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Groundwater Governance: Development, Degradation and Management
(A Study of Andhra Pradesh)

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RESEARCH UNIT FOR LIVELIHOODS AND NATURAL RESOURCES
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Foreword

The Centre for Economic and Social Studies (CESS) was established in 1980 to undertake research in the field of economic and social development in India. The Centre recognizes that a comprehensive study of economic and social development issues requires an interdisciplinary approach and tries to involve researchers from various disciplines. The centre's focus has been on policy relevant research through empirical investigation with sound methodology. In keeping with the interests of the faculty, CESS has made important contributions to social science research in several areas; viz., economic growth and equity, agriculture and livestock development, food security, poverty measurement, evaluation of poverty reduction programmes, environment, district planning, resettlement and rehabilitation, state finances, education, health and demography. It is important to recognize the need to reorient the priorities of research taking into account the contemporary and emerging problems. Social science research needs to respond to the challenges posed by the shifts in the development paradigms like economic reforms and globalization as well as emerging issues such as optimal use of environmental and natural resources, role of new technology and inclusive growth.

Dissemination of research findings to fellow researchers and policy thinkers is an important dimension of policy relevant research which directly or indirectly contributes to policy formulation and evaluation. CESS has published several Books, Journal Articles, Working Papers and Monographs over the years. The Monographs are basically Research Studies and Project Reports done at the Centre. They provide an opportunity for CESS Faculty, Visiting Scholars and Students to disseminate their research findings in an elaborate form.

The CESS has established the Research Unit for Livelihoods and Natural Resources (RULNR) in the year 2008 with financial support of Jamsetji Tata Trust (JTT). The core objectives of the RULNR are to conduct theoretical and applied research on policy relevant issues on human livelihoods and natural resource management (NRM), especially in areas related to Dry-land, Forest and River Basins Ecosystems and to provide an effective platform for debates on policy relevant aspects for academicians, policy makers, civil society organizations and development practitioners. RULNR intends to adopt a multidisciplinary approach drawing on various disciplines such as ecology, economics, social anthropology, political science.

This RULNR-CESS Monograph titled "*Groundwater Governance: Development, Degradation and Management (A Study of Andhra Pradesh)*" by Dr.M. Srinivasa Reddy and Prof. V. Ratna Reddy attempts to understand and identify the gaps in groundwater development as well as management in terms of technical knowledge, scale, and participatory approaches. The Monograph is divided in to two parts. While the 1st Part of the Study attempts to assess the groundwater situation in Andhra Pradesh (AP) using spatio-temporal analysis and highlights the importance of hydrological information at an appropriate scale to the user communities from a socio-economic perspective, second part of the Monograph explores the possible options for community based groundwater management in the Indian context. Based on the evidence, 1st Part of the study shows how groundwater is depleting along with increasing dependence over the years across the regions of AP. It is argued that the negative externalities could be mitigated to a large extent with proper dissemination of information among the communities. This must be fostered through policy support that paves the way for treating the resources as a common pool resource instead of allowing it to be exploited like a private resource.

The main focus in the 2nd Part of the Study is to understand the functioning and efficiency of groundwater management institutions by comparing and contrasting three participatory groundwater models in AP, viz. the APFAMGS, WASSAN and CWS. The study has attempted to assess the operational modalities and the impact of these institutions on access, equity and sustainability of groundwater use at the village and household level using the qualitative and quantitative information. All these three models have the common goal and objective of sustainable groundwater management, though the approaches followed and the implementation modalities are different and thus can be grouped into two broad categories, as: i) knowledge intensive (APFAMGS); and ii) social regulation (SRWM and APDAI). The study observes that the social regulation approach works better for sustainable groundwater management when compared to the knowledge intensive approach, as the latter is not designed to address equity. The most important lessons from these models include: i) creation of information at appropriate scale through community involvement; and ii) generating demand for demand management of groundwater with the help of this information.

Though these three approaches have proved that communities are capable of managing groundwater in a sustainable manner, sustainability of these initiatives is a major concern in all the approaches. Besides, in the absence of contribution, the financial sustainability of the initiatives would be a big concern, especially once the external funding stops.

Thus, the experience of the three models reveals that wide ranging policy changes are required to scale up the achievements of these small scale initiatives. Unless wide-ranging policy changes are brought in, these initiatives remain as models rather than being adapted at a wider scale. Replication of these models could be possible with high transaction costs, but the sustainability of these initiatives remains uncertain in the present policy environment.

Therefore, this Monograph calls for wide-ranging policy changes so as to adapt these initiatives in a wider scale as the demand management models cannot be effective as long as policy environment is supply-sided and thus, provides valuable suggestions to policy makers. I hope it would be useful to the farmers, research community, policy makers, development practitioners and all those interested in the sustainable management of groundwater.

S.Galab
Director, CESS

CONTENTS

List of Tables

List of Figures

List of Maps

Acronyms and Abbreviations Used

AARF	-	Actual Annual Rainfall
ACWADAM	-	Advanced Centre for Water Resources Development and Management
AEI	-	*Aide e Enfance de l Inde* (Luxembourg)
AFPRO	-	Action for Food Production
AP	-	Andhra Pradesh
APDAI	-	Andhra Pradesh Drought Adaption Initiative
APFMGS	-	Andhra Pradesh Farmer Managed Groundwater Systems
APMIP	-	Andhra Pradesh Micro-Irrigation Project
APSIDC	-	Andhra Pradesh State Irrigation Development Corporation
APTRANSCO	-	Andhra Pradesh Transmission Corporation Limited
APWALTA	-	Andhra Pradesh Water Land and Trees Act
APWELL	-	Andhra Pradesh Groundwater Borewell Irrigation Schemes Project
AEC	-	Arcadis Euro Consult
ayacut	-	Command area or the area served by an irrigation project such as a canal, dam or a tank
BC	-	Backward Caste
BCM	-	billion cubic metres
BIRDS	-	Bharathi Integrated Rural Development Society (an NGO working base at Allgadda and surrounding Mandals of Kurnool District)
BUAs	-	Borewell Users Associations
BPL	-	Below Poverty Line
BWs	-	Borewells
C	-	Command
C	-	Critical (Groundwater Categorization)
CBGM	-	Community Based Groundwater Management
CBIs	-	Community Based Institutions
CBOs	-	Community Based Organisations
CESS	-	Centre for Economic and Social Studies
CGWA	-	Central Ground Water Authority
CGWB	-	Central Groundwater Board
CI	-	Crop Intensity
CIGs	-	Common Interest Groups
Coastal Andhra	-	Circar Districts of Andhra Pradesh (or) is a region of Inida's Andhra Pradesh State
CPRs	-	Common Pool/Property Resources

CRD	-	Commissioner of Rural Development
cum	-	cubic meters
CW	-	Community Well
CWB	-	Crop Water Budgeting
CWC	-	Central Water Commission
CWS	-	Centre for World Solidarity
DDP	-	Desert Development Programme
de facto	-	actual, though not official
DIPA	-	Development Initiatives and Peoples Action (an NGO working base at Giddalur and surrounding Mandals of Prakasam District)
DoRD	-	Department of Rural Development
DPAP	-	Drought Prone Area Programme
DRDA	-	District Rural Development Agency
DT	-	Distribution Transformer
DWMA	-	District Water Management Agency
FAO	-	Food and Agricultural Organization
FFS	-	Farmers Field Schools
FGD	-	Focus Group Discussions
FWS	-	Farmer Water Schools
GEB	-	Gujarat Electricity Board
GEC	-	Groundwater Estimation Committee
GIA	-	Gross Irrigated Area
GIS	-	Geological Information System
GMC	-	Groundwater Management Committee
GoAP	-	Government of Andhra Pradesh
GoI	-	Government of India
Gonchi	-	collective community efforts in bringing water from a stream and distributing the same equally to irrigate a stipulated *ayacut* area
GP	-	*Gram Panchayat* (Village *Panchayat*; the third tier of the *Panchayat Raj* system; *Panchayat* being a representative body or Village representative body)
Grama Samakhyas	-	Village Organisations
GWD	-	Groundwater Development
Ha	-	Hectare or up to 2.50 acres of land
HDI	-	Human Development Index
HESA	-	Hydro-Ecosystem Analysis
HHs	-	Households

Hivre Bazar	- a village in western Maharashtra called Hivre Bazar, where a watershed development scheme was implemented under the *Adarsh Gav Yojana* (AGY) of the government of Maharashtra in the mid-1990s.
HMR	- Hydrological Monitoring Records
HP	- Horse Power
HPI	- Human Poverty Index
HU	- Hydrological Units
HUN	- Hydrological Unit Network
I&CAD	- Irrigation and Command Area Development
ID	- Irrigable Dry
II	- Irrigation Intensity
IRM&ED	- Institute for Resource Management and Economic Development
IWMI	- International Water Management Institute
Jal Chitra	- ability to allow a user to draw a community based water resource map of the village
JGS	- *Jyoti Gram* Service
Kharif	- Cropping season from June to September or Agricultural Season between June to October (or) Monsoon crop growing season
kwh	- kilowatt hour
LMF	- Large and Medium Farmer (above 5 acres of land)
LNRMI	- Livelihoods and Natural Resources Management Institute
Ltd	- *Limited*
Mahila Samkhyas	- Federation of Women Thrift and Self-Help Groups
Mandal	- administrative block/unit (erstwhile block Panchayat)
MAR	- Managed Aquifer Recharge
mcm	- million cubic meters
MDGs	- Millennium Development Goals
MF	- Marginal Farmer (up to 2.5 acres of land)
mha	- million hectares
MMS	- Mandal Mahila Samkhyas (Federation of all the SHGs in the Mandal)
MoWR	- Ministry of Water Resources
MP	- Madhya Pradesh
NA	- Not Applicable
NABARD	- National Bank for Agriculture and Rural Development
NC	- Non- Command

NCIWRD	-	National Commission on Integrated Water Resources Development
Neerugatti	-	waterman (a person dedicated to allocating water among the farmers - responsible for opening and closing the sluice and also for providing irrigations)
NGOs	-	Non-Governmental Organisations
NGRI	-	National Geographical Research Institute
NIA	-	Net Irrigated Area
Non-ayacut	-	Non-Command
NRM	-	Natural Resource Management
O&M	-	Operation and Maintenance
OB	-	Observation
OC	-	Other Caste
OE	-	Over Exploited
OLS	-	Ordinary Least Squares
OW	-	Owned Well
Pani Panchayats	-	Water User Associations
PCI	-	Per Capita Income
PGM	-	Participatory Groundwater Management
PHM	-	Participatory Hydrological Monitoring
PRA	-	Participatory Rural Appraisal
PRIs	-	Panchayat Raj Institutions
Rabi	-	Cropping season from October to December or the cropping season that follows the Kharif (November to March (or) winter crop growing season
Rayalaseema	-	Ceded Districts of Andhra Pradesh (or) is a geographic region in the state of A.P in India
RIDS	-	Rural Integrated Development Society (an NGO working base at Garladinne and surrounding Mandals of Anantapur District)
RNE	-	Royal Netherlands Embassy
RULNR	-	Research Unit for Livelihoods and Natural Resources
S	-	Safe
SC	-	Scheduled Castes
SC	-	Semi-Critical
SERP	-	Society for Elimination of Rural Poverty
SF	-	Small Farmer (2.5 to 5 acres of land)
SGD	-	Stage of Groundwater Development
SGWD	-	State Ground Water Department
SPS	-	*Samaj Pragati Sahayog*

SPSS	-	Statistical Package for Social Science
sq. km	-	square kilometer
SRWM	-	Social Regulations in Water Management
ST	-	Scheduled Tribes
Tahasildar	-	Revenue Official
Taluk	-	administrative unit
Telangana	-	formerly *Nizam* Territory of Andhra Pradesh (or) is a region in the present state of A.P, India
tmc	-	thousand cubic meters
TMCs	-	Tank Management Committees
UN	-	United Nations
UP	-	Uttar Pradesh
UT	-	Union Territory
VIF	-	Variance Inflation Factor
VO	-	Village Organisation
WASSAN	-	Watershed Support Services and Activities Network
WS	-	Watershed
WSC	-	Watershed Committee
WSD	-	Watershed Development
WSDP	-	Watershed Development Programme
WUAs	-	Water Users Associations
WUG	-	Water User Group

Annexure
List of Maps, List of Figures and List of Tables

Acknowledgements

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M.Srinivasa Reddy
V.Ratna Reddy

Executive Summary

Hydrological knowledge or information has been mostly confined to the domain of scientific community, while the communities that actually interact with the hydrological aspects such as groundwater and surface water on a day-to-day basis are hardly aware of the information that could critically influence their livelihoods. From the perspective of the communities, information pertaining to groundwater aquifer characters, potential to provide the water resources, and surface groundwater interactions in varying geo-hydrological conditions are important. The public relevance of the resources and their linkages with ecological systems gives rise to externalities that could be pervasive. In a number of countries, especially the developing countries, groundwater is the single largest source of drinking as well as irrigation water. In the absence of scientific information with the communities, extraction of groundwater resources for productive purposes has become a risky venture leading to adverse impacts on livelihoods. The externalities associated with over-exploitation of groundwater resources and the resulting widespread failure of wells is identified as one of the main reasons for pushing farmers in to debt trap and the resultant widespread farmer suicides in India. The negative externalities are also increasingly becoming severe in the context of climate variability. Lack of information at an appropriate scale is proving to be a stumbling for community based groundwater management.

This study attempts to understand and identify the gaps in groundwater development as well as management in terms of technical knowledge, scale, and participatory approaches. The monograph is divided in to two parts. Part One attempts to assess the groundwater situation in Andhra Pradesh (AP) using spatio-temporal analysis and highlights the importance of hydrological information at an appropriate scale to the user communities from a socio-economic perspective. Part Two explores the possible options for community based groundwater management in the Indian context. The main focus here is to understand the functioning and efficiency of groundwater management institutions by comparing and contrasting three participatory groundwater models in AP, viz. the APFAMGS, WASSAN and CWS.

Trends in Groundwater Development: Spatio-temporal Analysis

The spatio-temporal analysis of groundwater development has been looked from multiple dimensions and the assessments are re-emphasised from all the angles. The analysis brings out some interesting aspects. These include:

- The methodological basis of groundwater assessment is rather weak and hence, the assessments may have limited use for the farming communities.

- There is a secular trend in groundwater development over the years.
- This trend is only broken due to severe droughts or very good monsoons.
- Regional variations indicate that Telangana had a late entry in the case of mechanisation and enrgisation of groundwater exploitation, though it has over taken the Rayalaseema Region by mid-nineties.
- The level of groundwater development and its adverse impacts are more severe in Rayalaseema Region.
- There is imbalance in the development and available groundwater in the command and non-command areas. While the command areas have under-development of groundwater, the non-command areas have excess development.
- Similarly, DPAP districts face the adverse impacts of groundwater development when compared to the non-DPAP districts.
- Though the level of groundwater development at the aggregate level is not alarming, the micro-situation is a cause of concern as the number of villages included under the over-exploited category is increasing over the years.
- The trends in groundwater development are reflected very well in the area irrigated under wells. Though the area under well irrigation is expanding, the area irrigated per well is either stagnant or declining.
- The micro-impacts are clearly seen in the case of well failures and the resulting farm distress in some regions.
- The free power policy of the state has neither helped in expanding the area under wells nor reduced the burden on the farmers substantially.
- The dual policy of free power and supply regulation does not seem to have any significant impact on agriculture.

Factors Influencing Groundwater Development

The multiple regression analysis of the factors influencing groundwater development does not prove to be of much help in better understanding of groundwater management. This is because the policy variables such as WSD, literacy and HDI did not reveal any clear impact towards checking groundwater development. This could be due to the reason that in the absence of groundwater institutions these factors may have limited influence. Besides, our analysis also does not include any institutional variables due to the non-existence of any formal groundwater institutions at the district level. An assessment of the role of institutions on groundwater development on the backdrop of Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) experience reveals that innovative institutional arrangements can address the information bottlenecks to a large extent.

Hydrology is treated as a pure physical science and hydrological information is often generated and disseminated in an esoteric form with little or no effort to bring it closer to the user communities. Unlike other physical sciences, hydrology or hydrological information plays a vital role in the day to day livelihoods of groundwater-dependent communities. The existing link between the scientific information and the users is very weak, serving no real purpose of helping the farming communities. Often, the information provided at a macro scale is inadequate and inappropriate to suit the micro-level situation and needs of the farmers.

The case of APFAMGS clearly brings out the great possibilities for demystifying hydrology and makes it user friendly through capacitating communities in generating scientific hydrological information at the village level. While these are found to be highly productive in terms of benefits to the user communities, sustaining and scaling up such initiatives calls for an integrated approach of combining physical and social sciences along with policy makers and development practitioners (NGOs). A detailed assessment of some of community based initiatives in groundwater management, including APFAMGS, is taken in second part of the Monograph.

Community Based Groundwater Management

The main benefits perceived due to the community based institutions are awareness about groundwater followed by crop methods and groundwater irrigation methods. Among the reasons for non-participation is the absence of tangible benefits followed by non-feasibility. While 70 per cent of the non-participating farmers felt that there are no tangible benefits in the APFAMGS and APDAI villages, only 35 per cent of the farmers perceived this reason in the case of SRWM village (Madirepalli). This perception is greater among the well-sharing farmers when compared to the well owners. Similarly, 81 per cent of the sample farmers in the APFAMGS village have endorsed the benefits from groundwater institutions, while 100 per cent agreed about the benefits in the other two villages. Lack of benefits is attributed to the reason that farmers do not follow the suggestions of the management committee, as the institutions play only an advisory role. However, the sample farmers in APFAMGS and APDAI villages perceive that the advisories are being followed or adopted.

Overall, the performance in terms of physical indicators and farmers' perceptions appears to be better in case of Madirepalli Village (SRWM) where social regulation is in place;

while the performance of APFAMGS where there is no regulation seems to be poor. The APFAMGS initiative is the oldest among the three models. In fact, during the field work, the APFAMGS interventions were terminated, as the NGOs were waiting for the extension of the project. Hence, the poor performance of APFAMGS raises the issue of institutional sustainability (Reddy et al., 2011), and this is applicable even for the other two initiatives. The difference between the other two initiatives is that the APDAI initiative is backed by the Governmnet (DoRD), while the SRWM is NGO-driven. The better performance of SRWM could be due to the intensive approach it has adopted in promoting water sharing - it has taken almost three years to organise the farmers and build awareness before initiating the well-sharing process. Besides, the SRWM worked with small groups of well-owning and well-sharing farmers, whereas the groups were bigger in the area-based approach followed by the APDAI.

The three models considered here have the common goal and objective of sustainable groundwater management. All the three institutions are led by NGOs with support from different agencies including the State Government. However, the approaches followed and the implementation modalities are different and can be grouped as: i) knowledge intensive; and ii) social regulation. These approaches have their advantages as well as disadvantages in terms of achieving their objectives and the sustainability of the initiatives.

i) Knowledge-based Approach

The APFAMGS initiative is based on the principle of demystifying science through enhancing the capacities of the communities in terms of their skills and scientific knowledge. The focus is on facilitating or making communities assess the groundwater potential at the village level and estimating the available water before each crop season. These estimates are integrated at the hydrological unit level, providing the much needed scientific scale for assessing the groundwater. At the same time, the scale at which observation wells are monitored (village level) is more appropriate to the communities. For, official groundwater assessment is made based on the observation wells located at the Mandal (more than 30 villages) level and does not reflect the situation at the village level. Crop water budgets are prepared by the communities at the village level and the suggested cropping pattern for the season is provided (based on the groundwater availability) to the community. These details are shared across the villages within the hydrological unit.

The "do-it-yourself" approach with relatively better scientific or technical inputs has clearly improved the awareness of the well owners. The initiative is highly successful in demystifying science and needs to be considered at the policy level to promote institutional linkages for generating such information at the village level. While such an awareness has helped in checking further expansion of groundwater development, i.e., new wells, it has failed to encourage other conservation practices such as increased investments in recharge structures or equity by sharing the water with un-irrigated farmers. Though our sample village does not provide any evidence on the reduction in water-intensive crops (paddy), it has been achieved in other places (Reddy, 2012). The limited impact is mainly due to the reason that neither social regulations are imposed, nor economic incentives are provided, for adopting such measures. In fact, farmers feel that the APFAMGS merely plays an advisory role without any incentives or disincentives to follow the advisories. The result is a lot of useful information generated at the appropriate scale, helping only the well-owning farmers while the farmers hitherto not having wells are dissuaded from digging new wells (through information-based awareness)-there is no incentive for them to support the initiative; in fact, they are not even members of the committee.

Farmers are very much interested in having institutional arrangements in the lines of APFAMGS for managing groundwater. However, sustainability of the APFAMGS initiative is a big question mark in the absence of linkages with formal institutions, and policy or legislative backing of the movement[1]. Moreover, the exit protocol is not clearly defined. In a number of villages, the activities of the APFAMGS came to a standstill during the two years' gap (2009-11), due to the delay in the extension of the project. One suggestion made by the farmers in this regard is to bring the initiative under the groundwater department's purview so that the process would go on in the long run (Reddy *et al.*, 2011).

ii) Social Regulation Approach

The other two models, viz. the SRWM and APDAI, have adopted social regulation to manage groundwater. Though awareness building and data generation by the village communities are important components, the process is not so systematic. The most important aspect of these two models is to bring consensus among the communities to share water between well owners and others. Incentives such as reduced risk of well failure as no new wells are allowed, subsidies for micro-irrigation, provision for protective irrigation to the dry plots of the well owners, and the irrigation backup they get in the event of well failure, are put in place. Besides, there is provision for water harvesting structures to increase recharge, and distribution losses are reduced through pipeline supply of water and increased water use efficiency through promotion of micro-irrigation (subsidies).

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[1] Though HUNs are registered bodies and can ta~~keup~~ activities like input procurement, output marketing, etc., they are yet to be functional in these activities.

Social regulation appears to be effective in terms of stopping new borewells as well as a larger number of households, especially the marginal and small, benefiting from sharing water with well owners. This not only helped in increasing the cropped area, but also provided protective irrigation to a number of plots during critical periods, thus saving the crops. This also resulted in equity in the distribution of water and overall improvement in welfare. However, there are differences between the two models of social regulation in terms of their effectiveness: the SRWM appears to be more effective when compared to APDAI. One reason could be that the SRWM is older following an intensive approach and worked with smaller groups of farmers compared to the APDAI initiative. Though APDAI mostly follows the SRWM approach, it has adopted a broader (area-based) and formal approach involving the department. Besides, groundwater management is one of the pilots under the APDAI and hence, there are chances of dilution as far as the departmental involvement is concerned.

