the main source for irrigation by the farmers in the urban fringe of Dharwad-Hubli. Because of the insufficient water supply from rainfall, and its use for irrigation, the groundwater level decreased. The result was that bore-wells fell dry or that pumping yields decreased. The decrease in amount of irrigation water had the effect that only a part of their land could be irrigated and that cropping patterns were adjusted to the availability of water. Small landowners cultivated a more specialised pattern of water use efficient crops. With the available water for irrigation would these crops give relative good yields. These cropping patterns in relative amount of ha with more water use efficient crops were comparable with that of the medium and large

landowners in both seasons. But we have to command that the overall economic revenues of these crops are low, mainly because of its high supply on the markets, which lowers the prices.
Stability, as described in the theory, is a measure of the constancy of the productivity despite small-scale fluctuations in water supply and economic conditions of the farmer households. This measure of constancy of productivity is in general more secure for all the irrigating farmers. This stability will be strengthened by the adjustment of the cropping patterns to the circumstances of drought. The more water use efficient crops were less vulnerable to insufficiency of water which gives a particular measure of stability. It appeared from fig. 7.1 and 7.2 that the crops which are relatively more resistant to drought circumstances, mainly cropped in Winter/Summer season, were also cropped in Rainy season during the drought. When these crops will be irrigated it will maintain the yields on a higher level. But in the long run when water supply stays insufficient, this will have decreasing effects on the yields. This appeared also from the yield fluctuations of particular crops on the information about Karnataka over years. In general, the Karnataka yields showed a small increase in productivity for most of the crops over the last decennia. But this drought will have serious long during consequences. The water supply from the monsoons will not fill up the total loss of groundwater, which was used for irrigation during the drought, while the use of this resource will continue for the next Winter/Summer seasons. The amount of irrigation water from groundwater will possibly decrease more, because the amount of bore-wells will continue to grow. This higher density of bore-wells will have a decreasing effect on the water yields and a decline in productivity of the farmers, especially for the Winter/Summer seasons.
Equitability is the term used to express how evenly or fairly water and access to water are distributed among the households on in the urban fringe of Dharwad-Hubli. For the research on the socio-economic distribution of water, we divided the irrigating farmers of the research population in landowner categories. This was based on the amount of land they possessed. The reason for this decision was the given that land can be seen as capital which made the owners more or less creditworthy for investments. These investments were necessary for the access to the groundwater resource for irrigation. The landowners had to invest in private bore-wells, especially during the drought. It appeared that a large landowner household possessed on average more bore-wells, than a medium or small landowner household. This confirms the pattern of the potential creditability of the landowners. This higher amount of bore-wells enabled the large landowners to irrigate more ha with corresponding higher yields. The share of irrigated ha on their total cropping ha was relatively low compared that of the small and medium landowners. But the average scale of production was almost nine times that of small landowners and more than three times that of the medium landowners. We may assume that the relatively lower share of irrigation enabled large landowners to irrigate more intensively. It appeared that the average litre/ha water use was the highest for large landowner households. A reason for this is that most of the large landowners were situated on black soils, which have high water retention but require also more water for cropping, especially during the drought. And most of the small landowners, with the lowest water use intensity, were situated on the red soils which require less water for cropping. It appeared that the large landowners did not possess on average the deepest bore-wells. And they also did not have on average the most powerful pumpsets. But the large landowners possess the most powerful combination in the ratio hp/m. This given in combination with the highest average amount of bore-wells per household gave the large landowners the opportunity to use the highest amount of water per day. This daily water use is five times as much as that of the small landowners, and more than three

times that of the medium landowners during the research period in Winter/Summer season. This explains in short the equitability, with the distribution of water over the irrigating landowner categories in the urban fringe of Dharwad-Hubli. It appears that the present access to water depends mainly on the possession of more bore-wells. And as we have seen before, these are not evenly distributed between the landowner households. In general have large landowner households a better access to water for irrigation than medium and small landowner households. And we may assume that in the long run, the large landowners are able to invest in deeper bore-wells with more powerful pumpsets because of their accumulative advantages of scale. This will have some negative sustainable effects on the small landowners, who do not have this measure of accumulative advantages because of their scale and capital, and who are more dependent on their production for the repayment of investment credit. A higher bore-well density will have negative effects for the access to groundwater for irrigation, for especially the small landowners.