Despite the formal approach, participation and rule following is limited in the APDAI. People indicated that there are no tangible benefits from the initiative, and 50 per cent of the farmers felt that the institutional arrangements are not feasible. This view is more conspicuous among those sharing wells. This sceptical nature could be due to the larger contribution (75 per cent) from the farmers, which is substantial (total costs are Rs.8 to 10 thousand per acre). On the other hand, the approach of peoples' contribution could provide the much needed ownership and sustainability[2]. It is observed that the formal process of entering an agreement with the witness of the *Tahsildar* has also discouraged some villages from joining the initiative.

The formal approach of APDAI appears good on paper, as it follows an integrated approach of drought adaptation. The integration also involves various departments such as rural development, groundwater, agriculture, etc., but the feasibility of such integration is doubtful. The approach involves the existing institutions such as the *Mahila Samakhyas*, which provide the assurance of sustenance in the medium run at least. However, at the same time, there is also a danger of acquiring the stamp of a Government programme where people look for freebies rather than regulation and contribution.

On the whole, the social regulation approach seems to work better for sustainable groundwater management when compared to the knowledge intensive approach. Water use and sharing through regulation has increased the area under protective irrigation in

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[2] Of late people's contribution in Government programmes has lost its importance, as people are increasingly considering Government programmes as welfare measures rather than developmental. Hence, their contribution is treated as negative rather than as ownership.

an equitable manner. The knowledge intensive approach is not designed to address equity. In the absence of any regulations, formal or informal, farmers do not have any incentive to follow the good practices in the given policy environment. Encouraging sharing of water between well owners and others would result in achieving the twin objectives of conservation and improved access with equity. How to attain this on scale needs serious consideration at the policy level.

Sustainability of these initiatives is a major concern in all the approaches. None of the approaches have a well-defined exit protocol, while the APDAI appears to be well placed in this regard as its process involves a number of departments and formal institutions. At the same time, it requires strong leadership at the village level to implement and take the initiative forward, especially in the context of peoples' contribution. In the case of SRWM, its present success is mainly due to the commitment of NGO partners in the absence of any contribution from the farmers. Besides, in the absence of contribution, the financial sustainability of the initiatives would be a big concern, especially once the external funding stops. The weak sustainability of APFAMGS initiative was already evident during the no fund phase. Hence, fund flows appear to be critical for the success of the initiatives. The initiatives may continue in some of the villages due to strong leadership and commitment of the local NGOs even beyond the present funding, as they are at a smaller scale. Thus, scaling up these initiatives requires much more planning and designing.

Limitations of the Models

All these models suffer from limited scientific knowledge application at the ground level. The APFAMGS, which focuses on "demystifying" science, does not follow a rigorous scientific approach towards groundwater recharge and balance estimation, water budgeting based on crop water requirement, etc. Similarly, the well-sharing and social regulation models do not integrate technical inputs for estimating the groundwater availability. Moreover, they do not consider scale impacts at a watershed or basin scale, as the positive impacts observed in the study locations may be causing negative impacts downstream. Unless the impacts are considered at a scale of a hydrological unit, it is difficult to assess the real impacts.

Due to the short duration of these interventions, we are not able to provide hard core evidence to support some of the impacts that are measured in terms of farmers' perceptions. In the absence of long term data, the issue of attribution is also a problem. The changes in groundwater balance could be due to rainfall and other climatic fluctuations. Therefore, it is necessary to keep these limitations in view while considering scaling up of these initiatives.

Policy Directions for Scaling Up

The assessment of the three models indicates that CBGM is neither simple nor easily forthcoming. It calls for a lot of effort, working through complex rural dynamics at various levels. The reason is that appropriate policies to support or encourage such initiatives are not in place. Often, the existing policies work towards achieving opposite objectives rather than going in tandem with the participatory initiatives. The three approaches have proved that communities are capable of managing groundwater in a sustainable manner. The communities are also capable of understanding and using the technical aspects of hydro-geology. However, since groundwater is widely considered as a private property, there are no incentives for managing it at the community level. Furthermore, there are no economic incentives or disincentives for managing groundwater in a sustainable manner. Hence, unless wide-ranging policy changes are brought in, these initiatives remain as models rather than being adapted at a wider scale. Creating demand for these initiatives is as important as demand management of groundwater, and the demand management models cannot be effective as long as policy environment is supply-sided.

Some of the important policy interventions for promoting CBGM on a wider scale include:

- Need for dispelling the notion of groundwater as private property and making it a common property in the real sense. This calls for wide-ranging legislations and legal support.
- Establishing or moving towards community-based property rights on groundwater.
- Moving towards aquifer planning at the hydrological unit level to start with and then to watershed or river basin scale.
- Creating hydrological information at a much smaller scale appropriate for short-term farming decisions. This could be attained through creating low cost infrastructure at the village level and providing training at the local level to take up the responsibilities on a regular basis with the necessary economic incentives.
- Water sharing at the village level needs to be promoted as a first step in this direction. Existing wells could be linked and termed as common property.
- Incentives to conserve and manage water resources rather than exploit the resources such as free power and support prices for water-intensive crops like paddy.
- The present policy distortions of free power and the input and output pricing policies need to be rationalised to match conservation objectives.

- Regulation through pricing is the most effective instrument, but is hardly adopted at the policy level. In the absence of realistic pricing, water use efficiency remains a dream.

- As long as water rights are linked to land, water sharing is the best option to achieve equity. Encouraging and strengthening the existing traditional group wells in AP through differential and higher incentives in electricity tariffs, subsidies for micro-irrigation kits, etc., would help improve the equity and sustainability of groundwater.

- Andhra Pradesh Water Land and Trees Act (APWALTA) bans drilling new wells in villages notified as over-exploited. The Government may encourage only new wells on group sharing basis in villages/micro-basins that are identified as critical and semi-critical with respect to groundwater development. Strengthening and enforcing the existing regulations like APWALTA could be a starting point in this direction.

- Delinking land and water rights need to be treated as an important policy goal, at least in the long run.

Thus, the experience of the three models reveals that wide ranging policy changes are required to scale up the achievements of these small scale initiatives. Replication of these models could be possible with high transaction costs, but the sustainability of these initiatives remains uncertain in the present policy environment. However, the conclusions drawn here are based on the experience of a few villages and hence cannot be generalised. While these findings provide some insights, there is a need for better understanding of such initiatives through a large scale systematic research covering the existing initiatives across the country.

PART- I
GROUNDWATER: DEVELOPMENT, DEGRADATION AND MANAGEMENT

Chapter - 1

INTRODUCTION

I. Background

Groundwater management is the most challenging part of water management. Hitherto, groundwater policies were in the lines of encouraging over exploitation. These policies are in the nature of providing incentives for groundwater development such as subsidised credit, power, etc. While these policies helped in promoting groundwater development in the regions where groundwater development was below potential, they have led to over exploitation of the resource in fragile resource regions. The inter-connectedness of aquifers and the linkages between surface and groundwater have far-reaching environmental impacts. If the existing models are accurate, degradation of aquifers could adversely affect stream flows and water availability of downstream water users. As a result of degradation, majority of the resource-poor farmers have lost or are losing access to water, as the water tables go down. Even when they own borewells, they cannot compete with the resource-rich farmers in deepening their wells (Reddy, 2005). That is, the poor are denied their rightful share in the Common Pool Resources (CPR's). As groundwater is the single largest source of irrigation and domestic water supply in a number of regions, its governance assumes importance and urgency.

In India the so-called water sector reforms have not looked at policies that would encourage development of institutions for resource management. Sustainable management of groundwater resources is crucial for ensuring long-term livelihood security for farmers dependent upon it. In the absence of institutions that mitigate the tendency to over exploit CPRs, a rural agrarian system will be pushed towards extinction, especially when climate change-induced frequent droughts may create severe problems. Farming communities are perceptive about the fact that improved availability of water for irrigation significantly enhances livelihood security. Moreover, the poverty alleviation goals necessitate a focus on the specific needs of the poor, especially the women and the landless and land-poor families. The issue of how to secure the rights and entitlements to water for the poor people needs to be addressed on a priority basis. Though there are top down, state regulations on groundwater exploitation, they are inadequate and ineffective in the absence of awareness and clarity on rights and responsibilities of the user communities.

It is argued that the scientific knowledge should be shared with the farmers because of the simple reason that the sustainability of the resource lies in their hands (FAO, 2008). But the problem is with availability of accurate and reliable data. The available data is very sparse with low credibility due to the non-representativeness of the data. While farmers require at the village (micro-watershed of about 500 hectares) level, the available data in India is based on an observation well and a rain gauge station for every 25 sq km. One of the ways towards better and sustainable groundwater management is through improving the awareness among communities and building their capacity to measure and monitor groundwater levels on a seasonal basis. However, there are no success stories of such initiatives. Most of the success stories in world over pertain to tradable water rights, quotas, water prices, taxes, etc.

II. Objectives and Setting

This study is an attempt to examine the dynamics of groundwater development over time and across regions, and highlight the importance of reliable information at an appropriate scale. The study also focuses on the importance of involving local communities in generating such information and managing groundwater with appropriate capacities to measure and monitor the resource. It is argued, based on the evidence, that farmers are capable of understanding and learning the technical skills of hydrological monitoring though the methodological flaws in assessment need to be addressed. The basic idea is how to demystify science and make it accessible and user friendly to the communities. Specific objectives include: a) to examine the spatio-temporal variations in groundwater development in Andhra Pradesh (AP); b) to discuss the relevance of the existing information to the user or farming communities; and c) to explore the possibilities for generating reliable and useful information based on the existing experience at the ground level.

The study is based on the evidence from AP, which is among the states where groundwater is the single largest source of irrigation as well as domestic water supplies. Besides, the state is severely affected by groundwater depletion, which is a cause of concern in terms of resource sustainability in general and groundwater and energy resources in specific. Management strategies can be planned only when the resource status/potential is known and the constraints are identified. Analysis of the trends in groundwater development and the examination of categorical shifts are considered as major steps towards formulating policies and programmes that aim to increase equity and enhance the sustainability of groundwater resources. Thus, the study is expected to help frame future policy that will facilitate and promote efficient and equitable groundwater management. Uneven distribution of groundwater in AP severely affects some regions, as the drought and desert prone (DPAP and DDP) areas of AP have poor groundwater potential. These areas are characterized by large human and cattle populations which are continuously putting heavy pressure on the already fragile natural resource base for food, fodder and fuel. Any analysis which attempts to study the overall groundwater development in AP should consider these regional disparities.

The State of AP, consisting of an area of 2.75 lakh sq km, is endowed with a variety of physiographic features ranging from hills and undulating plains to a coastal deltaic environment. The state has three major river basins-Godavari, Krishna and Pennar. The entire state falls under the semi-arid region of Peninsular India and is characterized by hot summers and cold winters. Geomorphologically, the state can be categorized into pedi-plains, coastal alluvial plains and hill ranges (Figure 1 in *Annexure*). Major constraints are imposed by the spatio-temporal variations in water availability, though in aggregate terms, the water is sufficient to meet current demands in all but the driest years (FAO, 2004). The state receives an annual rainfall of 940 mm on an average, with wide variations across the districts. It ranges from 1200 mm in Srikakulam District to about 550 mm in Anantapur District. The majority of the rainfall (66%) is received from the south-west monsoon during June-September, while the north-east monsoon (October-December) contributes about 25% of the annual rainfall. Based on the rainfall, topography and climate the state is divided into nine agro-climatic zones-high altitude and tribal zone, Krishna Zone, Godavari Zone, North Coastal Zone, Northern Telangana Zone, Central Telangana Zone, scarce rainfall zone, Southern Telangana Zone and Southern Zone (Figure 2 in *Annexure*).

The State of AP is underlain by rock types ranging from Archaean to recent alluvium with varied texture and structures. Nearly 85% of the state, i.e., about 2.33 lakh sq km, is underlain by hard rock's - igneous, volcanic and metamorphic rocks, mainly granites, gneisses and khondalites in the Eastern Ghats, Cuddapah (middle upper Protozoic), Kurnool and Deccan traps (Eocene). The remaining 15% of the area, i.e., 0.42 lakh sq km is underlain by soft rocks-tertiary and Gondwana sandstones & shales and alluvium of recent age. Dolerite dykes, quartz reefs, feldspathic and pegmatite veins extending from a few meters to a few kilometers cut across the country rocks at many places. The dolerite dykes have been emplaced along major prominent fractures. The vertical joints in granites are also aligned to the major direction of fractures/lineaments. Fluorite and apatite rocks contain fluoride-bearing minerals and are the main source of fluoride in groundwater (Figure 3 in *Annexure*).

Soils play an important role in improving groundwater recharge. The soils of the state are broadly classified into red, black and alluvial. Red sandy soils cover the largest area in the state (67%) and occur widely in the Telangana and Rayalaseema regions. The black soils are in general transported by rivers. The deltaic alluvial soils, coastal alluvial soils and coastal sandy soils are formed by the riverine system. Changes in land use can have significant effects on infiltration rates through the soil surface on water retention capability of soils and on sub-surface transmissibility (Swallow *et al.*, 2001).

The state's total renewable water resources (annual), both ground and surface water are estimated to be about 108.15 bcm (3820 tmc), out of which about 62.29 bcm (2200 tmc) is currently being utilized for drinking, agriculture, industry and power generation purposes. The per capita annual water resources work out to be slightly more than 1400 cum, and the utilization is about 800 cum (AP Water Vision, 2004). Countries or regions are considered water stressed when the annual per capita availability is between 1000 and 2000 cum. With the availability below 1700 cum, a region is deemed 'water stressed'; with less than 1000 cum, it becomes 'water scarce' and below 500 cum it becomes ''absolutely water scarce". The current percentage of withdrawal of available water in AP is 58%. As per UN indicator, if the percentage withdrawal is more than 40%, the country is considered as water scarce. The average per capita water availability in AP as against India between 1951 and 2010 and the requirement for the year 2050 reflect the water stress (Table 1.1). This calls for efforts towards efficient management supported by appropriate policy framework for proper water governance.

Table 1.1: Per Capita Availability of Water in AP Compared to India (in cum)

Year	India	Andhra Pradesh
1951	5,177	3600
1991	2100	1600
2001	1750	1400
2010	1,588	1400
2050	1140	912

Source: Central Water Commission and Central Ground Water Board

GoAP (2003), Water Conservation Mission

This part is organised into three chapters. The following chapter provides an overview of groundwater situation covering spatio-temporal aspects. Factors influencing groundwater development are estimated in chapter three. In this chapter the experience of farmers managed groundwater systems under the project titled Andhra Pradesh Farmers Managed Groundwater Systems (APFAMGS) is discussed under the role of local institutions along with the overall arguments and calls for credible and reliable hydrological information at the habitation level.

CHAPTER II

GROUNDWATER DEVELOPMENT IN AP: A SPATIO-TEMPORAL ANALYSIS

A recent expert group report (GoI, 2007) indicated that groundwater resources in the country are under severe stress. In 2004, an alarming 28% of the blocks in the country were in the category of semi-critical, critical or over exploitedblocks, leading to a progressive lowering of the water table. The report perceives shortcomings in the legislative actions, including slowing down of development by the permit system, difficulties in enforcing regulations, scope for corruption and depriving new water users of water allocation. Unfortunately, groundwater development is still treated as a supply side issue, without any concern for demand side aspects.

I. Estimates of Groundwater in India

India with 2.4% of the world's total area has 16% of the world's population, but has only 4% of the total available fresh water. This clearly indicates the need for water resources development, conservation and their optimum use. At the aggregate level, India is not short of water. The water resources potential of the country has been assessed from time to time by different agencies (Table 2.1). It may be seen that since 1954, the estimates have stabilized and are within the proximity of the currently accepted estimate of 1869 billion cubic metres (bcm), which includes replenishable groundwater that gets charged on annual basis.

Table 2.1: Estimates of Water Resources of India

Agency	Estimate (in bcm)	% Deviation (from 1869 bcm)
First Irrigation Commission (1902-03)	1443	- 23
Dr. A.N. Khosla (1949)	1673	-10
Central Water & Power Commission (1954-66)	1881	+ 0.6
National Commission on Agriculture	1850	- 1
Central Water Commission (1988)	1880	+ 0.6
Central Water Commission (1993)	1869	-

Source: GoI (2007), Report of the Steering Committee on Water Resources for Eleventh Five Year Plan (2007-2012), Planning Commission, May.

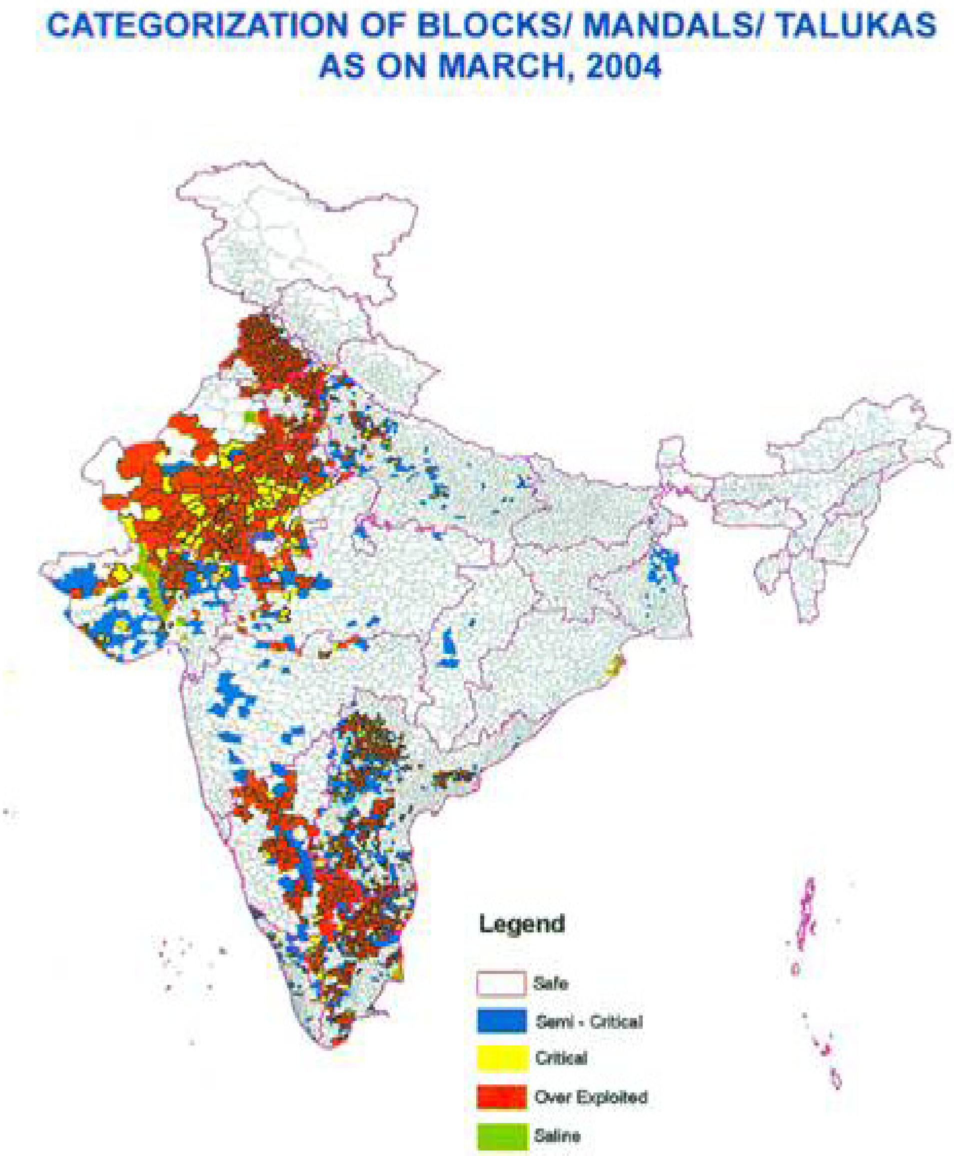
Within the limitations of physiographic conditions, socio-political environment, legal and constitutional constraints and the technology available at hand, the utilizable water resources of the country have been assessed at 1123 bcm, of which 690 bcm is from surface water and 433 bcm from groundwater sources (CWC,1993). Harnessing of 690 bcm of utilizable surface water is possible only if matching storages are built. Trans-basin transfer of water, if taken up to the full extent as proposed under the National Perspective Plan, would further increase the utilizable quantity by approximately 220 bcm. The irrigation potential of the country has been estimated at 139.9 million hectares (mha) without inter-basin sharing of water and 175 mha with inter-basin sharing. The requirement of water for various sectors has been assessed by the National Commission on Integrated Water Resources Development (NCIWRD) in the year 2000. This requirement is based on the assumption that the irrigation efficiency will increase to 60% from the present level of 35% to 40%. The Standing Committee of the Ministry of Water Resources (MoWR) also assesses it periodically (Table 2.2).

Table 2.2: Water Requirement for Various Sectors

Sector	Water Demand in km^3 (or bcm)					
	Standing Sub-Committee of MoWR			NCIWRD		
	2010	2025	2050	2010	2025	2050
Irrigation	688	910	1072	557	611	807
Drinking Water	56	73	102	43	62	111
Industry	12	23	63	37	67	81
Energy	5	15	130	19	33	70
Others	52	72	80	54	70	111
Total	813	1093	1447	710	843	1180

Source: GoI (2007), Report of the Steering Committee on Water Resources for Eleventh Five Year Plan (2007-2012), Planning Commission, May.

The annual replenishable groundwater resource for the entire country is 433 bcm. The overall contribution of rainfall to the country's annual replenishable groundwater resource is 67% and the share of other sources, including canal seepage, return flow from irrigation, seepage from water bodies and water conservation structures taken together is 33%. In the states of AP, Delhi, Haryana, Jammu & Kashmir, Jharkhand, Punjab, Tamil Nadu, Uttar Pradesh, Uttarakhand and the UT of Pondicherry, the contribution of other sources is more than the national average of 33%, mainly because of canal seepage and intensive irrigation. The southwest monsoon being the most prevalent contributor of rainfall in the country, about 73% of the country's annual replenishable groundwater recharge takes place during the *kharif* period of cultivation. Keeping 34 bcm as the allocation for natural discharge during the non-monsoon season, the net annual groundwater available for utilization in the entire country is about 399 bcm (Figure 4 in *Annexure*). The state-wise groundwater resources availability, utilization and categorization of over exploited and critical blocks are given in Table 2.3 to assess the relative status of AP.



Source: GoI (2006), Dynamic Groundwater Resources of India (as on March 2004), New Delhi.

II. Status of groundwater in AP

In this sub-section, we examine the hydrological information that is available at the official level in AP. The official data sources are used to highlight the scale and intensity of the data generated on groundwater with the objective of identifying the gaps in information available at various levels. AP is one of the few states in India that compile detailed hydrological information. The source-wise composition of irrigation varies across regions. While the rain-fed and drought-prone regions have experienced a shift towards groundwater irrigation, the river basin endowed regions have continued to depend on surface water resources.

In AP, the first groundwater resource estimation was undertaken in the year 1985 and subsequently the same exercise was carried out five times till 2007. The Stage of Groundwater Development (SGD) in AP over the years is analysed on the basis of the groundwater resource estimation made by the State Groundwater Department (SGWD). These estimates are available at the district and regional level on the basis of command and non-command areas and also on the basis of drought prone (DPAP) and non-drought prone areas. The estimates are based on the readings from the Observation (OB) Wells or assessment units located at the *Taluk/Mandal*/Groundwater Basin/ Watershed level (Table 2.4). The assessment unit is not same over the years. The number of assessment units was only 47 *Taluks* in 1985, though the coverage was expanded to all the *Mandals*, groundwater basins and Watersheds since 1993. These units are assumed to be valid for 26,586 villages spread over a geographical area of 0.28 million sq km in the state. Given the high spatial variations in the structure and quality of geo-hydrology and aquifers, the relevance of district or *Mandal* level data is quite dubious.

The methodology adopted in Groundwater Estimation Committee (GEC) 1997 is reasonably valid in an approximately homogenous hydrologic terrain like alluvium. However, this may not be applicable for hard rock terrain where the hydro-geological conditions vary widely within small areas under the prevailing heterogeneous set up. Methodological refinements may be needed in this regard. Significantly, almost two-thirds of the area, including AP, is occupied by hard rock terrain (GoI, 2002). A committee appointed in 2001 has suggested modifications to the GEC-1997 methodology. The committee also left some important issues, such as norms of recharge components, return flow from irrigation, groundwater draft, base flow, spring discharge and specific yield, unresolved, and recommended for further studies and estimates. As a result, the methodology used for estimation is neither perfect nor appropriate for addressing the needs of the users, who need to know the actual groundwater available in their village on a season to season basis.

Table 2.3: State-wise Groundwater Resources' Availability, Utilization and Categorization of Assessment Units in India (in bcm)

State/ Union Territory	Annual Replenish able Groundwater Resource	Natural Discharge during Non-Monsoon Season	Net Annual Groundwater Availability	Annual Groundwater Draft	Stage of Groundwater Development (SGD) (%)	Categorization of Assessment areas (in Number)	
						Over Exploited	Critical
Andhra Pradesh	36.5	3.55	32.95	14.9	45	219	77
Arunachal Pradesh	2.56	0.26	2.3	0.0008	0.04	0	0
Assam	27.23	2.34	24.89	5.44	22	0	0
Bihar	29.19	1.77	27.42	10.77	39	0	0
Chhattisgarh	14.93	1.25	13.68	2.8	20	0	0
Delhi	0.3	0.02	0.28	0.48	170	7	0
Goa	0.28	0.02	0.27	0.07	27	0	0
Gujarat	15.81	0.79	15.02	11.49	76	31	12
Haryana	9.31	0.68	8.63	9.45	109	55	11
Himachal Pradesh	0.43	0.04	0.39	0.12	30	0	0
Jammu & Kashmir	2.7	0.27	2.43	0.33	14	0	0
Jharkhand	5.58	0.33	5.25	1.09	21	0	0
Karnataka	15.93	0.63	15.3	10.71	70	65	3
Kerala	6.84	0.61	6.23	2.92	47	5	15
Madhya Pradesh	37.19	1.86	35.33	17.12	48	24	5
Maharashtra	32.96	1.75	31.21	15.09	48	7	1
Manipur	0.38	0.04	0.34	0.002	0.65	0	0
Meghalaya	1.15	0.12	1.04	0.002	0.18	0	0
Mizoram	0.04	0.004	0.04	0.0004	0.9	0	0
Nagaland	0.36	0.04	0.32	0.009	3	0	0
Orissa	23.09	2.08	21.01	3.85	18	0	0
Punjab	23.78	2.33	21.44	31.16	145	103	5
Rajasthan	11.56	1.18	10.38	12.99	125	140	50
Sikkim	0.08	0	0.08	0.01	16	0	0
Tamil Nadu	23.07	2.31	20.76	17.65	85	142	33
Tripura	2.19	0.22	1.97	0.17	9	0	0
Uttar Pradesh	76.35	6.17	70.18	48.78	70	37	13
Uttaranchal	2.27	0.17	2.1	1.39	66	2	0
West Bengal	30.36	2.9	27.46	11.65	42	0	1
Total (States)	**432.42**	**33.73**	**398.7**	**230.44**	**58**	**837**	**226**
Union Territory (UT)							
Andaman & Nicobar	0.33	0.005	0.32	0.01	4	0	0
Chandigarh	0.023	0.02	0.02	0	0	0	0
Dadra & Nagar Haveli	0.063	0.003	0.06	0.009	14	0	0
Daman & Diu	0.009	0.0004	0.008	0.009	107	1	0
Lakshadweep	0.012	0.009	0.004	0.002	63	0	0
Puducherry	0.16	0.016	0.144	0.151	105	1	0
Total (UTs)	**0.597**	**0.036**	**0.556**	**0.181**	**33**	**2**	**0**
Grand Total	**433.02**	**33.77**	**399.25**	**230.62**	**58**	**839**	**226**

Source: GoI (2006), Dynamic ground water resources of India (as on March 2004), Central Ground Water Board, New Delhi.

Table 2.4: Details of Groundwater Assessment in Andhra Pradesh

Year of Assessment	Assessment Unit	No. of Units Assessed	Methodology	Actual Number
1985	Taluk	47	Water table fluctuation	308
1993	Mandal	1108	Water table fluctuation and rainfall infiltration	1124
2002	Groundwater Basin	1157	GEC 1997 methodology	1157
2004	Watershed	1229	GEC 1997 methodology	1229
2007	Watershed	1229	GEC 1997 methodology	1229

Source: GoAP, Groundwater Resource Estimated Reports, Groundwater Department, Hyderabad

Groundwater resource of the state is estimated on a regular basis by the MoWR in close collaboration with the Ground Water Department of Government of AP. The administrative set up of the state was reconstituted into *Mandals* in 1985. Accordingly, groundwater resources in the state were estimated in 1995, following the norms recommended by the GEC 1984, taking 1993 as a base year. In 1997, a detailed methodology, along with a guide book giving all the computations needed for assessment was published by the GEC, a high power committee of the MoWR. This is often referred as the GEC 1997 methodology. In 2004, groundwater resource estimation using data of 2001 was completed, based on GEC 1997. Based on the recommendations of the "Groundwater Estimation Committee on Hard Rock Terrain", resource estimation was carried out again in 2005 with the base data of 2004. As per the methodology followed, the status of groundwater is given simply as a ratio of the utilization and recharge, which is called the SGD. It can also be called the stage of groundwater utilization for clarity.

The groundwater status was estimated for the year 1984-85 using the water table fluctuation method. The data of Central Groundwater Board (CGWB) observation well network, supplemented by SGWD observation well data, were used. All the calculations were made for the year 1984-85. The number of observation wells monitored in the year 1984-85 by CGWB and SGWD are 321 and 2698 respectively. The district-wise groundwater development in the state ranges between 6% and 59% and that of entire state is of the order of 28%. Recharge computations have been made separately for *ayacut* (command) and *non-ayacut* (non-command) areas. It is observed that most of the groundwater development is confined to the non-*ayacut* areas.

The total dynamic groundwater resources of AP were thus estimated at 25.3 bcm per annum as in 1984-85 and the utilizable groundwater resources for irrigation were worked out to be 25.30 bcm per annum (Table 2.5). The net annual groundwater draft in 1984-85 was 7.07 bcm. Thus, a balance of 18.23 bcm was available for future development. It is to be remembered that these estimates consider only the dynamic groundwater resources of water table aquifers.

Table 2.5: Estimates of Groundwater in Different Years of Assessment (in bcm)

Year	Annual Availability	Annual Utilisation	Balance	SGD
1985	25.30	7.07	18.23	28
1993	35.29	10.13	25.16	29
2002	30.56	12.97	17.59	43
2004	32.76	14.86	17.90	45
2007	34.70	14.11	20.59	41

Note: Data compiled from Groundwater Resource Estimated Reports of different years, Ground Water Department, GoAP.

The net groundwater availability per annum, as per 1993 estimates, for the entire state was estimated to be about 35.3 bcm, which was 14.4% of the total quantity of water received through normal precipitation. From this, about 15%, i.e., 5.3 bcm was earmarked for drinking and other committed uses, leaving a balance of 30 bcm for irrigation. The net annual groundwater draft for irrigation was 7.09 bcm. The level of groundwater development across districts ranged between 7% and 43%, and for the state as a whole it was 25%. However, during this period, 5 *Mandals* were categorised under dark and 60 *Mandals* under semi-critical zones.

In 2002 the state was divided into 1193 assessment units, which include basins with defined hydrological boundaries in hard rock areas with areas ranging between 50 and 450 sq km and *Mandals* (administrative blocks) in alluvial areas including 36 Saline *Mandals*. Computations of net groundwater availability, its utilisation and availability for future use in all the assessment units for command, non-command and poor groundwater quality areas were made separately. The estimates showed the groundwater availability at 30 bcm, usage at 13 bcm and the balance at 17 bcm per annum. This clearly indicates that these aggregate estimates do not reflect micro-realities where declining water levels and drying up wells is observed.

The watershed boundaries were revised to 1229 during 2004. The estimates showed that groundwater availability was 32.8 bcm, usage was 14.9 bcm and the balance was 17.9 bcm per annum. These estimates included 1.3 bcm of net annual groundwater availability in poor quality and saline areas. The usage in saline areas was about 0.21 bcm. In comparison with 2002 estimates, there was a definite increase (by about 13%) in groundwater usage across sectors. This was corroborated by a steep decline in the mean water levels almost everywhere in the state. In many areas, water level stands in fractured formation, rather than in weathered formation, as shown by the network of existing Piezometers, and the drying up of traditional OB Wells. Groundwater development was at the highest level (45%) during 2004 due to the prevailing unprecedented drought conditions. The situation eased by 2007 with consecutive good monsoons resulting in a decline in the SGD (41%).

Groundwater Development in Command and Non-command Areas

In 2007, estimates were made separately for command and non-command areas using the GEC 1997 methodology, based on the data from Transmission Corporation of Andhra Pradesh Limited (APTRANSCO), Revenue Department and Irrigation Department. Corrections factors were applied based on the field observations. The total groundwater resources were estimated at 34.7 bcm (17.89 in non-command area + 16.81 in command area) and utilization was 14.11 bcm (10.53 in non-command area + 3.58 in command area), while the balance available resource was 20.59 bcm (7.36 in non-command area + 13.23 in command area). The average SGD for the entire state was 41%, of which 59% was in non-command areas while 21% was in command areas. The annual groundwater availability in AP during 2007 was 34.7 bcm. The overall draft in 2007 was around 14 bcm.

Table 2.6: Mandals and Villages under Different Categories (2007)

Category	Number of Watersheds	Number of Mandals	Number of Villages
Over Exploited	132	108	5096
Critical	89	60	1064
Semi-Critical	175	155	2632
Safe	833	782	17219

Source: GoAP, (2008), Groundwater Resource Andhra Pradesh, Groundwater Department, Hyderabad, August.

The state has been categorized into four zones, viz., safe (<70%), semi-critical (70% to 90%), critical (90 to 100%) and over exploited (>100%), based on the percentage of groundwater exploitation. About 5096 villages, spread over 108 *Mandals* and 132 watersheds, fall in the over exploited category consequent to the drying up of shallow aquifers (Table 2.6). Along with the overall groundwater development at the state and district level (Figure 2.1), the variation between command and non-command areas was also examined. The assessment shows that groundwater resources have reached a very critical stage in non-command areas (Table 2.7). All the areas of the state that are not served by canal command, including the areas in districts like West Godavari, Anantapur, etc., are showing very high usage of the available groundwater and this is reflected in the SGD, which exceeds 70% of the safe limit of exploitation. The total groundwater resources are estimated at 17.89 bcm in non-command areas and 16.81 bcm in command areas, while the utilization is 10.53 bcm in non-command areas and 3.58 bcm in command areas, and the balance available resource is 7.36 bcm in non-command areas and 13.23 bcm in command areas. The average SGD for the entire state is 41%, of which 59% is in non-command areas, while 21% is in command areas.

The estimates show that the overall SGD in AP has gone up from 28% in 1985 to 41% in 2007, except during the year 1993, when it declined to 24%. However, opposite trends are observed in the case of command and non-command areas between 1985 and 2002- while the command areas have experienced an increasing trend, the non-command areas have experienced a declining trend. However, both command and non-command areas have shown an increasing trend between 2002 and 2004, which is due to the consecutive droughts during that period. Between 2004 and 2007, there was a decline in the level of development, reverting back to 2002 levels.

The overall SGD in Coastal Andhra was lesser when compared to the other two regions in all the groundwater resource estimated years. On the other hand, in Rayalaseema Region the SGD was higher compared to the other two regions during these years, except in 1985, when Telangana was marginally higher than this region. The trend with respect to the SGD in command areas was same in all the three regions during the estimated years 1985 to 2002, when it increased from 1985 to 1993 and then declined. After 2002, the trend was same in case of Coastal Andhra and Telangana Regions (increased between 2002 and 2004 and declined between 2004 and 2007) while the SGD in Rayalaseema showed an increasing trend during both the periods. The non-command areas of all the three regions exhibited a similar trend with respect to the overall SGD.

On the basis of overall SGD, districts were categorised as 'very high usage' (>70%), 'high usage' (>50% & <70%), 'moderate usage' (>30% & <50%) and 'low usage' (<30%) districts. As per the estimates of 1985, the SGD in coastal districts ranged from 8% (Guntur) to 74% (West Godavari). The three districts of Coastal Andhra (Srikakulam, Guntur and Krishna) show an increase in groundwater development compared to the other six districts in the region.

In the Rayalaseema Region, the SGD ranged between 37% in Kurnool and 94% in Chittoor. While Anantapur District showed an increase in SGD, the other three districts, i.e., Kurnool, Cuddapah and Chittoor showed a decrease in SGD between the years. In the Telangana Region, the SGD varied from 6% in Adilabad to 99% in Ranga Reddy. While in Nalgonda District there was an increase in the use of groundwater and the SGD was raised from 52% to 53%, in all the other eight Telangana districts, the stage of development decreased-ranging from 2% in Khammam to 13% in Mahabubnagar, compared to the previous estimates. However, no district from any region came under

Table 2.7: District/Region-wise Stage/Level of Groundwater Development in AP

District/ Region	Stage/Level of Groundwater Development (%)														
	1985			1993			2002			2004			2007		
	C	NC	T	C	NC	T	C	NC	T	C	NC	T	C	NC	T
Srikakulam	1	37	10	18	17.9	18	15	23	21	10	10	10	19	35	28
Vizianagaram	2	20	9	13.1	13.1	13.1	15	30	25	19	28	24	16	24	21
Visakhapatnam	3	24	15	15.8	15.8	15.8	12	32	27	71	29	34	56	19	23
East Godavari	12	33	18	13.2	13.2	13.2	15	40	22	14	71	31	14	36	20
West Godavari	19	61	35	23.7	23.7	23.7	5	115	74	3	94	48	6	75	28
Krishna	9	56	23	15.9	15.9	15.9	18	35	26	14	53	24	19	70	29
Guntur	6	12	8	6.5	6.6	6.5	6	30	9	9	57	10	10	43	11
Prakasam	3	19	13	13.6	13.6	13.6	6	54	26	32	76	57	14	64	34
Nellore	13	54	32	32.5	32.5	32.5	33	49	41	36	53	44	29	53	38
Coastal Andhra	**8**	**34**	**18**	**16.5**	**19.6**	**17.8**	**13**	**49**	**28**	**16**	**53**	**29**	**15**	47	25
Kurnool	3	18	12	17.6	17.5	17.5	13	36	27	21	59	42	30	48	37
Anantapur	10	41	32	36.9	35.9	36.9	35	80	73	30	97	76	58	103	90
Cuddapah	15	58	46	35	35	35	13	64	56	43	82	74	27	87	69
Chittoor	8	88	44	33.7	33.7	33.7	NA	94	94	NA	72	72	NA	67	67
Rayalaseema	**8**	**51**	**34**	**29.1**	**31.6**	**31.1**	**17**	**72**	**63**	**28**	**78**	**66**	**36**	**76**	**65**
Ranga Reddy	32	52	50	36.4	36.4	36.4	20	60	58	NA	103	103	NA	99	99
Nizamabad	5	90	33	35.2	35.2	35.2	NA	81	81	71	96	86	69	79	75
Medak	10	62	43	30.8	30.8	30.8	NA	71	71	NA	87	87	NA	74	74
Mahbubnagar	15	51	41	33.2	33.3	33.3	52	94	83	34	73	62	15	61	49
Nalgonda	5	55	31	27.2	27.2	27.2	32	27	28	11	77	52	18	73	53
Warangal	16	71	55	33.9	33.9	33.9	19	67	41	56	80	69	59	70	65
Khammam	5	14	12	10	10	10	25	53	46	22	19	20	25	16	18
Karimnagar	11	104	59	40.8	40.8	40.8	15	20	18	34	79	53	17	81	47
Adilabad	3	7	6	13.1	13.2	13.2	10	76	57	33	33	33	28	32	31
Telangana	**9**	**52**	**36**	**29.1**	**27.8**	**28.3**	**22**	**58**	**49**	**36**	**66**	**56**	**33**	**58**	**51**
Andhra Pradesh	**8**	**46**	**28**	**21.1**	**25.6**	**23.6**	**16**	**58**	**42**	**22**	**65**	**45**	**21**	**59**	**41**

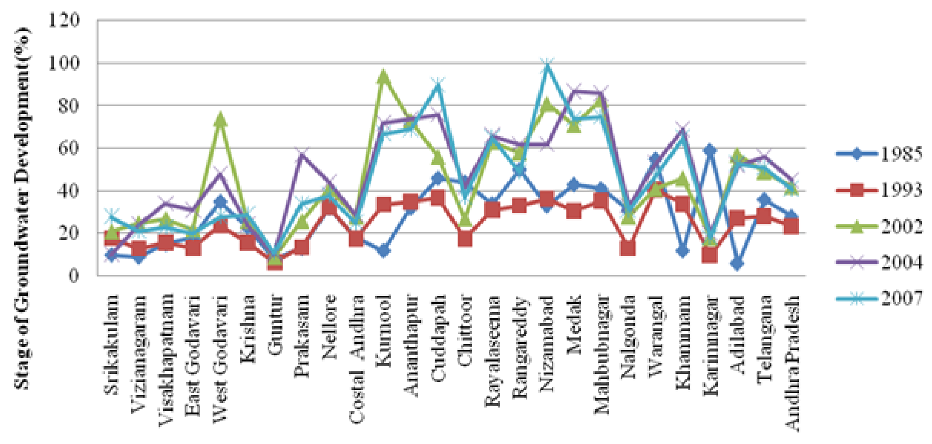
Note: 1. Data compiled from Groundwater Resource Estimated Reports of different years, Groundwater Department, GoAP.
2. C= Command; NC= Non-Command; T=Total (both command and non-command taken together).

the 'very high usage' category. Three of the districts in the Telangana Region (Ranga Reddy, Warangal and Karimnagar) came under the 'high usage' category, while two districts from Coastal Andhra (West Godavari and Nellore), three from Rayalaseema (Anantapur, Cuddapah and Chittoor) and four from Telangana (Nizamabad, Medak, Mahbubnagar and Nalgonda) were under the 'moderate usage' category; and seven Coastal

Andhra districts (Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, Krishna, Guntur and Prakasam), one Rayalaseema district (Kurnool) and two Telangana districts (Khammam and Adilabad) were under the 'low usage' category.

Groundwater development estimates in 1993 showed that none of the districts from any region came under the 'very high' and 'high usage' category. Only one district from the Coastal Andhra (Nellore), three in Rayalaseema (Chittoor, Cuddapah and Anantapur) and six districts from the Telangana Region (Mahbubnagar, Ranga Reddy, Medak, Nizamabad, Karimnagar and Warangal) came under the 'moderate usage' category; while all the districts from Coastal Andhra, only one from Rayalaseema (Kurnool) and three from the Telangana Region (Adilabad, Khammam and Nalgonda) came under the 'low usage' category. During 2002, one district in Coastal Andhra (East Godavari), two in Rayalaseema (Chittoor and Cuddapah) and three in the Telangana Region (Ranga Reddy, Medak and Nizamabad) were found to be under the 'very high usage' category. The 'high usage' districts included one in Rayalaseema (Anantapur) and two in Telangana (Mahbubnagar and Nalgonda). The 'moderate usage' category included one district in Coastal Andhra (Nellore) and two in Telangana (Karimnagar and Warangal), while seven districts in Coastal Andhra (Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, Krishna, Guntur and Prakasam), only one in Rayalaseema (Kurnool) and two in Telangana (Adilabad and Khammam) were under the 'safe/low usage' category.

Figure 2.1: District-wise and Region-wise Level of Groundwater Development (%) in AP



The severe drought conditions preceding 2004 reflected in three districts in Telangana (Ranga Reddy/Hyderabad, Nizamabad and Medak) and three in Rayalaseema (Anantapur, Cuddapah and Chittoor), falling under the 'very high usage' category in 2004. One district in Coastal Andhra (Prakasam) and four in Telangana (Warangal, Mahbubnagar, Karimnagar and Nalgonda) came under the 'high usage category', while four districts in Coastal Andhra (Visakhapatnam, East Godavari, West Godavari and Nellore), one in Rayalaseema (Kurnool) and one in Telangana (Adilabad) were under the 'moderate usage' category. The 'safe/low usage' districts were Vizianagaram, Srikakulam, Krishna and Guntur from Coastal Andhra (four districts), and only one from Telangana (Khammam). The situation continued during 2007, when the number of 'very high usage' districts comprised three from Telangana (Ranga Reddy/Hyderabad, Nizamabad and Medak) and one from Rayalaseema (Anantapur). The 'high usage' districts included two districts from Rayalaseema (Cuddapah and Chittoor) and two from the Telangana Region (Warangal and Nalgonda). Two districts in Coastal Andhra (Nellore and Prakasam), one in Rayalaseema (Kurnool) and three in Telangana (Mahbubnagar, Karimnagar, Adilabad) came under the 'moderate usage' category. As many as seven districts from Coastal Andhra (Krishna, Srikakulam, West Godavari, Visakhapatnam, Vizianagaram, East Godavari and Guntur) and only one in Telangana (Khammam) were under the 'low/safe usage' category.