Diversity is a measure for the number of different types of strategies of the households. The idea is that diversity allows the landowner households to spread risks and maintain a minimum level of subsistence even when some activities fail. As we have seen in the chapter before, many households used different strategies. One of the strategies we discussed was the joint family, to keep the capital together. But a more important strategy of agrarian household is diversification. This strategy is mainly used as financial security, despite disappointing harvests. This appears from the fact that dependence on ‘self-employment’ of farmer households, has declined in importance through the 1980’s, in favour of dependence on casual daily paid wage employment. A condition for diversification of households is the availability of alternative jobs. This condition is more easily met in the urban-fringe areas than more rural areas. The urban fringe area offers a more diverse job spectrum of agricultural and non-agricultural employment. The twin city of Dharwad-Hubli gives many alternative employment opportunities for diversification of agrarian households. In the chapter before it appeared that in almost 33% of the households in the research population, there was at least one member with a non-agricultural job. This diversification has taken place over all landowner categories. These jobs varied between government servant, teacher, factory worker, merchant, construction worker etc. This off-farm employment was mainly situated in the cities. It can not be confirmed from my research, that the landowner households were totally dependent on the conditional wage levels of the family member with the non-agricultural job, during the drought. But it appeared that the wages of the non-agricultural jobs were at least partly responsible for some particular investments by the family.

We found that this strategy of diversification is complementary with the existence of joint families. It appeared that in most of the joint families there was diversification. We found that 71% of the diversified households concerned a joint family. A potential reason for this was that there would be sufficient agricultural labourers within the family and some of the members could have another job in the cities. Another important factor which we discussed with the investment making is the common capital of joint families. Joint families can use the common capital to invest in education for one or more members. To secure that some members will get a good job with secured high wages in the cities. We found these higher wage jobs in the cities, like teacher and governmental jobs, only by some large and small landowner joint families. The alternative jobs of the medium landowners existed of business and merchant jobs. These jobs were not based on contracts and were not predictable continues wages. But the alternative to bring your own products to the nearby markets, sometimes daily or weekly, can also bring in higher economic revenues, through bypassing of intermediate traders. In general we may assume that the opportunities for alternative jobs for agricultural household members, are higher in the urban-fringe areas compared to more rural areas.

9.4 Conclusions on sustainable development

We discussed before what the effects of this present water-management were on the productivity, stability, equitability and diversity of the agrarian system in the urban fringe of Dharwad-Hubli. The drought circumstances during the research period, showed the vulnerable side of the water-management system. We found that the groundwater level decreased as result of the insufficient water supply from rainfall, and its use for irrigation. In the long run of the drought, was the result that bore-wells fell dry or that pumping yields decreased. The decrease in amount of irrigation water had the effect that only a part of their land could be irrigated and that cropping patterns were adjusted to the availability of water. The consequences of this were a decline in productivity and lower economic revenues. We found that the small landowners cultivated a more specialised pattern of water use efficient crops. With the available water for irrigation would these crops give relative good yields, but the economic revenues of these crops are lower. This is mainly due to the high supply of these crops on the markets, because these crop were also cultivated by most of the medium and large landowners, mainly on a bigger scale. These water use efficient crops were relatively more resistant to the drought circumstances, and with a certain amount of irrigation it will maintain good yields. But when the water supply stays insufficient, it will also have decreasing effects on the yields of these crops. We may assume that this will happen, because the water supply form the monsoons will not fill up the total loss of groundwater. This will have serious consequences for the cultivation of crops over the coming Winter/Summer seasons, which is mainly conditional upon (additional) irrigation. As we see, during a longer drought, this will appear a low sustainable system, which will recover to a lower level of productivity.