Groundwater Development in DPAP and Non-DPAP Districts

When the districts are categorised as DPAP and non-DPAP districts, the trends in groundwater development shows that the overall SGD in DPAP districts are higher than that of non-DPAP districts in all the assessment years except in 1985, when non-DPAP districts had a marginally higher level of groundwater development (Table 2.8). So far as command areas of DPAP and non-DPAP districts are concerned, except in 1985 and 2002, the command areas of DPAP districts had higher level of groundwater development than that of non-DPAP districts. The command areas of DPAP and non-DPAP districts exhibited a similar trend in all the years, i.e., increase in 1993 and 2004 and decline in 2002 and 2007, when compared to the respective previous years' estimates. As far as non-command areas of DPAP and non-DPAP districts are concerned, except in 2007, non-DPAP districts had higher level of groundwater development than the DPAP districts. Both command and non-command areas within the respective zones showed similar trends. The severe drought conditions during 2004 has led to groundwater exploitation (increased availability), especially in the non-DPAP districts and hence 2004 is showing higher groundwater balance despite increase in use.

Overall, the SGD of most districts was under the safe category in 1985 and 1993 (Table 2.9). In 1985, while all the command areas fell under the safe category, one was under semi-critical, two were under critical and one was under over exploited category. However, the situation changed after 1993. As far as the overall groundwater development was concerned, some districts which were under safe category during earlier years slipped to

Table 2.8: Groundwater Estimates for DPAP and Non-DPAP Districts in AP

Scheme/ Year	Annual Groundwater Availability (mcm)			Groundwater Utilization/Draft (mcm)			Groundwater Balance (mcm)			SGD (%)		
DPAP	C	NC	Total	C	NC	Total	C	NC	Total	C	NC	Total
1985	4832	7774	12606	298	3047	3345	4534	4727	9261	6	39	27
1993	4562	9747	14307	1019	2461	3481	3542	7286	10823	22	25	24
2002	3423	12369	15792	437	7122	7559	2986	5247	8233	13	58	48
2004	3918	11473	15391	963	7302	8265	2955	4171	7126	25	64	54
2007	4760	11405	16165	1153	6795	7948	3607	4611	8218	24	60	49
Non-DPAP												
1985	7261	5435	12696	703	3025	3728	6558	2410	8968	10	56	29
1993	8415	7277	15690	1722	1895	3612	6693	5382	12078	20	26	23
2002	7825	6943	14768	1315	4101	5416	6510	2842	9352	17	59	37
2004	11048	6319	17367	2366	4223	6589	8682	2096	10778	21	67	38
2007	12054	6481	18535	2433	3731	6164	9621	2749	12370	20	58	33
AP												
1985	12093	13209	25303	1001	6073	7074	11092	7737	18229	8	46	28
1993	12975	17024	29997	2740	4356	7093	10235	12668	22904	21	26	24
2002	11248	19312	30560	1752	11223	12975	9496	8089	17585	16	58	42
2004	14966	17792	32758	3329	11525	14854	11637	6267	17904	22	65	45
2007	16814	17886	34700	3586	10526	14112	13229	7360	20588	21	59	41

Note: 1. Data compiled from Groundwater Resource Estimated Reports different years, Ground Water Department, GoAP.
2. C=Command (ayacut); NC=Non-Command (non-ayacut); Total=Overall (both command and non-command areas together).

semi-critical (West Godavari, Cuddapah, Ranga Reddy, Medak and Nizamabad) and critical stages (Chittoor) in 2002. In the same year, the command areas of 18 districts were under safe category, whereas non-command areas of 15 districts were under safe, four were under semi-critical, two were under critical and one was under over exploited category, thus indicating the deteriorating situation in the non-command areas. In 2004, the overall groundwater development had pushed five districts into the semi-critical category (Chittoor, Cuddapah, Kurnool, Medak and Nizamabad).

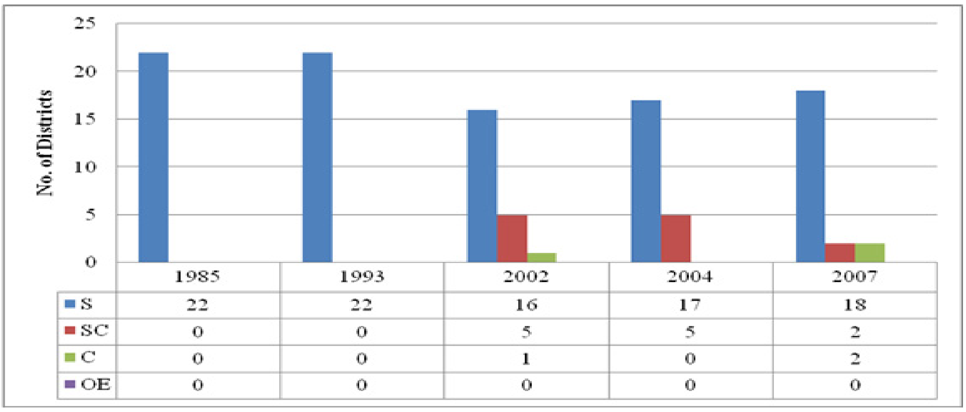
But the worrying feature in this year was that the non-command areas of as many as 10 districts were under semi-critical and three were under the critical category. Even the command areas in two districts came under the semi-critical category during the same year. In 2007, two of the districts slipped into the semi-critical category (Medak and

Table 2.9: Districts by Category of Groundwater Development in AP

Category	No. of Districts falling under Different Categories												
	1985			1993	2002			2004			2007		
	C	NC	Overall	Overall	C	NC	Overall	C	NC	Overall	C	NC	Overall
Safe	22	18	22	22	18	15	16	17	9	17	19	12	18
Semi-Critical	0	1	0	0	0	4	5	2	10	5	0	8	2
Critical	0	2	0	0	0	2	1	0	3	0	0	1	2
Over Exploited	0	1	0	0	0	1	0	0	0	0	0	1	0
NA	1	1	1	1	5	1	1	4	1	1	4	1	1
Total	23	23	23	23	23	23	23	23	23	23	23	23	23

Note: 1. Data compiled from Groundwater Resource Estimated Reports different years, Ground Water Department, GoAP.
2. C=Command (ayacut); NC=Non-Command (non-ayacut); Total=Overall (both command and non-command areas together). NA= Not applicable or available.
3. Area under command in each district is considered and hence total number of districts turns out to be more.

Figure 2.2: Districts Falling under Different Categories in AP



Source: Data compiled from GoAP, Groundwater Resource Estimated Reports different years, Ground Water Department, Hyderabad.

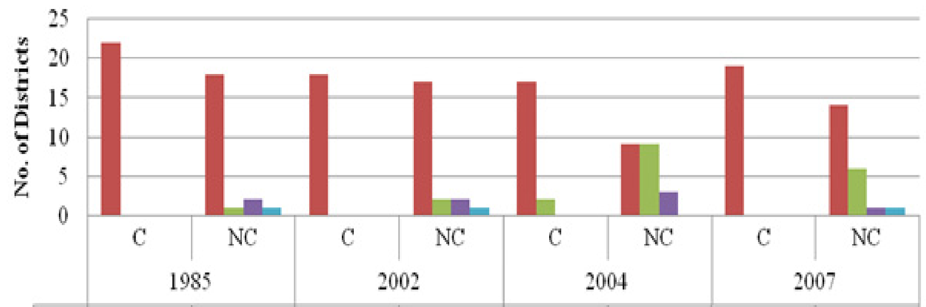
Note: S= Safe; SC=Semi Critical; C=Critical; OE= Over Exploited

Nizamabad), while two slipped into the critical category (Anantapur and Ranga Reddy), as far as the overall groundwater development was concerned. However, the situation with respect to Non-command areas was found to deteriorate as 12 districts were under the safe category, 8 districts were under semi-critical, while one each came under the critical and the over exploited categories. On the other hand, the situation in command areas seems to have improved as 19 districts were under the safe category.

Stage of Groundwater Development by Assessment Units (Mandals)

As far as the proportion of assessment units (both command and non-command areas)

Figure 2.3: Districts under Different Categories across Command and Non-Command Areas in AP



	1985 C	1985 NC	2002 C	2002 NC	2004 C	2004 NC	2007 C	2007 NC
S	22	18	18	17	17	9	19	14
SC	0	1	0	2	2	9	0	6
C	0	2	0	2	0	3	0	1
OE	0	1	0	1	0	0	0	1

Source: Data compiled from GoAP, Groundwater Resource Estimated Reports different years, Ground Water Department, Hyderabad.

Note: S= Safe; SC=Semi Critical; C=Critical; OE= Over Exploited

falling under safe category was concerned, the share of safe assessment units at the aggregate level remained the same (92%) during 1985, 1993 and 2002, after which it declined in 2004 (86.4%) and thereafter, again increased in 2007 (90.2%). While in 1985, the performance of Telangana Region was the least compared to the other two regions, its performance in 1993 was similar to that of Rayalaseema Region. However, from 2002 onwards, the situation in Rayalaseema Region became worse than the other two regions. The Telangana Region followed a similar trend as that of AP. The proportion of assessment units under the safe category in the command areas in the Telangana Region was lesser when compared to other two regions, except in 2007 (data in this regard are available only after 2002 onwards). Moreover, the percentage of assessment units under the safe category showed a declining trend in the Rayalaseema Region. With regard to the percentage of safe category, the assessment units in the districts under the non-command areas, the trend observed in Coastal Andhra was the same as that of AP (percentage of safe assessment units declined in 2004 and again increased in 2007). One important observation is that in 2002, all the regions performed better as the number of assessment units falling under the safe category are more compared to 2004 and 2007. However, the situation in Rayalaseema Region worsened in 2007 compared to 2004, while in other two regions and also at the aggregate level, there is improvement.

The overall percentage of assessment units falling under the semi-critical category across regions was more in 2004 (14.7%) and less in 1993 (5%) at aggregate level. Except in

Table 2.10: Region-wise Percentage of Assessment Units (Mandals) Falling under Different Categories in AP

Year/Region	Safe			Semi-Critical			Critical			Over Exploited		
1985	C	NC	Overall	C	NC	Overall	C	NC	Overall	C	NC	Overall
Coastal Andhra	NA	NA	92	NA	NA	3.0	NA	NA	2.8	NA	NA	2.6
Rayalaseema	NA	NA	79	NA	NA	7.3	NA	NA	8.5	NA	NA	5.6
Telangana	NA	NA	73	NA	NA	21.0	NA	NA	2.9	NA	NA	2.7
Andhra Pradesh	NA	NA	81	NA	NA	11.2	NA	NA	4.1	NA	NA	3.2
1993												
Coastal Andhra	NA	NA	92	NA	NA	1.6	NA	NA	0.5	NA	NA	0.2
Rayalaseema	NA	NA	90	NA	NA	6.0	NA	NA	3.0	NA	NA	0.0
Telangana	NA	NA	90	NA	NA	7.6	NA	NA	1.3	NA	NA	0.4
Andhra Pradesh	NA	NA	91	NA	NA	5.0	NA	NA	1.4	NA	NA	0.3
2002												
Coastal Andhra	100	100	92.0	1.1	8.7	2.6	0.0	2.1	1.2	0	6.6	3.7
Rayalaseema	100	52.6	60.7	0.0	16.8	12.0	1.6	10.8	9.4	0	20.7	17.9
Telangana	85.7	61.9	68.5	1.5	21.2	15.7	0.0	5.8	4.7	0	12.8	10.7
Andhra Pradesh	99.4	72.9	75.9	1.0	16.3	9.8	0.2	5.9	4.3	0	12.8	9.6
2004												
Coastal Andhra	92.9	75.3	86.4	3.9	9.4	5.9	0.0	3.1	1.6	3.2	11.5	6.1
Rayalaseema	96.7	38.4	47.0	0.0	20.3	20.5	0.0	7.8	6.0	3.3	33.6	26.5
Telangana	89.5	44.9	54.8	5.3	21.6	20.1	1.5	10.2	8.1	3.8	22.8	16.8
Andhra Pradesh	92.5	52.5	65.3	3.8	17.6	14.7	0.4	7.5	5.1	3.4	22.0	14.7
2007												
Coastal Andhra	97.6	80.6	90.2	0.7	11.5	5.6	0.0	3.5	1.2	1.0	3.8	2.3
Rayalaseema	84.8	35.8	45.7	1.5	23.9	18.8	3.0	11.1	10.7	10.6	29.2	24.8
Telangana	88.1	56.7	64.9	9.0	21.1	19.5	0.7	8.2	6.7	2.2	13.8	8.9
Andhra Pradesh	93.2	59.0	70.6	3.1	18.8	14.0	0.6	7.4	5.4	2.7	14.5	9.7

Note: 1. Data compiled from Groundwater Resource Estimated Reports different years, Department of Ground Water, GoAP.
2. C=Command (ayacut); NC-Non-Command (non-ayacut); Total=Overall (both command and non-command areas).

2004, the overall percentage of assessment units falling under the semi-critical category in the command areas were found to be more in Telangana Region than in the other two regions. Moreover, an increasing trend was also observed in the command areas of this region over the years. No single assessment unit was under semi-critical category in the command areas of the Rayalaseema Region during the years 2002 and 2004. As far as the non-command areas at the aggregate level were concerned, the percentage of assessment units falling under the semi-critical category showed an increasing trend from 16.3% in 2002 to 18.8% in 2007. Except in 2007, the overall percentage of assessment units falling under the semi-critical category in the non-command areas were more in the Telangana Region than in the other two regions. However, Rayalaseema Region overtook Telangana in 2007.

Assessment units (at the aggregate level for both command and non-command areas) falling under the critical category increased over the years except in 1993. In Rayalaseema, the percentage of assessment units under the critical category at the aggregate level was relatively higher than the other two regions (lowest in Coastal Andhra Region), and greater than the percentage of overall Andhra Pradesh. However, fluctuations were observed during these years (decreasing in 1993 and 2004; increasing in 2002 and 2007). But in the Telangana Region, the percentage of assessment units falling under this category were relatively lower than in the Rayalaseema Region. Except in 2004, the percentage of assessment units falling under the critical category in the command areas were more in Rayalaseema Region (2002 and 2007) than in the other two regions. No single assessment unit was under the critical category in the command areas of the Coastal Andhra Region during the years 2002, 2004 and 2007. Likewise, a similar trend (with respect to the assessment units falling under the critical category) was also observed in case of the non-command areas of the Rayalaseema Region. In case of Coastal Andhra, the percentage of assessment units falling under the critical category increased marginally.

At the aggregate level, the percentage of assessment units falling under the over exploited category ranged from 0.3% in 1993 to 14.7% in 2004. Except in 1993, the overall percentage of assessment units falling under the over exploited category at the aggregate level was more in Rayalaseema than in the other two regions. Moreover, the overall percentage of assessment units falling under the over exploited category increased both at the aggregate level and also across all the regions, except in 1993. However, the percentage of assessment units falling under the over exploited category was very low in Coastal Andhra compared to the other two regions (except 1985 and 1993), and it was also lower than overall Andhra Pradesh. In 2002, no single assessment unit came under this category in the command areas across all regions. A high percentage of assessment units was recorded in 2004 for all the regions, compared to the other years, except, in the Rayalaseema Region, where higher percentage of assessment units were recorded in 2007. The trend in the non-command areas across different regions showed that Coastal Andhra performed better than the other two regions - the percentage of assessment units falling under the over exploited category were lesser here compared to the other

Table 2.11: DPAP and Non-DPAP Districts-wise Percentage of Assessment Units in AP

Scheme/ Year	Categorization of Assessment Units											
	Safe			Semi - Critical			Critical			Over Exploited		
DPAP	C	NC	Total	C	NC	Total	C	NC	Total	C	NC	Total
1985	NA	NA	82.4	NA	NA	9.8	NA	NA	4.4	NA	NA	3.2
1993	NA	NA	92.9	NA	NA	5.2	NA	NA	1.4	NA	NA	0.0
2002	93.9	64.1	70.1	0.0	15.7	12.5	0.6	7.3	6.2	0.0	13.1	11.1
2004	94.5	50.4	56.3	1.2	21.0	19.8	0.0	7.2	6.0	4.3	21.0	17.7
2007	92.9	57.1	64.1	1.8	20.4	16.8	1.2	7.3	6.6	4.2	15.2	12.5
Non-DPAP												
1985	NA	NA	79.9	NA	NA	13.0	NA	NA	3.6	NA	NA	3.4
1993	NA	NA	88.5	NA	NA	4.6	NA	NA	1.3	NA	NA	0.6
2002	100	89.0	83.4	1.6	17.5	6.3	0.0	3.3	1.9	0.0	12.5	7.5
2004	91.4	56.4	77.1	5.1	11.3	8.0	0.6	8.0	4.0	2.9	23.7	10.7
2007	94.0	63.9	79.0	3.8	16.1	10.3	0.3	7.8	3.8	1.9	13.1	6.1
AP												
1985	NA	NA	81.4	NA	NA	11.2	NA	NA	4.1	NA	NA	3.2
1993	NA	NA	91.1	NA	NA	5.0	NA	NA	1.4	NA	NA	0.3
2002	99.4	72.9	75.9	1.0	16.3	9.8	0.21	5.9	4.3	0.0	12.8	9.6
2004	92.5	52.5	65.3	3.8	17.6	14.7	0.42	7.5	5.1	3.4	22.0	14.7
2007	93.2	59.0	70.6	3.1	18.8	14.0	0.62	7.4	5.4	2.7	14.5	9.7

Note: 1. Data compiled from different Groundwater Resource Estimated years Reports, Groundwater Department, GoAP.
2. C-Command (ayacut); NC-Non Command (Non-ayacut); Total-overall (both Command and Non-Command areas)
3. In 1985 and 1993 groundwater resource estimations calculated/worked out only taken the overall- wise Groundwater Resource(both Command and Non-Command area together) and other Resource Estimations are taken in Command, Non-Command and overall-wise (2002, 2004 and 2007)

two regions. The Rayalaseema Region had a higher percentage of over exploited units, followed by Telangana in all the estimated years. A high proportion of over exploited units was recorded in 2004 in all the regions.

DPAP & Non-DPAP Districts:

With respect to the percentage of assessment units falling under the safe category across DPAP and non-DPAP Districts, at the aggregate level, while the performance of DPAP districts were better than that of the non-DPAP districts during1985 and 1993, the non-DPAP districts performed better than DPAP districts during the other estimated years (2002, 2004 and 2007). In 2004, the percentage of assessments units falling under the safe category across DPAP and non-DPAP districts, in non-command areas was found to be lesser compared to the other years.

The percentage of assessment units falling under the semi-critical category under DPAP was higher than the non-DPAP districts at aggregate level in all the years except in 1985. While, in the command areas, the percentage of assessment units falling under the semi-critical category under non-DPAP was higher than in the DPAP districts, in case of non-command areas, the reverse trend (the percentage of assessment units falling under the semi-critical category are more in DPAP than in the non-DPAP districts) was observed except in 2002.

Furthermore, the percentage of assessment units falling under the critical category under DPAP was higher than the non-DPAP districts at the aggregate level. Except, in 2002, the percentage of assessment units falling under the critical category in the non-command areas of non-DPAP districts was higher than the DPAP districts.

Similarly, the percentage of assessment units falling under the over exploited category in DPAP Districts was higher than the non-DPAP districts, at the aggregate level, except in 1985 and 1993. And the percentage of assessment units falling under the over exploited category in the command areas of DPAP districts were higher than the non-DPAP districts, except in 2002. A similar trend was also observed in case of the non-command areas (the percentage of assessment units was more in DPAP than non-DPAP districts), except in 2004.

When the performances of the command and non-command areas are compared within their respective districts (DPAP and Non-DPAP Districts), the command areas are found to be performing better than their non-command counterparts in all the estimation years (2002, 2004 and 2007).

The Micro-Picture: Over Exploited Villages

In AP, the number of over exploited villages has gone up from 1481 in 2002 to 3449 in 2008. This number increased to 4190 during 2004 due to the severe drought conditions (Table 2.12). At the state level, the number has more than doubled over a period of six years. Across the regions, the increase almost doubled in Coastal and Rayalaseema Regions -the number of over exploited villages went up by almost three times in Telangana. Though these figures are based on the sample wells, they reflect the severity of groundwater depletion at the micro- level.

Among the assessment units, about 30% reported the depletion repeatedly. The proportion of repeated units are the highest in Rayalaseema (50%) followed by Telangana (40%) and Coastal Andhra (10%). The average number of times repeated in this depletion category (other than safe category) was more in non-command areas when compared to command areas in all the three regions. Similarly, the percentage of assessment units repeated and the average number of times repeated were more in DPAP districts than in the non-DPAP districts. The extent of repeated units was 35% in the DPAP districts, as against 21% in the non-DPAP districts.

Over Exploitation of Groundwater: Existence of Inwell Bores

Over Exploitation of Groundwater: Failure of Dugwells

Table 2.12: District/Region-wise Distribution of Over Exploited (OE) Villages in OE Basins and Number of Failed Wells

District/ Region	2002		2005		2008		% of Assessment Units Reporting Repeated Depletion
	No. of OE Villages	No. of Failed Wells	No. of OE Villages	No. of Failed Wells	No. of OE Villages	No. of Failed Wells	
Srikakulam	0	2977 (384)	0	2977 (384)	0	2598 (188)	2.6
Vizianagaram	0	6872 (739)	4	6872 (739)	0	6161 (302)	0
Visakhapatnam	4	4106 (382)	0	4106 (382)	0	2961 (259)	4.7
East Godavari	0	705 (488)	32	705 (488)	0	921 (642)	5.3
West Godavari	132	1251 (563)	152	1251 (563)	118	1001 (809)	23.9
Krishna	0	4733 (1906)	34	4733 (1906)	40	2969 (571)	10
Guntur	0	1720 (199)	11	1720 (199)	4	3899 (513)	0
Prakasam	28	9386 (601)	145	9386 (601)	121	11907 (5047)	26.8
Nellore	19	7532 (1117)	150	7532 (1117)	123	10449 (1070)	8.7
Coastal Andhra	**183**	**39282 (6379)**	**528**	**39282 (6379)**	**406**	**42866 (9401)**	**9.6**
Chittoor	89	24396 (1382)	569	24396 (1382)	601	41986 (2880)	51.5
Cuddapah	499	23141 (919)	345	23141 (919)	379	28191 (1525)	68.6
Anantapur	133	19031 (962)	385	19031 (962)	420	24476 (3128)	68.3
Kurnool	5	6222 (538)	106	6222 (538)	46	5667 (1501)	9.3
Rayalaseema	**726**	**72790 (3801)**	**1405**	**72790 (3801)**	**1446**	**100320 (9034)**	**50**
Mahbubnagar	36	51723 (2554)	378	51723 (2554)	158	45495 (9360)	48.4
Ranga Reddy	112	12328 (2458)	390	12328 (2458)	332	10431 (1737)	37.8
Medak	45	25491 (1976)	380	25491 (1976)	247	9840 (2743)	47.8
Nizamabad	150	4099 (923)	196	4099 (923)	231	1534 (482)	75
Adilabad	0	3321 (416)	47	3321 (416)	77	1909 (344)	3.8
Karimnagar	38	12492 (491)	294	12492 (491)	153	115 (16)	45.6
Warangal	125	12230 (825)	330	12230 (825)	208	13339 (4446)	44
Khammam	9	5290 (349)	34	5290 (349)	16	1918 (248)	8.7
Nalgonda	57	21017 (1065)	208	21017 (1065)	175	6220 (1786)	50.8
Telangana	**572**	**147991 (11057)**	**2257**	**147991 (11057)**	**1597**	**90801 (21162)**	**39.8**
Andhra Pradesh	**1481**	**260063 (21237)**	**4190**	**260063 (21237)**	**3449**	**233987 (39597)**	**30.3**

Note : Figures in the brackets indicate the total no. of failed tubewells

Source : 1. OE Villages Data (data compiled from): GoAP, Groundwater Resource Estimated years Reports, Groundwater Department, Hyderabad

2. Failed Well Data (data compiled from): GoAP, 3rd and 4th Minor Irrigation Census, Directorate of Economics and Statistics, Hyderabad

For an in-depth understanding of the severity of groundwater depletion, the relationship between "over-exploitation" and the "incidence of well failures" during 2002-2008 was examined with the help of simple correlation. At aggregate level, "over-exploitation" and the "incidence of well failures" are found to be positively correlated and the relationship was also statistically significant at 1 per cent level in AP during 2005 and 2008 (Table 2.13).When this relationship was examined region-wise for these three periods, except Coastal Andhra, it turned out to be statistically significant at 10 percent level in the other two regions during 2005. In 2008, the positive and statistically significant relationship between "over-exploitation" and the "incidence of well failures" was found only in case of Rayalaseema region.

Table 2.13: Correlation between Over-Exploitation and the Incidence of Well Failures

Region	Total Wells			Tubewlls		
	Estimated Years			Estimated Years		
	2002	2005	2008	2002	2005	2008
Coastal Andhra	-0.202	0.362	0.566	-0.088	0.180	0.618***
Rayalaseema	0.564	0.903***	0.981**	0.099	0.993*	0.708
Telangana	-0.179	0.602***	0.132	0.210	0.778**	0.161
Andhra Pradesh	0.278	0.725*	0.692*	0.112	0.596*	0.332

Note: Figures in the brackets refer to the Coefficient of Correlation and *, **, *** indicate level of significance at 1, 5, 10 per cent respectively.

Apart from examining the relationship between "over-exploitation" and the "incidence of well failures (all types of wells), an attempt has also been made to examine the relationship with respect to number of failed tubewells. The correlation between number of over-exploited villages and incidence of tubewell failure was found to be positive and statistically significant in AP during 2005 only (Table 2.13). However, region wise analysis found statistically significant relationship in case of Rayalaseema and Telangana regions and not in case of Coastal Andhra region. One interesting observation is that while at aggregate level the positive relationship between "over-exploitation" and the "incidence of well failures did not turn out to be statistically significant during 2008, the relationship was found to be statistically significant in case of Coastal Andhra region and not in other two regions.

III. Trends in Groundwater Irrigation

The area under well irrigation reflects the changes in groundwater development. Historically, the major sources of irrigation in AP are tanks, canals and wells in the same order of importance. Till the early 1970s, tanks were the dominant sources of irrigation in the Telangana and Rayalaseema Regions, while canals were the main source in the

Coastal Andhra Region. After the 1970s, well irrigation emerged as the major source in Telangana and Rayalaseema Regions. Over a period of four and half decades, the proportion of area under irrigation in the state went up - from 27% in 1963 to 40% in 2008 (Table 2.14). The growth in the area under irrigation was found to be more in the Telangana Region (from 21% to 38% between 1963 and 2008) when compared to the Coastal and Rayalaseema Regions, resulting in a substantial decrease in regional disparities. During this period, the intra-regional disparities also decreased in all the three regions.

Across the sources, the area under canals increased by three percentage points in Coastal Andhra and one percentage point in Telangana Region, between 1963 and 2008. The Coastal Andhra Region experienced 4% decline in the area under canals between 1993 and 2008, which could be due to the severe scarcity of water in the major systems during the period ending in 2008. After taking this into account, the increase in area under canal was found to be more in the Coastal Andhra Region between 1963 and 1983, which stagnated after 1983. Similarly, the picture is of stagnation or marginal improvement in the case of Rayalaseema. Inter as well as intra-regional disparities in the area under canals decreased substantially over the period of 45 years. While tank irrigation declined in all the regions, well irrigation gained more in Telangana when compared to other Regions. The increase in well irrigation was the main reason for the overall decline in disparities in the state.

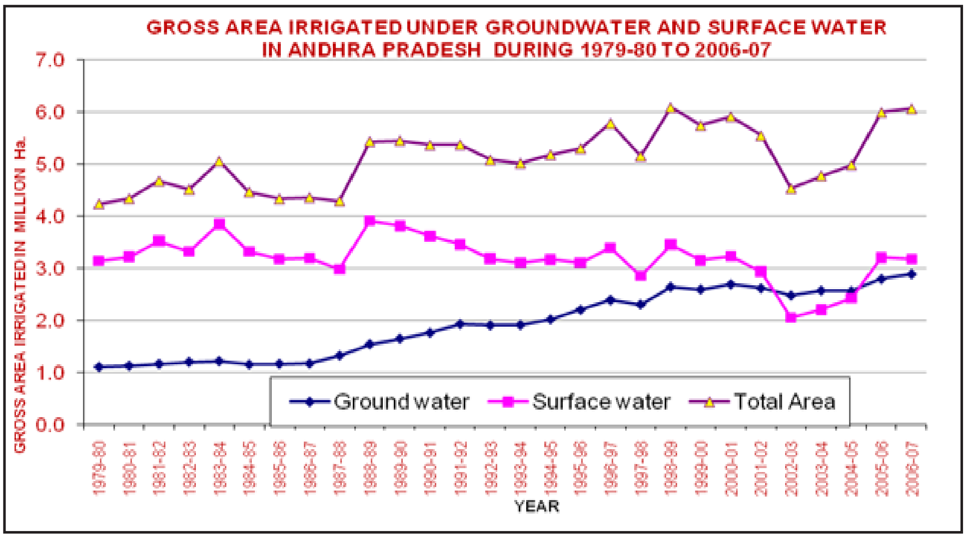
Table 2.14: Source-wise Area Irrigated (Area Irrigated by Source/Net Irrigated Area) Across Regions of AP

Triennium Ending	Canal			Tank			Well		
	Coastal Andhra	Rayala-seema	Telan-gana	Coastal Andhra	Rayala-seema	Telan-gana	Coastal Andhra	Rayala-seema	Telan-gana
1963	46	19	14	24	32	49	5	24	12
1973	62	29	27	26	29	39	9	37	26
1983	63	31	27	23	21	37	12	44	32
1993	60	25	21	19	15	20	16	57	54
2003	57	20	17	18	12	15	21	66	64
2008	55	19	13	15	8	12	25	72	72

Source: Data compiled from Season and Crop Reports various years', GoAP , Directorate of Economics & Statistics, Hyderabad

Telangana and Rayalaseema have experienced drastic shifts in the composition of irrigation. By 1980s, well irrigation was the dominant source of irrigation, replacing tank irrigation in the two regions. Though canal irrigation still dominates in the Coastal Andhra Region, well irrigation has replaced tank irrigation in the second place. The

Figure 2.4: Gross Area Irrigated by Groundwater and Surface Water



Source: Data compiled from GoAP, Season and Crop Reports various years', Directorate of Economics & Statistics, Hyderabad.

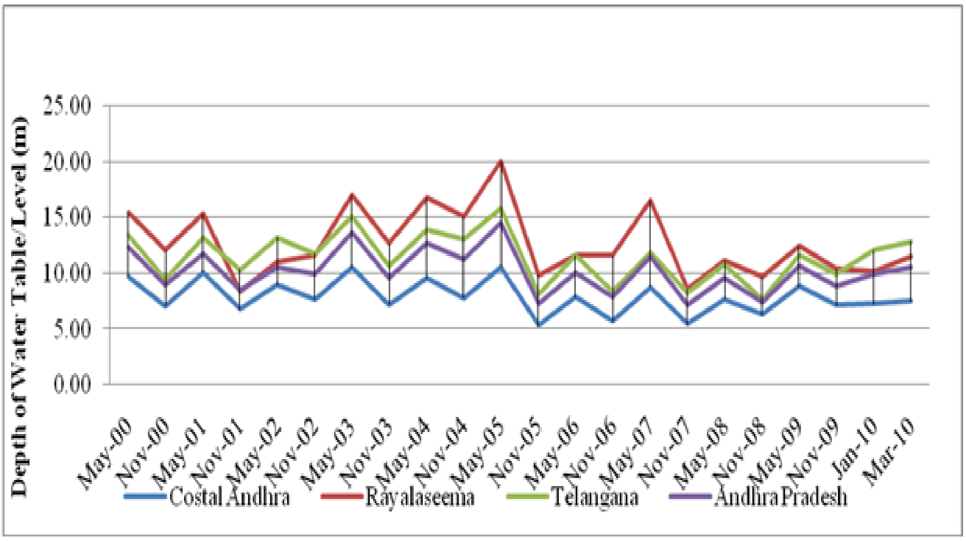
reasons for this are now well established (Reddy and Behera, 2009). The relative shares of the three important sources in the net irrigated area indicate that well irrigation in Telangana has gone up from 12% to as much as 72%, against a marginal in the case of canal irrigation (Table 2.14). Even the Coastal Andhra Region recorded a five-fold increase in the area under wells, while area under canals increased from 46% to 55%. The proportion of area under canals remained the same at 19% in Rayalaseema, though it experienced an increase in well irrigation by almost three times.

The area under groundwater irrigation is nearly equal to the area under irrigation by all surface water sources put together, especially during the years of low rainfall (Figure 2.4). The population of wells increased from 0.8 million (0.7 million dugwells and 0.1 million borewells) in 1971 to about 2.5 million (0.9 million dugwells and 1.6 million borewells) in 2007. The area under groundwater irrigation has increased from 0.8 million hectares to about 2.8 million hectares during the same period. It can be seen that the area irrigated per well is almost constant, but water is being drawn from deeper depths. The increase in exploitation of groundwater in some places is alarming and may not be sustainable unless measures are taken to control its use by increasing its efficiency.

On an average, the density of wells increased from five wells to over 10 wells per sq km. However, in hard rock areas, it is over 20 wells per sq km, while in some pockets it is as high as 100 wells per sq km. Consequently, well yields decreased considerably and water levels went down alarmingly. About 48% of the net groundwater availability is in command areas, which constitute about 23% of the state's geographical area, and where groundwater utilization is only 25%. Here, the problem is of surplus, resulting in water logging and water quality problem.

The existing surface water bodies and canal seepages are able to contribute about 4% to 5% towards groundwater recharge, and about 9% to 10% is added by way of natural infiltration. Large scale recharge measures implemented considering riparian rights in the past could increase recharge only by 1%, which also requires proper maintenance and is not very cost- effective (Kumar et.al., 2008). Water levels during the pre-and post-monsoon periods indicate that groundwater depths are highly linked to rainfall with a little lag. Water tables have gone up to below 10 m range in both Telangana and Rayalaseema Regions during 2004-05 and 2008-09, while it increased during 2010 (Fig. 2.5). Groundwater depths are the highest in the Rayalaseema Region during most of the years. Groundwater depletion adversely affects the small and marginal farmers disproportionately (Reddy, 2004). Though the small and marginal farmers are now able to invest in groundwater extraction due to availability of cheap technologies, they are often at a disadvantageous position while competing with the large farmers in well deepening. As a result, they become the first victims of groundwater depletion and pay huge price in terms of direct and indirect costs. Their investments become dead or waste as they are not able to compete with large farmers in investing deeper wells.

Figure 2.5: Region-wise Average Depth of Water Level in Pre- and Post-Monsoon Periods



Source: GoAP, Ground Water Department, Hyderabad.

IV. Free Power and Groundwater Development

Groundwater development and degradation are often validly linked to the energy policies of the state. Subsidies on power (often charged at flat rate irrespective of the quantity consumed) are expected to further aggravate groundwater mining. While there are pros and cons of power subsidies on groundwater in specific and agriculture development in general, it is arguably detrimental from the resource (environment) point of view. The arguments in favour of power subsidies are that they enhance the viability of farming and increase the access to water either through water markets or otherwise, especially among the small and marginal farmers. On the other hand, it is argued that small and marginal farmers become the victims of over exploitation (Reddy, 2004). In either case, resource degradation is imminent, resulting in 'tragedy of commons' in the long run.

The announcement of free power to farmers in 2004 by the AP Government is seen as populist act that is unmindful of economic and environmental consequences. It was argued that the policy would not only increase the power consumption adding to the burden of the exchequer, but also aggravate the problem of the already dwindling resource. Here, an attempt is made to assess the impacts of free power policy using the official data. Different indicators are examined to assess the impact of free power. These indicators include growth in agricultural service connections, energisation of wells and power consumption. None of the indicators have revealed any significant changes after the introduction of free power in 2004. The number of agricultural service connections have reached their peak during 2000-01 and declined drastically during 2004-05 (Table 2.15). A similar trend was observed across the regions though the changes are more substantial in the Telangana and Rayalaseema regions when compared to the Coastal Andhra Region. In fact, the Coastal Andhra Region recorded only a marginal increase in the number of service connections during 2004-05. This could be due to the severe drought conditions prevailing between 2001 and 2004. The impact is severe in the rain-fed regions of Telangana and Rayalaseema. Though there was substantial improvement in the number of service connections during 2006-07, the number was much below the 2000-01 peak. Moreover, the increase was mainly due to better groundwater situation during the post-2004 period and cannot be attributed to the free power policy of the state. This is evident from the proportion of wells energised during this period and the actual power consumption.

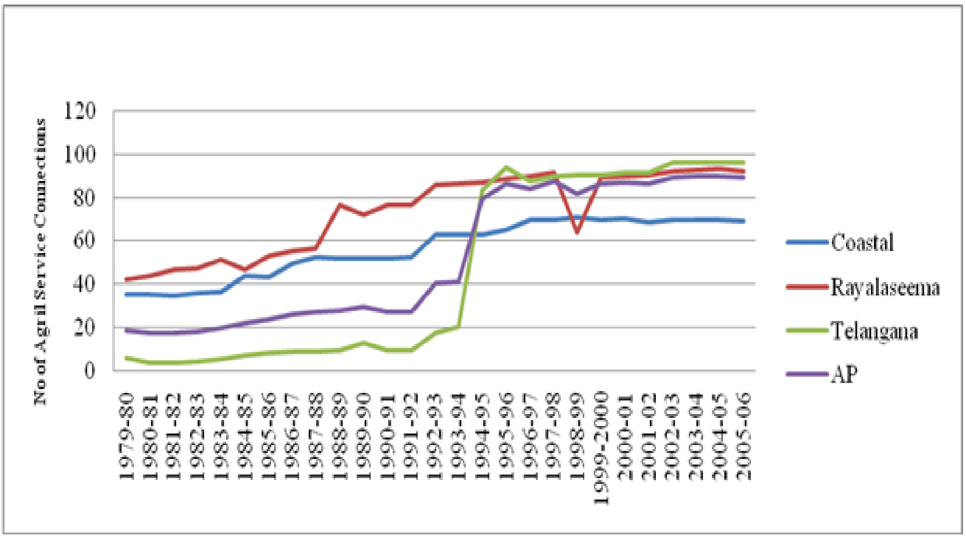
The proportion of wells energised shows a secular trend over the period of 25 years in the Coastal and Rayalaseema regions, while the Telangana Region recorded a jump in the energisation of wells after 1993-94 (Fig.2.6). By mid-1990s, Telangana over took Rayalaseema in well energisation. In fact, the share of Telangana in well energisation was

Table 2.15: Year-wise Growth in Agricultural Service Connections across Regions

Region	No. of Agricultural Service Connections during the Reference Years				
	1984-85	1993-94	2000-01	2004-05	2006-07
Coastal Andhra	8430	20085	22239	22586	25015
Rayalaseema	4632	23109	26001	15656	17624
Telangana	31182	58983	70053	26518	44338
Andhra Pradesh	44244	102177	118293	64760	86977

Source: 1.Data compiled from APTRANSCo Ltd, Power Development in Andhra Pradesh (Statistics) various years, and Hyderabad.
2.Data compiled from GoAP, Statistical Abstract of Andhra Pradesh various years, Directorate of Economics & Statistics, Hyderabad.

Figure 2.6: Region-wise Proportion of Wells Energised Over the Years

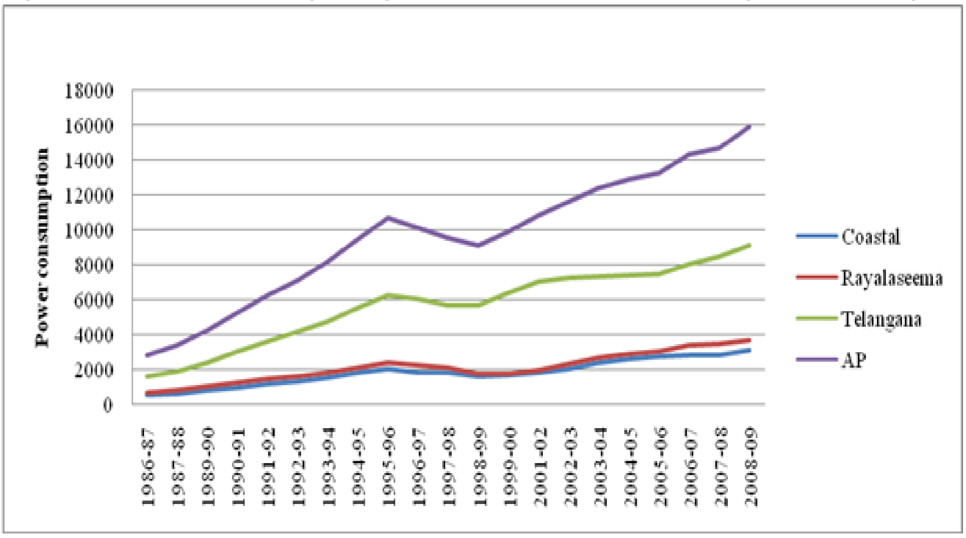


Source: 1.Data compiled from APTRANSCo Ltd, Power Development in Andhra Pradesh (Statistics) various years, and Hyderabad.
2.Data compiled from GoAP, Statistical Abstract of Andhra Pradesh various years, Directorate of Economics & Statistics, Hyderabad.

the main reason for the higher state average after mid- nineties. However, such shifts or changes are not evident after the advent of free power policy in 2004. This is also evident in the case of power consumption across regions, which show a smooth trend (Fig. 2.7). The consumption of energy in the DPAP districts, which have majority of the borewells and electric pump sets, has also not shown any shift after the advent of free power policy (Fig. 2.8).

Interestingly, the increasing trends observed in the case of pumps energised and the total power consumption in each year, the per pump power consumption has remained the same over the years (Figure 2.9). This indicates that there is no change in power consumption at the individual level, before or after free power policy. This could be due to supply regulation of power at the state level. In fact, farmers complain that they get less than seven hours of supply against the promised nine hours of supply per day. As a result, the aggregate power consumption has gone up from about 1200 million kilowatt hours in 2004-05 to about 1350 million kilowatt hours. The financial burden of the free power policy is about Rs.1350 crores at the rate of Re.1 per kilowatt hour. However, as the data clearly indicates, this burden is not due to the free power policy. For, power was already subsidised heavily even prior to the free power policy. Under the flat rate regime, the state was collecting only about Rs.3 crores at the rate ranging from of Rs.1800 to Rs.2640 per connection respectively for 3 and 5 HP pumps. Since there was no increase in power consumption (apart from the normal), the free power burden is mainly in terms of loss in revenue due to the flat rate collections from the existing number of energised wells. At the present level of energisation (24.48 lakh pumps in 2006-07) with an average flat rate of Rs. 2200 per pump per year the burden on the state is Rs. 538.56 crore, which has gone up from more than Rs. 400 crore during 2004-05. In effect, the state is losing more than Rs. 500 crore per year and this would go up over the years with

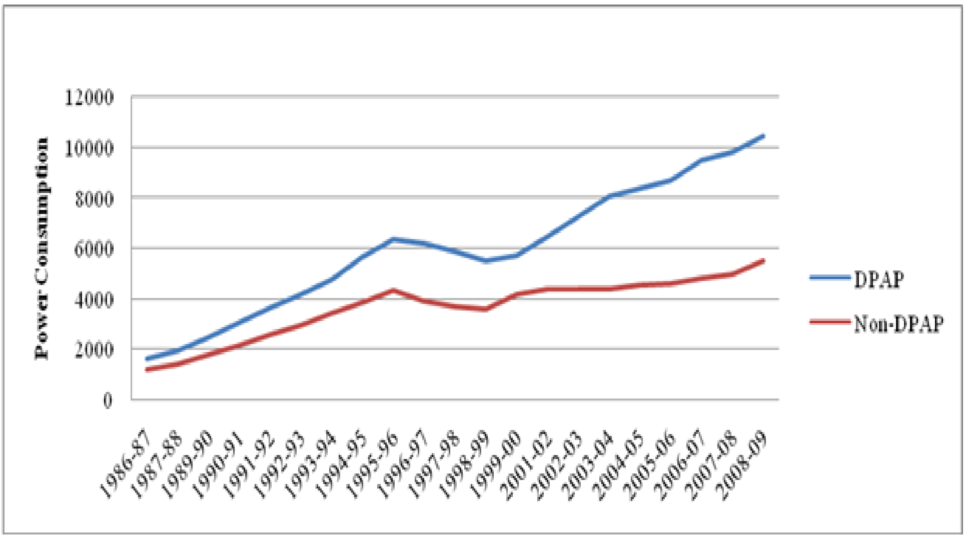
Figure 2.7: Three Year Moving Average of Electricity Consumption in Agriculture by Regions



Source: 1. Data compiled from APTRANSCo Ltd, Power Development in Andhra Pradesh (Statistics) various years, and Hyderabad.