As result we may assume that the amount of bore-wells will continue to grow. But this higher density of bore-wells will have a decreasing effect on the pumping yields and a corresponding decline in productivity. These consequences will effect all landowner categories, but in different measures. It appeared that the present access to water depends mainly on the possession of more bore-wells. We mentioned that the initial investment costs of the first bore-well were higher. And we found that the amount of bore-wells was decisive for the amount of irrigated hectares, with its corresponding higher yields. According to these given, we found that large landowners were in general in a better position to make additional investments in the long run. These investments can be in more and deeper bore-wells, and more powerful pumpsets. The logical reason for this is that the groundwater and electricity costs for use are negligible. It appears that in the long run of this subsidizing policy, the main beneficiaries of this system are inevitably the large landowners. Because the resulting higher bore-well density will have negative effects for the access to groundwater for irrigation, for especially the small landowners, who do not have these accumulative advantages because of their scale and capital, and who are more dependent on their production for the repayment of investment credit.

But as we have seen before, the households use the different strategies to get more continues economic revenues. The most important active strategy is diversification, which is mainly practised by joint families. The urban fringe area gives many opportunities for non-agricultural jobs, especially for the small and medium landowners to regain their economic revenues from alternative sources. These revenues can also be used for investments in more bore-wells. But the main sustainability problem stays the same; the bore-well density will becomes inevitably higher.

9.5 More sustainable development

For a more sustainable outcome in this inevitable proliferation of bore-wells, there should be regulations on bore-well depth and the use of less powerful motors. But this is a complex problem where the subsidizing policy of electricity is used in a wrong way. Because of its private character of bore-wells, decisions in depth and motor power are made in particular within the households. This private decision making process is merely based on the tension between yield-growth and risk minimizing. But as we may assume this proliferation as result of the individual household calculations will be in advantage of the large landowners.

The role of social and governmental institutions should be based on water saving techniques and the original intension of the irrigation projects. According to Abu-Zeid (1980), had irrigation projects originally the intension to increase and improve the food-production radically and benefit all classes of farmers. The advantages of restrictions imposed on well construction are not always understood properly by the farmers. But the adverse effects of unplanned growth of wells in the study region are being felt already. Farmers should be enlightened on these aspects (Venkata Reddy, 1990). The role of social institutions would be that the large heterogeneous farmer group must become more involved to enable them to take responsibility for operating the ground water aquifer in a way that is more socially equitable, economically efficient, and environmentally sustainable (Virmani, 2000). To avoid top-down implementations, with policy and regulations it is better to involve the farmers in the information process. Landowner participation is an important element when we realise that they are the decision makers of their private resources. Landowner participation will only be realised when they get informed by the consequences of their decisions. As we mentioned geologists play in many cases a part in the decision making process of the landowners by localising the crucial factors for placing the bore-well. Geologists have to inform the landowners on the maximum of powered pump-sets required, and the fixed amount of land which can be irrigated. Farmers also should be informed about the most efficient way to use water for crops, to avoid the tendency of over-irrigation and keeping the productivity on the same level.

The subsidizing policy of the governmental institutions on electricity is used in a wrong way. This subsidizing is a reward to use more. Not all classes of farmers will benefit, but especially the irrigating farmers. All the irrigating landowners in the research benefited from this policy, but through their accumulative advantages were the main beneficiaries of this system the large landowners. Policy on the water-management of irrigation should pay more attention to efficient water use facilities. In the chapter three, we mentioned that micro-irrigation the latest and most efficient method is for irrigation on the field scale. The term micro-irrigation is used to describe the method of irrigation which is characterised by low rate applied water. It has high water use efficiency and should be adopted on a large scale for various crops (Patel, 1999). These advanced methods of irrigation are known as sprinkler and drip (trickle) irrigation. Of these methods it appeared that drip or trickle irrigation is the most efficient method for irrigating the crops. With this method is water applied to the crop area near the root zone on a daily basis and as there is no moisture stress, the crop growth is not affected at all. This can also have its effects on the productivity of farmers. But these techniques are relative new, and the purchasing costs are relative high. To make these water use efficient methods more attractive for all farmers, governmental institutions should point their subsidizing policy more on these new techniques.