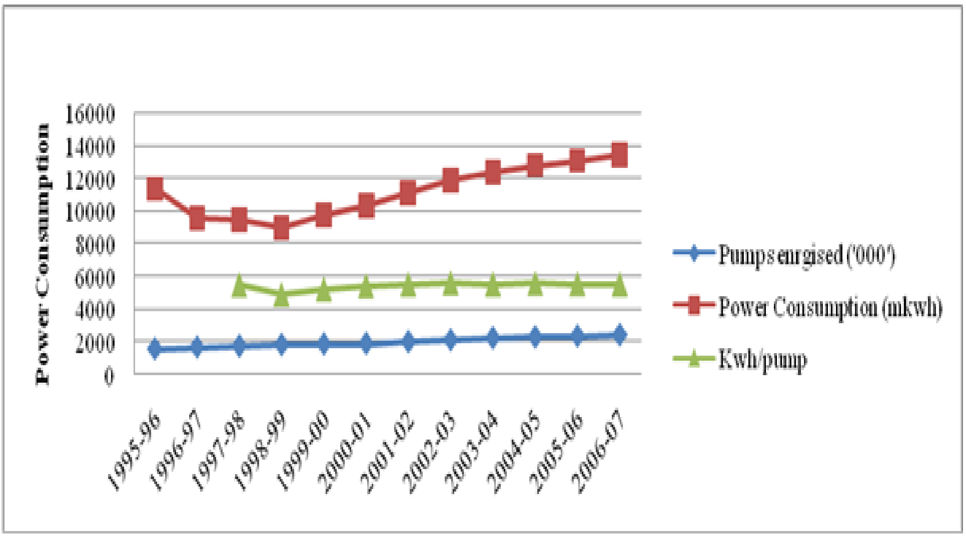
2. Data compiled from GoAP, Statistical Abstract of Andhra Pradesh various years, Directorate of Economics & Statistics, Hyderabad.

Figure 2.8: Three Year Moving Average of Energy Consumption in Agriculture by DPAP and Non-DPAP Districts



Source: 1. Data compiled from APTRANSCo Ltd, Power Development in Andhra Pradesh (Statistics) various years, and Hyderabad.
2. Data compiled from GoAP, Statistical Abstract of Andhra Pradesh various years, Directorate of Economics & Statistics, Hyderabad.

Figure 2.9: Three Year Moving Average of Energisation and Electricity Consumption in Agriculture



Source: 1. Data compiled from APTRANSCo Ltd, Power Development in Andhra Pradesh (Statistics) various years, and Hyderabad.
2. Data compiled from GoAP, Statistical Abstract of Andhra Pradesh various years, Directorate of conomics & Statistics, Hyderabad.

increased number of energised wells. But for the supply regulation, the burden would have been higher. The state has adopted a dual policy of populism coupled with supply regulation which helped in checking the financial burden and also in maintaining the *status quo* in groundwater development. That is, the free power policy has not triggered an increased pace in the race for groundwater exploitation. The benefit to the farmers is only marginal (Rs.2200 per pump) on an average, if not negative, considering the reduced hours of power supply. The benefits seem to be more psychological rather than real to the farming community.

V. Conclusions

On the whole, the spatio-temporal analysis of groundwater development has been looked from multiple dimensions and the assessments are re-emphasised from all the angles. The analysis brings out some interesting aspects. These include:

- ❖ The methodological basis of groundwater assessment is rather weak and hence, the assessments may have limited use for the farming communities.
- ❖ There is a secular trend in groundwater development over the years.
- ❖ This trend is only broken due to severe droughts or very good monsoons.
- ❖ Regional variations indicate that Telangana had a late entry in the case of mechanisation and enrgisation of groundwater exploitation, though it has over taken the Rayalaseema Region by mid nineties.
- ❖ The level of groundwater development and its adverse impacts are more severe in Rayalaseema Region.
- ❖ There is imbalance in the development and available groundwater in the command and non-command areas. While the command areas have under-development of groundwater, the non-command areas have excess development.
- ❖ Similarly, DPAP districts face the adverse impacts of groundwater development when compared to the non-DPAP districts.
- ❖ Though the level of groundwater development at the aggregate level is not alarming, the micro-situation is a cause of concern as the number of villages included under the over exploited category is increasing over the years.
- ❖ The trends in groundwater development are reflected very well in the area irrigated under wells. Though the area under well irrigation is expanding, the area irrigated per well is either stagnant or declining.

- The micro-impacts are clearly seen in the case of well failures and the resulting farm distress in some regions.
- The free power policy of the state has neither helped in expanding the area under wells nor reduced the burden on the farmers substantially.
- The dual policy of free power and supply regulation does not seem to have any significant impact on agriculture.

CHAPTER III

FACTORS INFLUENCING GROUNDWATER DEVELOPMENT

I. District Wise Analysis

At this juncture it would be pertinent to examine the factors determining the variations in groundwater development across the districts in the state. For this purpose, multiple regression analysis has been adopted using a number of indicators that influence groundwater development. The basic specification is as follows:

$$GWD_{dt} = f(NF_{dt}, EF_{dt}, SF_{dt}, DF_{dt}) + U_{dt}$$

Where,

GWD_{dt} = Groundwater Development measured in terms of extent of utilisation with reference to potential in district '*d*' at time '*t*'.

NF_{dt} = The set of natural factors such as rainfall, irrigation, irrigation intensity, surface water bodies, canal irrigation, cropping intensity, etc., in the district.

EFd_{dt} = Economic Factors such as per capital income, extent of poverty, number of borewells, number of agricultural power connections, etc., in the district.

SF_{dt} = Social Factors such as Human Development Index, literacy level, etc., in the district.

DF_{dt} = Development Factors such as coverage under watershed development programme in the district.

U_{dt} = Error term.

The selection of independent variables is based on the theoretical considerations and the availability of data at the district level. The variables are drawn mainly from different sources such as statistical abstracts, season and crop reports, minor irrigation census, population census and departmental records including GEC Reports. An exhaustive list of indicators that are likely to influence the performance was prepared. All these variables were tried in different combinations and permutations. But, some of the variables, though important, did not find place in the specifications due to various reasons including multi-collinearity, non-significance, absence of variation and also unavailability of data*. The details of variable measurement and their theoretical/expected impact on groundwater development are presented in Table 3.1.

Table 3.1: Measurement and Expected Signs of the Selected Variables

Variable	Measurement	Expected Impact
Actual Annual Rainfall (AARF)	In mm per year	+ve
Irrigation Intensity (II)	Gross/net area irrigated in %	+ve
No. of Dugwells	Actual numbers	-/+ve
No. of Tubewells	Actual Numbers	+ve
Per Capita Income (PCI)	Rupees per year	+ve
No. of Tanks	Actual Numbers	-/+ve
Human Development Index (HDI)	Index of different indicators	+/-ve
Area under Canal Irrigation	In acres	-ve
Cropping Intensity (CI)	Gross/net cropped area in %	+ve
Area under Groundnut Crop	In acres	+ve
% of Below Poverty Line (BPL) Population	Percentage	-ve
% of Literate Population	Percentage	+ve
Number of Power Connections to Agriculture	Actual Number	+ve
WSD Coverage	Area in Hectares	-/+ve
Human Poverty Index (HPI)	Index	-ve
Area under Groundnut	In Acres	+ve

Linear regressions applying Ordinary Least Squares (OLS) were estimated to regress the dependent variable (GWD) against the selected independent variables (SPSS package). Regressions were run on cross sectional data across the districts. Various permutations and combinations of independent variables were used to arrive at the best fits. The estimates were carried out for all the five groundwater assessment years to assess the robustness of the estimates. Further, estimates were carried out for command/non-command and DPAP/non-DPAP areas as well, though the results are presented for non-command and DPAP areas only.

* Variables like percentage of the geographical area under cropping were tried in the regression models pertaining to all the five groundwater assessment years, but they did not turn out to be statistically significant in any of the cases. On the contrary their inclusion introduced multi-collinearity and therefore, dropped from the final specifications. Data related to evapo-transpiration was not available at the district level and hence not included in the analysis.

Table 3.2: Factors Influencing Groundwater Development over the Years in Non-Command and DPAP Areas

Variable	Year				
	1985	1993	2002	2004	2007
Overall					
Irrigation Intensity (II)	NA	+	NA	+	+
No. of Dugwells	NA	NS	NA	NA	NA
No. of Tubewells	NS	NS	NA	+	-
Per Capita Income (Rs./Year)	NA	NA	NA	NA	NS
No. of Tanks	NA	NA	NA	-	NA
Human Development Index (HDI)	NA	+	+	NA	NA
Area under Canal Irrigation (Acres)	NA	-	-	-	-
Cropping Intensity (CI)	NA	NA	+	NA	NA
Area under Groundnut Crop (acres)	NA	NA	+	NA	NA
Actual Annual Rainfall (mm)	NA	NA	NA	+	-
% of Below Poverty Line (BPL) Population	+	NA	NA	NA	NA
% of Literate Population	+	NA	NA	NA	NA
Number of Power Connections to Agriculture	+	NA	NA	NA	NA
Non-Command Areas					
Irrigation Intensity (II)	NA	+	+	NA	NA
No. of Dugwells	NA	NS	NS	NA	NA
No. of Tubewells	NA	NS	+	+	NA
Per Capita Income (Rs./Year)	NA	NA	NA	NS	NA
No. of Tanks	+	NA	NA	-	NA
Human Development Index (HDI)	NA	+	NS	NA	NA
Area under Canal Irrigation (Acres)	NA	-	NA	NS	-
Cropping Intensity (CI)	NS	NA	NA	NA	+
Actual Annual Rainfall (mm)	NA	NA	NA	-	NS
WSD (Area covered in Hectares)	NA	NA	NS	-	NA
% of Below Poverty Line Population	NA	NA	NS	NA	NA
% of Literate Population	+	NA	NA	NA	+
Number of Power Connections to Agriculture	+	NA	NA	NA	+
Area under Groundnut (acres)	-	NA	NA	NA	NA
DPAP Areas					
Actual Annual Rain Fall (mm)	-	-	NA	-	-
Number of Power Connections to Agriculture	+	NA	NA	NA	-
Area under Canal Irrigation	-	-	-	-	-
Cropping Intensity (CI)	NA	+	+	NA	NA
WSD (Area covered in Hectares)	NA	NA	+	NA	NA
% of Below Poverty Line (BPL) Population	NA	NA	NS	NA	NA
% of Literate Population	NA	+	NA	NA	NA
Irrigation Intensity (II)	NA	NA	NA	NS	NA
Human Poverty Index (HPI)	NA	NA	NA	-	NA

Note: + indicates positively significant; - indicates negatively significant; NS= Not Significant; NA= Not Applicable (not used in the specification). Detailed estimates are presented in the ***Annexure***.

Multi-collinearity between the independent variables was checked using the Variance Inflation Factor (VIF) statistic. Multi-collinearity is not a serious problem as long as the value of VIF is below 2. The best-fit specification was selected for the purpose of final analysis for each dependent variable. The indicative results are presented in Table 3.2 while the detailed results along with the descriptive statistics are presented in the *Annexure*.

The estimates indicate that not many variables turned out to be significant across the years in both non-command as well as DPAP areas, though the selected specifications explain more than 60% of the variations in the case of non-command areas and more than 80% of the variations in the case of DPAP districts (see Annexure). Most of the indicators have shown up with expected signs. At the state level, the area under canal irrigation turned out significant in four of the five years, with a consistent negative sign indicating that groundwater development is limited in the canal irrigated areas (Table 3.2). On the other hand, cropping intensity has shown a consistent positive impact in three out of five years. That is groundwater is used more intensively as the area under second and third crops increase. Human Development Index (HDI) turned out to be significant in two of the years with a positive sign. This means that human development could increase groundwater development due to the overall comprehensive development reflected in the HDI. Though the actual rainfall and number of tubewells turned out to be significant in 2004 and 2007, they were not consistent in the sign. Both the variables showed positive impact during 2004 and negative sign during 2007. It may be inferred that rainfall and number of tubewells would increase exploitation of groundwater in drought conditions (2004) while in good rainfall years, the demand would go down coupled with increased supply, resulting in a net negative impact on groundwater development.

In the case of non-command areas, the variables area under canal irrigation and irrigation intensity turned out to be significant in two of the years with signs similar to that of the state level. The number of tubewells, power connections, literacy and HDI revealed a positive impact on groundwater development. In the non-command areas, all these indicators, except the area under canal irrigation, promote groundwater exploitation. The number of tanks was seen to have a positive impact in one year and a negative impact in the other year. Furthermore, it is seen that the actual rainfall and the area covered under watershed development also have a negative impact on groundwater development. That is, in the command areas, watershed development could lead to checking of groundwater exploitation.

However, in the DPAP districts, WSD leads to exploitation, which is also evident at the field level studies (Reddy, *et al.*, 2010). That is, groundwater use in terms of the number of wells tends to increase after the advent of watershed development. Often this results in upsetting the recharge impact of watershed development. The actual rainfall and area under canal irrigation have a more clear negative impact on groundwater development in the DPAP districts, as they turned out to be significant in most of the years. On the other hand, cropping intensity has a positive impact on groundwater development. And literacy, also in line with non-command areas, and state-level impacts, has a positive impact on groundwater development.

Overall, the regression analysis of the factors influencing groundwater development does not prove to be of much help in a better understanding of groundwater management. This is because the policy variables such as WSD, literacy and HDI did not reveal any clear impact towards checking groundwater development. This could be due to the reason that in the absence of groundwater institutions these factors may have limited influence. Besides, our analysis also does not include any institutional variables due to the non-existence of any formal groundwater institutions at the district level. Therefore, it would be pertinent to examine the impact of institutions on groundwater management that are prevalent in some of the districts. The following section examines these aspects in detail, on the backdrop of Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) experience.

II. Managing Groundwater: Role of Local Institutions

Scientific information on geo-hydrology and groundwater is the domain of scientific community. The technicalities involved in generating such information are believed to be beyond the knowledge of a non-technical person, not to mention the illiterate farmer. But the increasing gap between the scientific information and the user, coupled with the fast deteriorating groundwater situation has led to institutional innovations of groundwater management. Some of the earlier institutional innovations have focused mainly on the community-based collective strategies such as forming rules and regulations for groundwater use and management (Deshpande and Reddy, 1990; World Bank, nd). None of the institutional arrangements based their approach on scientific information. Though some of them have achieved a fair amount of success, their spread and sustainability in the long run was limited, as they were driven by leadership and local conditions. Similarly, the regulator approaches of restricted power supply and no access to formal credit (to those who intend to have a borewell within a radius of 200 metres of another borewell) fail to encourage the farmers towards judicious use of groundwater.

In this context, the initiative of APFAMGS is a 'bottom up' approach grounded on farmer-generated hydrological information at the village level. The initiative is based on a multi-layered approach involving training of farmers for generating hydrological data, estimating water balance, crop water budgeting, participatory cropping decisions, creating awareness with proper communication strategies, etc. There is no incentive or dis-incentive structure linked to the initiatives; rather the focus is on behavioural change towards self-regulation using information and experience. In this section, we try to examine the approach in detail along with its relevance and scalability. The assessment is based on the material available on their official website (www//:apfmgs.org) and our field visits to some of their villages.

History

The APFAMGS project was launched in July 2003 in partnership with farmers for implementing demand side groundwater management- an alternative model to the supply side approach. The project was funded by the Royal Netherlands Embassy, New Delhi, and its implementation was guided by the Food and Agricultural Organization (FAO). The project, in partnership with the local Non-Governmental Organisations (NGOs)†, is implemented in 650 villages spread over 63 hydrological units across seven drought-prone districts* of Andhra Pradesh using hydrological boundaries as an operational unit. The main objective of the project is to "equip groundwater farmer users with the necessary data, skills and knowledge to manage groundwater resources available to them in a sustainable manner, mainly through managing and monitoring their own demand". The basic premise is that self-generated scientific data and knowledge will enable farmers to make appropriate farming choices using groundwater. The farming communities make informed decisions using hydrological data developed on the Geological Information System (GIS) platform. Elaborate institutional arrangements with equal representation of men and women were made to implement the programme.

Activities

The main activities include:

- Awareness on the emerging groundwater crisis and groundwater as a 'common good' at the habitation and hydrologic unit level.
- Demystify the science of hydrology through participatory learning, practicing and establishing a new relationship between farmers and groundwater**.
- Participatory planning and sharing information through crop water budgeting (CWB) workshops for evolving common strategies that limit damage to the groundwater system without sacrificing individual interest.

† Nine local NGO partners were involved under a nodal NGO namely Bharathi Integrated Rural Development Society (BIRDS).

* These districts are: Anantapur, Chittoor, Kadapa, Kurnool, Mahbubnagar, Nalgonda and Prakasam

** However, it is not easy to demystify science using the approach of participatory learning.

- Steps towards improving crop water efficiency and reduce chemical pollution.
- Introducing groundwater governance, transcending individual holdings and habitations without being coercive through voluntary choices such as reduced pumping, preventing construction of new wells, crop diversification, reduced application of chemical fertilizer/pesticides, etc.,

Approach

A comprehensive institutional structure integrating technical and social components was established. At the village level a Ground Water Management Committee (GMC) is the key institution of the farmers, including men and women. A network of GMC, viz., the Hydrological Unit Network (HUN), is formed at the hydrological unit level. These two are critical for providing 'demonstration effect' of the learnings from the project to the larger community of farmers beyond the project area. The HUNs have a legal status allowing them to receive funds as well as carry out business activities.

Making the farmers water literate is the core of the approach. The first step in this direction is to enhance the farmers' capacity to collect and analyse data on their own. Capacity building and training activities are part of the project components. Formal and informal techniques such as technical training related to recording rainfall, measuring draft from observation wells, cultural shows, practical training, exposure visits, exchange visits and workshops, are included. These capacities are used in the Participatory Hydrological Monitoring (PHM) exercise. In PHM, farmer volunteers** monitor water levels from 2026 observation wells (one well for every sq km) every fortnight. The daily rainfall measurement is collected from rain gauge stations from 190 rain gauge stations established for every 5 sq km in the project area. The collected information is displayed for the farmers to take farming decisions. Discharge measurements are also carried out to understand the pumping capacity in 700 monitoring observation wells. This is accomplished by measuring the time taken to fill a known capacity of drum. Along with the discharge, the farmers also measure the drawdown. Based on the measurement, the farmers have a good understanding of the pumping capacity of the wells, well performance, water requirement for different crops and the ways and means to increase the water use efficiency. In this way, science has been demystified and made user friendly for the farmers.

** To qualify to be a volunteer, the farmers have to undergo training (4 modules) and only the successful candidates are eligible to become a PHM volunteer. The rigorous training ensures that there is no dilution in technical observations. The volunteers are provided with measuring tools such as electrical water level indicators, stop watches and measuring drums (shared by a number of volunteers). The volunteers maintain a log book of the Hydrological Monitoring Records (HMR). The HMR data is also exhibited for public viewing on display boards maintained at strategic locations in the habitation. Seasonal groundwater quality measurements are carried out from public drinking water wells.

Crop-Water Budgeting (CWB)

The success of demystifying science is reflected in the CWB which helps farmers collectively prepare land use plans depending upon water availability. The CWB is taken up at the village level before the beginning of each season and aggregated at the HUN level. Using rainfall data and the assumed runoff coefficient (10%), groundwater recharge is estimated. The net availability of groundwater is estimated by either adding or deducting the previous season's balance (Table 3.3). There may be positive or negative water balance in each season depending on the recharge and draft. Based on the crop water requirements and the net available groundwater, crop areas are decided in a collective manner. By following local measures, the volunteers explain the area under each crop with the available groundwater. They estimate the area that can be devoted to paddy, the amount of water that can be used for paddy crop or other crops or a combination of different crops.

Table 3.3: A Sample of Groundwater Balance Estimates for a Few HUNs in 2008-2009 (in cubic Meters)

HU Name	No. of Habi-tations	Kharif Recharge	Kharif Draft	Kharif balance (+ Or -)	Rabi Recharge	Rabi Draft	Rabi balance (- or +)
Chinneru	18	1923040	6408000	4970881	19922151	13131920	1325550
Rallavagu	15	1785521	4255000	760671	12110183	5349920	4150503
Thundlavagu	7	1486319	4524000	2565112	11628227	7130900	959832
Peddavagu	5	646770	1240000	170896	1873654	3015560	-1762674
Lothuvagu	1	342844	582000	46692	696252	291400	161869
Chandravagu	4	507897	1020000	133397	1219209	2415680	-1727864
Buchammakonetivanka	1	244757	360000	80257	541018	1536500	-1122631
Konetivanka	3	298753	1050000	1536003	4231643	3671200	-494390
Bavanasi	12	2136940	3024300	4968380	15224395	11432080	1959941
Yerravanka	4	606641	1800000	271304	3239133	5476720	-3478769
Peddavanka	4	344320	2619000	2311120	9531133	6631520	9772

Source: APFAMGS Project report, http://www.apfamgs.org.

The estimates show that in 59 of the 63 Hydrological Units (HUs), groundwater balance is deficit. The CWB has also identified over-exploited aquifers. Water harvesting measures such as injection wells have been taken up in the over-exploited aquifers. In some areas, abandoned open wells have also been used to trap the flood flows and transfer them to the aquifers. Though there is no coercive mechanism to force the farmers to adopt the collective decisions, a survey is conducted after every season on the extent to which collective decisions were followed and discussed in the GMC. This data on actual cropping pattern is used to arrive at the actual draft. There is always a difference between the estimated and actual draft. Though individual farmer's decisions are respected, GMCs and HUNs are able to act as pressure groups to advocate change in cropping patterns, use of sustainable agricultural practices and water saving technologies in some places.