10. Conclusion

In the context of water-management of irrigation, we distinguished physical features, social and governmental institutions which have its influence on the manipulation of irrigation water by farmer households. In this research we tried to find out how water-management of irrigation is arranged socio-economically in the urban fringe area of Dharwad-Hubli. The research questions on the basis of this research were in general how access to irrigation is arranged socio-economically and the distribution of the water use. We described this on the hand of the operational properties in the context of water-management of irrigation. We found that groundwater is the most important water-resource for irrigation in the urban fringe of Dharwad-Hubli, especially during the drought. Because of the combination of insufficient water supply from the monsoons, the water use and evapotranspiration were all the other irrigation facilities dried up. But the deep groundwater aquifers did not suffer from water losses due to evapotranspiration. As result of this became bore-wells the most popular irrigation facility for the use of this water-resource, due to their greater reliability and moderate costs with virtually free power supply. Bore-wells have the character of private resource. Landowners, who invested in the construction of bore-wells in their own land, make their own decisions about the amount and frequency of irrigation. The role besides the electricity subsidizing policy, of social and governmental institutions was almost negligible for the water-management in bore-well irrigation.

This context of physical features and institutions were the conditions on the socio-economic arrangement of the water-management of irrigation in the urban-fringe of Dharwad-Hubli. For the research on the socio-economic distribution of access to the water-resources and water use, we had to divide the research population. The socio-economic classes in this research were based on the land property of the farmers. We divided the research population therefore in small, medium and large landowner categories. The idea was that land as property of a landowner plays an important role in the financial resources and makes the farmer more creditworthy for bank-loans. These conditions confirmed already the believe that the ownership of the private bore-wells tends to be skewed in favour of larger landowners. Theoretically, a landowner must have an adequate irrigable command area of his own land holding to earn an adequate return on his investment. In this context have farmers with large land holdings a natural advantage over small landowners. In addition, they are in a better position to finance the investment (Pant, 1992). This argument came true in the research, which revealed that the average amount of bore-wells per landowner household was the highest for large landowners and the lowest for small landowners. The access to the groundwater resource appeared to be uneven, and followed the pattern of the landowner categories on their creditworthy for investments. The daily use of water in Winter/Summer season of the landowner categories followed the same pattern. But it even appeared that the average daily use for a large landowner household was more than three times that of the medium, and five times that of the small landowners. The proportion of the daily water use for a medium landowner household was only 1.5 times as much than that of small landowners. This showed that the averages of the medium and small landowners were closer than the averages between the medium and the large landowners. This appeared also from the scale of production. The average scale of production by large landowners was almost nine times that of small landowners and more than three times that of the medium landowners. The result of this higher amount of bore-wells and higher daily water use is that these factors enabled the large landowners to irrigate more ha with corresponding higher yields of the crops. The share of irrigated ha on their total cropping