Achievements

The achievements are drawn from the self-assessment reports of the APFAMGS, and independent evaluation reports of the World Bank (nd), FAO (2008) and AFPRO (2006), coupled with our field experience. All the physical achievements reported (Table 3.4) by the end of 2007 are endorsed in the evaluation studies. The figures are quite impressive as most of the HUs (559 out of 650) have created the hydrological data base and are managing (636 Community Based Institutions (CBIs)) their groundwater. In fact, the data generated is the property of the GMC and is being sold to outside agencies for the purpose of research. More than 4000 farmers are trained to read maps and more than 10000 farmers can handle hydrological equipment. It is assessed that some of the achievements have surpassed the targets (FAO, 2008). During the field visits, we have observed the farmers presenting crop water budget estimates and taking the water table measurements. However, farmers are yet to be trained on using the GIS.

Farmer Field School

Three hundred Farmer Water Schools (FWS)[††] have been established to train the farmers to equip them with technical and non-technical aspects of groundwater management. Hydro-Ecosystem Analysis (HESA), which is a decision-making tool for groundwater management, is being adopted and supported by recharge and discharge factors. Crop plans and management of groundwater is based on this analysis and observations.

Table 3.4: Physical Achievements of APFAMGS Programme (2007)

Indicator	Achievement
Number of farmers capable of reading maps	4322
Number of farmers capable of handling hydrological equipment	10076
Number of farmers updating Hydrological Monitoring Records (HMR)	3052
Number of GMCs using GIS	0
Number of GMCs having hydrological database	559
Number of GMCs Sharing hydrological database	559
Number of farmers adopting alternative agricultural practices/inputs	14281
Types of alternative agricultural practices promoted	80
Number of CBIs involved in groundwater management	636
Number of women on the committees of CBIs	2060
Number of women farmer volunteers	1175
Number of GMCs operating Crop Water Kiosks(CWK)	9
Number of GMCs advising farmers on crop choices based on CWB	559
Number of GMCs promoting alternative agriculture	559

Source: APFAMGS Project report, http://www.apfamgs.org.

This is the same sequence used for Agro-Ecosystem Analysis in the classical Farmer Field Schools (FFS) approach (FAO, 2008).The focus of FWS is on the active and common farmers who can apply them directly on farm and also share them with a larger audience. The FWS has successfully created the first batch of over 10000 farmers who have already emerged as trainers to other farmers both under the project programme as well as for the government-run FFS. Such a training and adaptation has demystified hydrology, which is a hidden source, and helped farmers in understanding the resource availability and dynamics. Sharing of information across HUs resulted in evolving common strategies, limiting the depletion of groundwater table.

†† Under the FWS 10000 farmers meet once in every 15 days through 300 water schools to understand groundwater changes in the respective area for the entire hydrological season. Based on the understanding, farmers adopt suitable modification in their agricultural practices that can lead to significant reductions in groundwater use.

Some of the important achievements include reduction in groundwater pumping in a number of HUs. In 14 of the 63 HUs groundwater pumping has been reduced significantly, while in 9 other HUs the reduction was moderate, though it is dependent on the reliability of groundwater balance estimates. Overall, despite the reduction in pumping in number of HUs, the reduction is not significant enough to have a drainage basin-level impact. Reduced water pumping has a direct bearing on area under paddy, as paddy is water-intensive and the most preferred crop. In all, except in four HUs, the area under paddy cultivation has come down, ranging from a few acres to several hundred acres. The farmers' experience showed that they incur crop losses whenever they do not follow the collective advice due to water scarcity. Crop diversification has taken place in favour of pulses, oil seeds, fruits, vegetables, flowers, etc. Farmers try to offset the losses due to reduction in paddy by growing other high value crops. The risks associated with commercial crops such as mono-culture, reduced area under food crops, and loss in soil fertility, are also being addressed simultaneously. Water saving devices such as Sprinkler and Drip Irrigation were introduced for crops such as groundnut, sunflower, bengalgram, chillies and horticultural crops. It is estimated that groundwater pumping was reduced by more than 8% (equivalent to 5 mcm per year) over the project area due to water saving techniques.

Shortcomings

- The methodology adopted for generating the hydrological information is not fully scientific. There is a need to link the estimation methodology to the Government of India (GoI) methods of estimation.

- Provision of information alone may not be effective unless other policy issues that contradict the demand management of groundwater, viz., free power and distorted price policies that favour water-intensive crops such as paddy are corrected.

- Equity issues are not fully addressed in the management, as the fundamental issue of water rights is not addressed. It is necessary to address the issue of delinking water rights with land rights at the community level.

- Despite a systematic bottom-up approach towards sustaining the initiative, sustainability still remains a major concern in the absence of external funding and involvement of NGOs.

III. Future Directions for Policy and Research

This chapter along with chapter two highlights three important aspects of sustainable groundwater management in AP.

- Establishes the increasing importance of groundwater and its management.
- Highlights the drawbacks of the information on groundwater presently available through official sources.
- Innovative institutional arrangements can address the information bottlenecks to a large extent, though its effectiveness in achieving the objectives calls for an integrated approach.

Hydrology is treated as a pure physical science and hydrological information is often generated and disseminated in an esoteric form with little or no effort to bring it closer to the user communities. Unlike other physical sciences, hydrology or hydrological information plays vital role in the day to day livelihoods of groundwater-dependent communities. The existing link between the scientific information and the users is very weak, serving no real purpose of helping the farming communities. Often, the information provided at a macro-scale is inadequate and inappropriate to suit the micro-level situation and needs of the farmers.

The case of APFAMGS clearly brings out the great possibilities for demystifying hydrology and makes it user friendly through capacitating communities in generating scientific hydrological information at the village level. While these are found to be highly productive in terms of benefits to the user communities, sustaining and scaling up such initiatives calls for an integrated approach of combining physical and social sciences along with policy makers and development practitioners (NGOs).

The scientific community should gear up to meet the needs of groundwater users through provision of more scientific and appropriate information to the users. The estimation methodologies need improvement along with increasing the number of observation wells and rain gauge stations. Policy makers should focus on providing hydrological information at a much lower scale than it is being done presently. Appropriate scale and methods suitable for hard rock areas as well as alluvial soils need to be developed. This becomes critical in the context of climate change. Policies should move towards focusing on groundwater management rather than development. For this purpose, innovative policies are needed, involving local communities and NGOs as partners. Generation of hydrological information at the village level is quite possible through the involvement of local communities and the NGOs. The NGOs can help in the process of capacitating the communities to take up the scientific activities. Finally, an integrated policy approach (integrating all the relevant policies such as power and pricing) and delinking land and water rights are very important for ensuring equitable distribution of the common resources.

PART II

INSTITUTIONALISING GROUNDWATER MANAGEMENT:

A TALE OF THREE PARTICIPATORY MODELS IN ANDHRA PRADESH

CHAPTER IV

MANAGING GROUNDWATER: REVIEW OF APPROACHES

I. Introduction

While groundwater is studied extensively in terms of its hydro-geology and socio-economic aspects, sustainable management of groundwater has not been dealt with comprehensively either by researchers or policy makers. The increasing groundwater crisis consequent to it's over exploitation and degradation makes groundwater management imperative from the ecological as well as socio-economic point of view. Though the Approach Paper to the 12th Plan recognises this importance, it fails to provide any plan of action due to the absence of any clear understanding of groundwater management. The main bottleneck for bringing groundwater under a management regime is that groundwater is treated as private property by individuals, as a right attached to land ownership. Attempts towards changing this practice are not only perceived to be associated with huge transaction costs, but also resulted in socio-economic conflicts due to the existing inequity in groundwater distribution as well as its economic value.

From the economic point of view, groundwater irrigation is observed to be twice as efficient as surface water irrigation in hydrological terms (m3/ha), and ten times preferable (Llamas and Martínez-Santos, 2005). Besides, it has a large number of in *situ* services including environmental, and is promoted as a plausible option for poverty reduction (Burke *et al.*, 1999; Polak, 2004). Kumar (2007), for instance, estimated that the surplus value product generated from the groundwater in India's irrigated lands (15 major states) contributes nearly 5 per cent of its gross domestic product. A large fraction of the population directly or indirectly relies on groundwater resources for livelihood, as more than 60 per cent of irrigated agriculture is dependent on it (The World Bank, 2010). Groundwater plays a major role in achieving India's food security, besides turning into a net exporter of food, despite a twofold increase in population during the last 50 years (Shah, 2004). Groundwater development requires relatively smaller investment and shorter implementation periods when compared to the traditional surface irrigation system (Valencia Statement, 2004).

These virtues of groundwater in the absence of clearly-defined property rights have resulted in the sharp increase in groundwater use, and over-exploitation as well as degradation of the resource (Dhawan, 1995; Moench 1992; Bhatia, 1992). In India, the declining groundwater table has resulted in increasing the cost of pumping with declining yield. Failure of wells has become a common phenomenon in recent years, and has been causing widespread farmer distress (Reddy and Galab, 2006). Overdraft is generally a by-product of population growth, economic expansion, distorting impacts of subsidies, and financial incentives, in addition to the spread of energized pumping technologies (Burke *et al.*, 1999). According to Shah *et al.* (2000), groundwater development faces challenges due to three major problems: depletion due to overdraft, insufficient conjunctive use, and pollution due to growing agricultural activities.

About a quarter of India's agricultural production has been at risk due to growing depletion (Shah *et al.* 2000), which results in the persistence of poverty and low growth - a situation that has been further aggravated during recent years. Intensive use of fertilizers and pesticides, leaching from compost pits, animal refuse, dumping grounds for garbage, seepage from septic tanks and sewage, etc., affect groundwater quality (Burke *et al.*, 1999; Sharma, 2009). Another serious issue of groundwater quality is arsenic - approximately 50 million people worldwide are affected by arsenic (Alaerts and Khoury, 2004).

Groundwater over exploitation thus has serious implications for achieving the Millennium Development Goals (MDGs) (The World Bank, 2010). This is because declining access to groundwater not only affects agricultural production, but also education, health, gender, child mortality, poverty and hunger (Sharma, 2009). Although groundwater is not a scarce resource in most regions, sustainable management of the resource is the crux of the problem (Burke *et al.*, 1999). This part (II) attempts to explore the possible options for groundwater management in the Indian context. The main focus of the study is to understand the functioning and efficacy of groundwater management institutions by comparing and contrasting three participatory groundwater models in AP.

This chapter reviews the existing groundwater management practices at the policy level across the countries. Groundwater is a typical resource, as it has the attributes of common pool resource with greater feasibility for private access and management. In most situations, it is considered as a Common Property Resource (CPR) with extremely high use value (Burke, 1999). At the same time, the linkages between groundwater and land ownership facilitates private access and management. This dichotomy of common as well as private good qualities makes sustainable management of the resource extremely difficult. In some countries like Indonesia, Australia, USA and Peru, it is considered as a public good either through legal tradition or through the suppression of private ownership rights (IRM&ED, 2008). However, in countries like India, groundwater is treated as a *de facto* private property, though other precious resources, such as minerals, lying beneath private lands are treated as state property (Singh, 1995). This often results in over exploitation of groundwater and inequity in access. In order to ensure equity and sustainable use, countries like South Africa have abolished riparian laws through delinking land and water rights (Reddy, 2007).

Lack of clarity regarding property rights on groundwater also results in the poor implementation of sanctioning and enforcing water allocation mechanisms at the policy level. Rigid and static governance structures fail the policy makers to understand the changing groundwater scenario. Lack of information at appropriate scale is a bottleneck at the community level for adopting informed groundwater management practices (Reddy *et al.*, 2011). In the absence of appropriate information coupled with high economic value, the highly heterogeneous nature of groundwater availability in space and time is turning groundwater extraction into a high-risk venture. Therefore, it is necessary to understand the existing groundwater management systems at different levels (national, state and community). Based on a review of existing literature the basic management principles being adopted for groundwater management can be broadly grouped under three approaches, viz. regulatory, economic, and community-based. In what follows, we briefly discuss these approaches.

II. Regulatory Approaches

Regulation is the most commonly used instrument for managing groundwater use. Regulation mechanisms include restrictions on digging new wells, well depths and the volume pumped, demarcating groundwater protection zones, etc., which are generally enforced by the state administrative process (Shah, 2009). Apart from direct regulation, indirect regulation through restricted supply of electricity for pumping, restrictions on financing, etc., are also used to manage groundwater. These regulations consist of a complex and multilayer framework of a range of constitutional and statutory provisions at the central and state levels. Groundwater management in India falls within the jurisdiction of the State Government that is responsible for the financing, cost recovery and management of all water resources (Saleth, 2005). However, the Central Government has the concurrent power to make laws with respect to any matter for any part of the territory of India.

The Indian Easements Act of 1882, which mentions the private property rights over groundwater use, forms the basis for groundwater regulation in India (Saleth, 2005). It is adopted from the English Common Law, which gives every owner of land "the right … to collect and dispose within his own limits of all water under the land which does not pass in a defined channel" (The World Bank, 2010). Thus, groundwater is treated as an appendage to land because it is an easement connected to land, and persons who own the land also own the groundwater beneath it. They have also the right to transfer rights over groundwater along with the ownership of land.

The GoI introduced a Model Groundwater Bill during 1972 constituting a groundwater management agency at the state level, which is responsible for registrations and control of larger groundwater users. Some of the major elements of this bill include power to notify areas for control and regulation of groundwater development, grant of permission to extract and use water in the notified areas, registration of existing users in the notified areas, prohibition of carrying on sinking wells, etc. The Model Groundwater (Control and Regulation) Bill of 1992 proposes a kind of groundwater permits system. However, it did not set any withdrawal limits (GoI, 1992) and is confined only to the states of Tamil Nadu, Maharashtra, and Karnataka. The National Water Policy of 2002 also makes certain provisions on the control of groundwater extraction.

During the late 1990s, AP, Tamil Nadu, and Maharashtra enacted groundwater legislations. These legislations imposed restrictions on groundwater exploitation by making registration of wells as well as rigging technologies mandatory. The implementation and enforcement of these legislations are yet to bear fruit due to various reasons. For, these legislations have failed to take spatial distribution of the resource into account by putting all the regions together, irrespective of their level of groundwater development. That is, top-down regulations take an aggregate view of the situation, and often fail to capture the local-specific conditions such as geo-hydrology and socio-economic aspects of groundwater use. Hence, they are least likely to be socially and political viable. Similarly, socio-economic equity is not taken into account while enforcing the regulations; i.e., treating those having and those not having wells equally. The doctrine of prior appropriation reinforced the access rights of the existing well owners while curtailing new wells in over-exploited areas. Due to the negligence and conflict of interests of all sections of the society, enforcement has received scant attention (Sharma, 1995). Similarly, the monitoring mechanism to ensure that a particular regulation is enforced is a costly and difficult task in vast and remote regions (Kumar, 2007).

Limiting the power supply and formal credit are the indirect ways of regulating groundwater use. A number of states in India follow power supply regulation for one reason or the other. The main reason, often made explicit for restricted power supply, is supply constraint as well as reducing the burden on the exchequer due to subsidised or free power supplied to the farm sector. The externality of restricted power supply is the regulation of groundwater use. In fact, farmers express, "but for the limited power supply, their borewells would have gone dry", especially during drought years. The power supply restrictions are usually associated with subsidies or free power. The Gujarat Electricity Board (GEB) does not provide new electricity connection for extraction of groundwater in over-exploited, critical and saline areas without the consent of the Central Groundwater Authority (CGWA). It has also launched the *Jyoti Gram Scheme* (JGS), which puts separate feeders for agriculture and domestic services (Lakhina, 2007). Restricted power supply is being followed in a number of states including AP, Gujarat, etc. The power is supplied for only eight hours per day for agricultural purposes; AP has been supplying 7-9 hours a day power supply along with the free power policy for the last 7 years. Restricted power supply policy was observed to have little consequence in the case of large pumps and multiple wells, as the effectiveness of regulations undermines not only the availability of the diesel pump-set option but also by the presence of a 'kink' in the farmers' power demands (Saleth, 2005). As a result, misuse of power as well as groundwater is widespread, as farmers leave their pumps on round the clock. Hence, the combined impact of free but limited power supply for groundwater use needs to be assessed critically.

The National Bank for Agriculture Rural Development (NABARD) has adopted a policy not to provide refinance in critical and over-exploited areas. NABARD has prescribed spacing norms for different types of areas whereby the minimum distance between two groundwater abstraction structures can be indicated (IRM&ED, 2008). According to the NABARD regulation, the farmers do not get credit for a new borewell if it is located within 200 m radius of an existing borewell. Such restrictions are also imposed by other nationalized banks. Field research has shown that credit regulation was not very effective due to the availability of other credit avenues (mainly informal sources) at the village level (Kumar, 2007). This is despite the fact that the cost of credit from informal sources is high. The credit rationing policy of the banks is also trying to curb new power connections to borewells and place restrictions on electric power supply. Besides, enforcement is also lax due to the pressure on banks to achieve targets.

The Punjab Government has recently introduced the Punjab Preservation of Sub-Soil Water Ordinance 2008, which prohibits the planting of paddy by the farmers in the state before June 10, in order to conserve groundwater. The ordinance provides for the government agencies to plough the area with the standing crop of such farmers who transplant paddy before the notified date. The effectiveness of this order dissuading farmers from sowing early paddy, thereby conserving groundwater is, however, is yet to be seen.

A model bill to regulate and control development of groundwater has been circulated by the Ministry of Water Resources (MoWR) to all the States / Union Territories (UTs). So far, 11 States/UTs including AP, Goa, Tamil Nadu, Kerala, West Bengal, Bihar, Himachal Pradesh, Chandigarh, Lakshadweep, Pondicherry, and Dadra and Nagar Haveli have enacted and implemented groundwater legislation. However, the effectiveness of their implementation and enforcement is not known.

Some success in reducing groundwater draft through regulatory measures have reportedly been made in a few water-scarce countries such as Jordan, where a quasi-water policy requires measuring withdrawals from the irrigation wells, enforcement of pumping quotas and levy of volumetric groundwater fee (The World Bank, 2000). However, the situation is more complex in countries such as India where millions of individual private tubewell owners, dispersed through the length and breadth of the country with varying groundwater availability and demand conditions, are engaged in groundwater extraction. Putting into effect such an approach and overseeing its implementation in a country of the size of India is nearly impossible. For, the number of groundwater structures in India is estimated at about 23-25 million (The World Bank, 2010). Maharashtra has recently developed a groundwater management model, which involves regulation of more than 1.5 million irrigation wells. It includes a levy on groundwater use and a ban on deep tubewells. The Chinese, with stronger state commitment to groundwater regulation, with a more elaborate reach and local authority structures still find it impossible to regulate groundwater overdraft in North China Plains (Shah, Giordano and Wang, 2004a). Neither have the Americans been able to implement real groundwater demand management, with their elaborate structure or water rights and groundwater districts, nor the Spaniards and Mexicans, with their efforts to promote groundwater user associations.

III. Economic

Pricing of water or a complementary input such as electricity or diesel, water markets, and tradable water rights are some of the important economic instruments that are used in the case of groundwater management. Economic instruments include charges and taxes levied on irrigation wells or volume of water withdrawn such as the 1994 Water Law in China (Wang *et al.*, 2007), Law of the Nation's Water in Mexico (Shah et al., 2004a; Scott and Shah, 2004; Sandoval, 2004), and Israel (Feitelson, 2006). An example of taxes as an economic instrument is found in Chennai (Briscoe, 1999). Municipal water utility is paying the farmers to sell borewell supplies in order to meet the drinking water demand in the urban areas, which created an incentive for the farmers to put water to a higher-value use and reducing mismanagement in groundwater allocation. However, it is very difficult to collect and enforce such a fee in case of large resource users or poor governance environment (Shah, 2009).

Electricity pricing is a more commonly followed instrument in India. Electricity has the potential to regulate the use of groundwater. For instance, it is argued in the context of different regions of India that *pro rata* electricity pricing enhances groundwater use efficiency and sustainability without affecting net returns from farming (Kumar, 2005; Kumar, *et al.*, 2011). The study estimates the levels of pricing at which demand for electricity and groundwater becomes elastic and shows that pricing is socio-economically viable. Further, water productivity impacts of pricing would be highest when water is volumetrically allocated with rationing. Therefore, an effective power tariff policy, followed by the enforcement of volumetric water allocation could address the issue of efficiency, sustainability and equity in groundwater use in India (Kumar, 2005). Similarly, in the context of AP, which is the front-runner in the provision of free power along with supply restrictions, it is argued that pricing of electricity for irrigation is the only option for addressing agrarian distress (Kumar *et al.*, 2011). However, the impact of pricing on groundwater management could also vary, depending on the water productivity (Malik, nd).

In case of diesel pricing, it was found that price rise may not necessarily result in the reduction in groundwater use (Shah, 2007). On the contrary, farmers may opt for highly water-intensive and remunerative crops. However, the main difficulty with the price mechanism is that of implementation. There is lack of required administrative resources for metering and monitoring groundwater use and collecting user fees. During the 1970s, the GoI had faced difficulty in metering about 2 million wells and thus implemented a flat tariff on electricity used by agriculture. At present, the number of wells is over 20 million, aggravating administrative difficulties and transaction costs. Besides, pricing is a politically sensitive issue, especially when populism has become the norm (Kemper, 2007).

The development of private groundwater market has a long history in rural India (Pant, 2005; Saleth, 1994). Even though selling of water was traced out during the 1920s, it was only in the 1960s that systematic information started flowing (Saleth, 2005). Groundwater markets are widespread in Gujarat, Tamil Nadu, AP, Uttar Pradesh (UP), and West Bengal (IRM&ED, 2008). However, there are no clear-cut statistics about the total area under private groundwater market. Based on his studies from Gujarat and UP, Shah (1993) projected that the area irrigated under groundwater markets was about 50 per cent of the total Gross Irrigated Area (GIA) under private lift irrigation. Whereas Shankar (1992) mentions that the actual GIA ranges from 80 per cent in Gujarat to 60 per cent in UP. A Tamil Nadu study shows that it is not more than 30 per cent (Janakarajan, 1993).

A market is basically formed through a mutual understanding between two adjacent farmers to share water (Mukherji, 2007). It serves two purposes: promoting efficient use, and providing water to poor farmers who are either unable to afford wells or find it un-economical to do so (Shah, 1989, 1993; IRM&ED, 2008). The markets also increase cropping intensity and demand for agricultural labour, which ultimately benefits the landless and wage labour (Fujita and Hussain, 1995).