ha was relatively low compared to that of the small and medium landowners. But still the large landowners irrigated in absolute numbers more hectares than the medium and small landowners. But the proportions of these averages irrigated ha differed from the cropping scale proportions. The average irrigated ha of the large landowners was closer to that of the medium landowners, but still 1.3 times as much. Because of the smaller proportion of irrigated ha, the large landowners were able to use more water per ha. The average water use intensity in litre/ha was the highest for the large landowners and the lowest for small landowners. This could mean that large landowners cropped more water demanding crops, which would give higher economic yields on the markets. But a more plausible declaration for this higher water use intensity is the spread of the landowner categories over the two main soil types around Dharwad-Hubli. The small landowner households were relatively equally spread over the red and black soils. But most of the medium and large landowners cropped on blacksoil. These black soils are typified by their high water retention and are in general more fertile than the red soils. These blacksoils can give good crop yields if rainfall is adequate. But during the drought the landowners had to irrigate more on blacksoils to get good crop yields.
The argument that the large landowners cultivated more water demanding crops did not appear from the research. The relative distribution of the main crops was comparable over all the categories. Only the share of cotton was relatively high for the large landowners in Winter/Summer season. It appeared that the landowners cropped in general the same crops before the drought, but we may assume that during the three years of drought there was a shift in the amount of cropping hectares to more water use efficient and stable yield crops, to avoid yield reductions and to minimize the risk of bad harvests. The relative cropping shares of the main crops were overall lower by the large landowners. This is mainly due to the relative high share of other main crops cultivated by the large landowners. It appeared that the large landowners cultivated a more diversified cropping pattern than the small and medium landowner households. The shift in amount of cropping hectares to more water use efficient crops during the drought, led to a more specialised cropping pattern by the small and medium landowners. The cropping of maize in Rainy season could make an exception in the cropping patterns between the landowner categories, because of its higher water demand. It could be expected that maize should be cultivated relatively more by large landowners, because of their better access to irrigation water. This high yielding variety gives also higher economic yields on the market, which makes it more attractive to cultivate. It appeared that the relative amount of ha cropped with maize was comparable over all the categories. But the absolute amount of irrigated ha of maize by large landowners were substantial higher.
With the discussion of the main cultivated crops and its responds to irrigation we found that in general the large landowners were better off. This was mainly the result of their bigger scale of cropping and irrigation. This scale made it also possible to cultivate a more diverse cropping pattern. The water use costs were for all landowner categories low, and the electricity costs for the pump-sets were even negligible during the period of research. It appeared that the large landowners benefited the most of this. The higher productivity with irrigation and their irrigation scale gave the large landowners a corresponding better profit, compared to the other landowner categories.
The result is that these large scale profits and low costs enable large landowners to make new investments in the long run, which will give the large landowners a cumulative advance. New investments in irrigation facilities enable large landowners to improve the water conditions for more crops. Investments in these irrigation facilities give large landowners an opportunity to increase their yields. These cumulative effects are, because of their smaller cropping and irrigation scale and their less creditability, much

lower for the small and medium landowners. As we can imagine, there will be a growing socio-economic disparity between the irrigating farmers.
In this context we discussed the strategies of the households to maintain their economic revenues. This could be for living or support for investments. We found that families were hold together within joint families. The main reason for this was to keep the capital together for particular investments. But a more active strategy used by the households was diversification. We found that this strategy was complementary with the existence of joint families. These families were more able to split up family members into non-agricultural jobs. The urban-fringe area of Dharwad-Hubli offered many opportunities to agrarian household members to do non-agricultural jobs. We found this diversification over all landowner categories. And it appeared that the economic revenues from the family members with a non-agricultural job were mainly responsible for the initial investments in bore-wells of these diversified households. But because of these individual households strategies, it is not to say which categories would benefit the most of these strategies, and if this will tighten the growing gap of inequality between the landowner categories.

The drought circumstances during the research period, showed the vulnerable side of the water-management system. We found that the groundwater level decreased as result of the insufficient water supply from rainfall, and its use for irrigation. In the long run of the drought, was the result that bore-wells fell dry or that water yields decreased. If the water supply stays insufficient, it will also have decreasing effects on the yields of these crops. We may assume that this will happen, because the water supply form the monsoons will not fill up the total loss of groundwater. This will have serious consequences for the cultivation of crops over the coming Winter/Summer seasons, which is mainly conditional upon (additional) irrigation. As we see, during a longer drought, this will appear a low sustainable system, which will recover to a lower level of productivity. But as result of these consequences there will be investments in deeper bore-wells and more powerful pumpsets. We may assume that the amount of bore-wells in the urban fringe of Dharwad-Hubli will continue to grow. But this higher density of bore-wells will have a decreasing effect on the pumping yields and a corresponding decline in productivity. These consequences will affect all landowner categories, but also in different measures. It appeared that the present access to water depends mainly on the possession of more bore-wells. The amount of bore-wells was decisive for the amount of irrigated hectares, with its corresponding higher yields. We found that large landowners were in general in a better position to make additional investments in the long run. These investments can be in more and deeper bore-wells, and more powerful pumpsets. The resulting higher bore-well density will have negative effects for the access to groundwater for irrigation, for especially the small and medium landowners, who did not have or in a lower measure, these accumulative advantages of scale.

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