The impact of water markets on groundwater demand is not necessarily negative. Though markets encourage groundwater use efficiency, they often expand the area per well due to the incentive to sell water. However, the extent of the impact again may depend on water productivity. Groundwater market in Gujarat, for instance, does not consider the limit of the resources and is thus not sustainable in the long run (Kemper, 2007). Topography and distance between the source and the field also influences sustainability. In hard rock, deep alluvial or scanty rainfall areas, development of market sharing results in over-pumping and over exploitation (Roy, 1989). On the other hand, Shah (2009) mentions that tradable property ownership creates incentives for improving productivity and conservation.

IV. Community Management

Community management of groundwater is very limited in its spread despite the fact that the community management of irrigation (through tanks or canals) is very old. This is mainly because groundwater resource is considered to be private property. Participatory approach to groundwater management in India is based on the Western United States' experience of the communities in aquifer management. This model was also tried in Spain and Mexico where users are registered and organized into associations with a mandate to manage sustainably (Villarroya and Aldwell, 1998; Sandoval, 2004). Thus "community management" implies creation of self-governing water user organisations who take the responsibility of sustainable management of aquifers through collective action (Shah, 2009). The main objectives of the management process are to focus on the demand side through participatory data collection, analysis and dissemination (GoAP, 2007). It can also involve any mix of instruments including regulation, property rights, and pricing (The World Bank, 2010).

The Government of Andhra Pradesh (GoAP) and Punjab for instance started Groundwater Management Projects where farmers are equipped with the necessary data, skills and knowledge, for managing groundwater in a sustainable manner through managing and monitoring their own demand. They measure, and keep a daily track of rainfall, water levels, and well yields, calculating groundwater recharge from monsoonal rainfall, and estimating their annual water use based on the planned cropping pattern.

Empirical studies show that in the years when water availability was low either due to low rainfall or high groundwater abstraction during the preceding crop season, the farmers are now able to achieve a combination of crop diversification and water-saving irrigation methods (The World Bank, 2010).

A different type of peoples' participation was observed in Rajasthan. The villagers decided to stop sinking of borewells in order to preserve and judiciously use the water resources at their disposal. As a result, no borewell is found within the 4 km radius of the village (IRM&ED, 2008). In Kerala, two community managed groundwater projects were implemented for proper utilization of water for irrigation. As per the instructions, two persons can irrigate their land at a time. The farmers bear the electrical and Operation and Maintenance (O&M) charges and succeeded to achieve financial and source sustainability. Check Dam Movement was started in Gujarat, where farmers formed village-level local institutions (Gandhi and Sharma, 2009). Under this system, the villagers undertake planning, finance and construction of a system to check dams in and around the village in order to collect and store rainwater, recharge the groundwater aquifers, and thereby recharge the dugwells. As a result, the water table has increased, improving the agricultural income. However, there was no collective action on reducing over extraction. The communities were self-interested and every farmer in the community was free to extract whatever they wanted, rather than focusing on collective targets for crop diversification or water use reduction.

Community based management programs should be designed with a shared focus on improving agricultural productivity, income and water conservation. Water use reductions should not be explicitly sought, but realized by aligning efficient irrigation interventions with farmer incentives for higher profits. The Planning Commission (2007) also agrees with the fact that community management or control would not work well unless it serves some basic needs of the farmers. According to The World Bank (2010), stakeholders' participation in the management process is necessary because it disseminates understanding of issues that can be the impetus for up-scaling good practices in the sustainable use of groundwater. It also improves the self-regulatory capacity, counteracts corruption, and facilitates the coordination of decisions relating to groundwater, land use, and waste management. According to Burke *et al.*, (1999), socio-economic, political and institutional factors are the main determinants, which incentivise these stakeholders in sustainable groundwater management. As reliability of water supply declines, it poses tremendous risk to the people depending on it. It also influences farmers' decisions about investment in fertilizer, seed, and other inputs; the Government and other institutional investments; and economic returns. Thus, a detailed account about how people are using groundwater, why extraction rate is tremendously increasing, the pricing mechanism and sharing structure, etc., need to be analyzed for a better policy framework that bridges the gap between physical availability to administrative and institutional responses towards a sustainable management process. This calls for proper understanding of the property rights regime under which groundwater development and management falls.

There are a few participatory groundwater management initiatives implemented by different NGOs in various states (GoI, 2011). These include:

i) The APFAMGS programme in AP aimed at involving farmers in hydrologic data generation, analysis and decision making, particularly around crop-water budgeting;

ii) groundwater sharing under the AP Drought Adaptation Initiative (APDAI) involving Watershed Support Services and Activities Network (WASSAN), in parts of AP;

iii) experiences from Barefoot College, Tilonia, with a water budgeting tool known as *Jal Chitra*;

iv) efforts by the Foundation for Ecological Security (FES) at taking a micro-watershed unit for water balance and planning groundwater use along with communities at their sites in Rajasthan, Madhya Pradesh (MP) and AP;

v) experiences of the Advanced Centre for Water Resources Development and Management (ACWADAM) with *Samaj Pragati Sahyog* (SPS) in Bagli, MP, and with the *Pani Panchayats* in Maharashtra on knowledge-based, typology-driven aquifer-management strategies;

vi) the *Hivre Bazar* model of watershed development (WSD) and social regulation to manage water resources; and

vii) social regulation of groundwater use initiated by the Centre for World Solidarity (CWS). The operational modalities and their functioning need to be assessed critically in order to draw lessons for broader policy formulations.

Amidst this backdrop, this paper examines three institutional models that are addressing groundwater management in AP following different approaches. These institutions are assessed in terms of their structure, operational principles, functioning, and effectiveness in managing groundwater at the community level. A comparative assessment of the strengths and weaknesses of these approaches will be taken up in order to arrive at a feasible or acceptable institutional model for scaling up.

CHAPTER V

APPROACH AND PROFILE OF STUDY SITES

I. Approach

For the purpose of comparative institutional assessment, three villages were selected, where the community groundwater management practices have been adopted under different NGOs. Besides, one village where no such management practices were adapted was selected as the control village. The details of the sample villages are presented in Table 5.1. The sample villages consist of:

i) One village covered under the Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) implemented by the NGO, Bharati Integrated Rural Development Society (BIRDS). APFAMGS is a continuation of an earlier programme known as Andhra Pradesh Ground water Borewell Irrigation Scheme Project (APWELL) supported by the Royal Netherlands Government. The APFAMGS was implemented with the support of Food and Agricultural Organisation (FAO);

ii) One village, where the NGO, Centre for World Solidarity (CWS), along with its local partner NGOs, has been implementing the programme named "Social Regulations in Water Management (SRWM)";

iii) One village, where participatory groundwater management is being promoted as part of the Andhra Pradesh Drought Adaptation Initiative (APDAI) of the Department of Rural Development (DoRD). The NGO, WASSAN is the lead technical agency, and the initiative is being implemented by the SERP, through the *Mandal Mahila Samakhyas* (MMS); and

iv) One control village with substantial groundwater use, but not having any groundwater management institutions.

Of these three initiatives, the APFAMGS Project operates at a wider scale, covering 3,000 farmers in seven districts of AP, while the other two are working on an experimental basis on a small scale of a few villages. Though the APFAMGS initiative focuses on rain-fed and semi-arid regions, the socio-economic, agro-climatic and hydro-geological conditions vary widely across the locations and villages. An attempt was made to select a representative village from across the seven districts to identify the common elements in the institutional arrangement and the processes that may be common and relevant for comparison with other initiatives.

Table 5.1: Details of the Sample Villages

Village	Mandal	District	Ground water Model/Project	Implemen-ting Agency (NGO)	Year of Initiation of Project	Stage of the Project
Thaticherla	Komarolu	Prakasam	APFAMGS	DIPA (BIRDS)	2003-04	Ist Phase Complete. 2nd Phase Ongoing
Madirepalli	Singanamala	Anantapur	CWS/ SRWM	RIDS (CWS)	2003-04	Ongoing
Gorantlavaripalle	Nallacheruvu	Anantapur	WASSAN/ APDAI	WASSAN/ MMS	2007-08	Ongoing
Rajupalem	Komarolu	Prakasam	Control Village	NA	NA	NA

NA: Not Applicable

II. Profile of the Sample Villages

The sample villages vary in size (number of households) and socio-economic composition. The control village is the largest, with 374 households; while the smallest is Gorantlavaripalle, with 113 households (Table 5.2). The geographical area of the sample villages ranges between 300 and 1900 hectares, and the average family size ranges from 3.8 to 4.4 (Table 5.3). Socially, two of the sample villages are dominated by the Other Caste (OC) households, while two of them have a higher proportion of Backward Caste (BC) households. Two of the sample villages have more than 25 per cent of the households belonging to the Scheduled Caste/Tribe (SC/ST) households. In terms of economic composition, most of the sample villages are dominated by marginal and small farmers (Table 5.2). Only Madirepalli Village has about 50 per cent of the households from medium and large farmers. These variations help in understanding the dynamics of Community Based Groundwater Management (CBGM) in varying socio-economic contexts. The proportion of the sample from these villages ranges between 8 and 27 per cent. This is due to the size of the sample village, as the number of sample households chosen are 30 from each sample village.

Table 5.2: Socio-Economic Composition of the Households in the Sample Villages

District/ Farm Size	Village/ Social Categories/ No. of HHs			Total HHs	Sample HHs
	SC/ST	BC	OC		
Prakasam:Thaticherla					
Landless	10	30	5	45	0
Marginal Farmers	38	100	3	141	19 (14)
Small Farmers	10	40	15	65	8 (12)
Medium Farmers	2	0	10	12	3 (25)
Large Farmers	0	0	2	2	1 (50)
Total	**60**	**170**	**35**	**265**	**31 (12)**
Anantapur: Madirepalli					
Landless	2	6	1	9	0
Marginal Farmers	26	8	9	43	5 (14)
Small Farmers	3	4	30	37	8 (22)
Medium Farmers	0	25	30	55	12 (22)
Large Farmers	0	7	22	29	5 (17)
Total	**31**	**50**	**92**	**173**	**31 (18)**
Anantapur: Gorantlavaripalle					
Landless	7	0	0	7	0
Marginal Farmers	19	20	5	44	8 (18)
Small Farmers	2	30	20	52	19 (37)
Medium Farmers	0	0	10	10	3 (30)
Large Farmers	0	0	0	0	0
Total	**28**	**50**	**35**	**113**	**30 (27)**
Prakasam: Rajupalem					
Landless	28	0	4	32	0
Marginal Farmers	1	60	100	161	12 (8)
Small Farmers	1	10	150	161	13 (8)
Medium Farmers	0	0	10	10	3 (30)
Large Farmers	0	0	10	10	3 (30)
Total	**30**	**70**	**274**	**374**	**31 (8)**

Source: Field Survey (PRA/FGD Methods).

Note: Figures in the brackets indicate the per cent of sample farmer HHs taken for the study.

Access to Groundwater:

Access to groundwater and irrigation is at the core of groundwater management. The extent and nature of access across the sample villages would highlight the differences in the functioning and performance of the PGM. All the sample villages depend on groundwater irrigation. The extent of irrigation ranges between 15 per cent in Gorantlavaripalle to 34 per cent in Madirepalli (Table 5.3). On the other hand, more than 70 per cent of the households in the three villages, where groundwater institutions are present, have access to wells, as against 29 per cent in the control village. Variations in the extent of irrigation (percentage of area under irrigation) could be due to the groundwater potential in the respective villages. However, the contrast in the access to wells in one form or the other, explains the role of groundwater institutions. For instance, though only 15 per cent of the households in Thaticherla own wells, 70 per cent of them have access to groundwater through water sharing and community wells. On the contrary Rajupalem (control village) has only 29 per cent of the households reporting access to well water for irrigation, despite 17 per cent of them owning wells. In the control village, only 12 per cent of the households share water with others as against 37 to 46 per cent of the households in the villages with groundwater institutions (Table 5.3).

Table 5.3: Groundwater Access to Households in the Sample Villages

Particulars	Thaticherla	Madirepalli	Gorantlavaripalle	Rajupalem
No. of Households	265	173	113	374
Average Household Size	4.4	4.2	4.3	3.8
Total Geographical Area (in ha)	1903	307	1064	1676
Area under Irrigation (%)	32	34	15	22
% of HHs with Own Wells	15	43	26	17
% of HHs Sharing Wells	46	45	40	12
% HHs depending on Community Wells	10	0	0	0
% of HHs with Access to Wells	71	88	87	29
Main Occupation	Cultivation	Cultivation	Cultivation	Cultivation

Source: Field Survey.

There is a clear pattern in the access to groundwater across socio-economic groups of farmers. It is observed that the SC/ST farmers and marginal and small farmers seem to depend more on sharing water, while a large proportion of the OC farmers and large farmers have their own wells (Tables 5.4 and 5.5). The landholding pattern is more or less similar in all the sample villages, though we do not have specific information the hydro-geology of the villages. These two factors are critical in influencing the access and quality of groundwater.

Table 5.4: Details of Well Status of Groundwater Farmers across Social Categories and Farm Sizes in Sample Villages

District/Village/ Caste Category	Well Status of Groundwater Farmers			
	OW	WS	CW	All
Prakasam: Thaticherla				
SC/ST	7 (1)	27 (4)	6 (1)	40 (6)
BC	26 (4)	79 (13)	15 (2)	120 (19)
OC	6 (2)	16 (3)	5 (1)	27 (6)
Total	**39 (7)**	**122 (20)**	**26 (4)**	**187 (31)**
Anantapur: Madirepalli				
SC/ST	3 (1)	14 (4)	0	17 (5)
BC	18 (3)	26 (5)	0	44 (8)
OC	53 (11)	38 (8)	0	91 (19)
Total	**74 (15)**	**78 (16)**	**0**	**152 (32)**
Anantapur: Gorantlavaripalle				
SC/ST	2 (1)	5 (2)	0	7 (3)
BC	15 (4)	27 (7)	0	42 (11)
OC	40 (12)	10 (4)	0	50 (16)
Total	**57 (17)**	**42 (13)**	**0**	**99 (30)**
Prakasam: Rajupalem				
SC/ST	0 (0)	0 (0)	0 (0)	0
BC	7 (2)	9 (3)	0 (0)	16 (5)
OC	55 (16)	35 (10)	0 (0)	90 (26)
Total	**62 (18)**	**44 (13)**	**0 (0)**	**106 (31)**

Note: OW-Own Well; WS-Water Sharing; CW-Community Well.
Figures in the brackets indicate the No. of sample groundwater farmer HHs taken for the study
Source: Field Survey (PRA/FGD Methods).

Table 5.5: Distribution of the Sample HHs across Farm Size and Well Ownership Status

Village	Groundwater User Well Status	Economic Class			Overall
		MF	SF	LMF	
Thaticherla	Owned	47	29	24	55
	Water Sharing	79	21	0	45
	Total	61	26	13	100
Madirepalli	Owned	7	40	53	48
	Water Sharing	31	13	56	52
	Total	19	26	55	100
Gorantlavaripalle	Owned	6	76	18	57
	Water Sharing	54	46	0	43
	Total	27	63	10	100
Rajupalem	Owned	22	44	33	58
	Water Sharing	62	38	0	42
	Total	39	42	19	100
Overall	Owned	21	48	31	54
	Water Sharing	55	29	16	46
	Total	37	39	24	100

Source: Field Survey.

Note: MF- Marginal Farmers; SF-Small Farmers; LMF-Large and Medium Farmers.

III. Methodology

Qualitative as well as quantitative research methods have been used for the study. Primarily, Focus Group Discussions (FGDs) and household questionnaires were used to elicit the required information. Besides, basic secondary data about the villages were collected from the village secretary, elders, and key informants. Field research was conducted during the months of February and March, 2011. The study team collected information and held discussions with key professionals involved in APWELL/APFAMGS, CWS, and APDAI/WASSAN projects for a broader understanding on the objectives and processes involved in the design and implementation of the respective initiatives. The study team also interacted with the officers and consultants of the State Irrigation and Command Area Development (I&CAD) and the Groundwater Department both at the state and district levels. During the field visits, the team had discussions with the staff of local NGOs implementing the respective programmes. Important issues covered include communication and awareness strategy, community participation, groundwater management by community, impact on cropping pattern and yields, etc., For the purpose of quantitative household data collection, a detailed questionnaire was prepared, covering socio-economic, demographic, agriculture and groundwater management. In each village, about 30 households representing the socio-economic categories of the community were selected. The sample is divided into two groups, viz. well owners and those sharing wells or depending on community wells. The sample is divided in proportion to the actual number of well-owning and well-sharing households. At the end of the field visit, the gist of the information collected was shared with the villagers for the purpose of triangulation. Community wells are present only in one sample village (Thaticherla) under the APWELL/APFAMGS programme.

CHAPTER VI

PARTICIPATORY GROUNDWATER MANAGEMENT: THREE APPROACHES

I. Background

Water is a State Subject and so is its development, utilization and monitoring. The Government of AP is responsible for water resource planning, storage as well as use. Several Government Departments/Agencies, NGOs and people's institutions are involved in water development, use, monitoring and regulation. Water management is encouraged through institutional arrangements such as Water User Associations (WUAs) and Tank Management Committees (TMCs). These state promoted institutional arrangements are limited to surface water resources such as canals and tanks leaving groundwater development and management to private individuals. Though effectiveness and sustainability of canal and tank management institutions are being debated (Reddy and Reddy, 2005), the need for bringing groundwater under common resource management cannot be undermined. Hitherto groundwater management is left to private individuals, as it is perceived to have high transaction cost of organizing individual farmers at a scale to attain the benefits of community management.

On the other hand, as observed in the earlier section on review, there appear to be some small-scale institutional innovations that are working towards sustainable management of groundwater in different corners of the country. However, these innovations are confined to small areas in the absence of policy support in bringing groundwater under the management regime, and the possibilities for scaling up these models have not been explored. Here we make an attempt to explore the possibilities for scaling up and drawing lessons from PGM by comparing three such models that are in operation in AP.

The State of AP has a long history of community groundwater management, and is one of the first states to initiate a joint well programme way back in 1987. The three models selected are:

i) The Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) Project, which has its origins in APWELL programme;

ii) Social regulations in Water Management (SRWM) by the CWS (NGO) and its partners; and

iii) Collectivization of borewells under the Andhra Pradesh Drought Adaptation Initiatives (APDAI) programme being implemented by WASSAN with its partner NGOs. These initiatives have different origins and approaches to PGM (Table 6.1).

All the three models have been initiated in the arid and semi-arid districts of AP, where the extent of groundwater development is quite high. In what follows we discuss these three models in detail.

Table 6.1: Groundwater Management Programmes / Project Models in Andhra Pradesh

CBGWM Model	Description
APFAMGS (APWELL)	(a) Dug new borewells for a group of HHs not having access to water, with clear sharing, groundwater monitoring, and water use efficiency measures. (b) Limited to "new un-exploited" areas. APWELL has been transformed into the largest groundwater awareness programme in the state premised on: i) communities monitoring the groundwater status regularly with knowledge and scientific principles; ii) sharing the knowledge of various alternate crop systems and evolving norms for groundwater management (with facilitation); this process will lead to lesser groundwater depletion and better management.
Social Regulations in Water Management (CWS & Partners Programme)	This programme was initiated on a limited scale and based on regulations: (i) the community adopts a norm of "no new borewells "; (ii) increasing system efficiency through the provision of collective sprinkler irrigation sets; and (iii) borewell owners share their water with neighbouring farmers leading to substantial reduction of the number of water-less families in the village.
Collectivisation of borewells : APDAI (of CRD, facilitated by WASSAN)	This initiative followed an "area approach" for groundwater management where the borewell owners pool their individual borewells to provide supplemental /critical irrigation to a larger rain-fed area (entire block) for survival of rain-fed crops. The community has to abide by the following rules: (i) no new borewells for at least 10 years; (ii) all the land within the specified area (including water-less) will have a right for supplemental irrigation for Kharif rain-fed crops; and (iii) pipeline network is provided by the project so that water can be taken to any part in the block/area.

Source: Field Observation (PRA/FGD methods)

II. APFAMGS

The Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) has its origin in the APWELL Project initiated by the GoI in 1987. The APWELL Project was conceived in collaboration with the Netherlands Government, which funded a number of minor irrigation schemes in AP. The APWELL Project was approved for financing by the Netherlands Government in June 1994. From April 1995 to March 2003, the APWELL Project was implemented in seven districts of AP, viz. Prakasam, Mahbubnagar, Nalgonda, Anantapur, Kurnool, Chittoor and Cuddapah. The project was co-financed with 15 per cent (of total cost excluding establishment costs) contribution from the farmers, and the rest as a grant from the Royal Netherlands Government. The establishment costs and part of the cost of electricity infrastructure were borne by the GoI/GoAP[†]. Physical activities such as groundwater prospecting, drilling, yield testing, and construction of the distribution systems, were done through the Andhra Pradesh State Irrigation Development Corporation (APSIDC), with its technical staff under the Executive Engineer in each district[††] .

Table 6.2: APWELL Project Coverage on Completion (up to March 2003)

District	Villages	No. of Wells / WUGs	Total No. of HHs	HHs / WUGs	Total Ayacut (acres)	Ayacut per WUG (acres)	Ayacut per HHs (acres)	Avg. Yield (kg/ha)	Avg. Cost per Bore well (Rs.)	WUG Contri- -bution /Well (Rs.)
Anantapur	39	415	1396	3.4	4410	10.6	3.2	4009	131724	16159
Chittoor	110	419	2076	5	3481	8.3	1.7	3109	141242	17171
Cuddapah	59	415	2160	5.2	3978	9.6	1.8	2995	150625	18167
Kurnool	78	518	2013	3.9	5299	10.2	2.6	4557	143036	16765
Mahbubnagar	55	821	2741	3.3	8605	10.5	3.1	2604	129987	15610
Nalgonda	42	299	1439	4.8	3018	10.1	2.1	3569	153300	18796
Prakasam	87	575	2053	3.6	5698	9.9	2.8	3523	142660	16635
Total	**470**	**3462**	**13878**	**4**	**34489**	**10**	**2.5**	**3523**	**140102**	**19790**

Source: APWELL Project: Final Report, ARCADIS Euroconsult, 2003, pp.76-77.

† For Details on funding pattern, see APWELL Final Report, ARCADIS Euroconsult, 2003, pp.45-50

†† A technical assistance team, consisting of national and international experts on various disciplines, based in Hyderabad, advised and coordinated project activities in the field. In each district, local NGOs were contracted to implement the social, institutional, gender, agricultural, and watershed aspects of the project. For this the NGOs appointed a dedicated team consisting of Agricultural Production Trainers (APTs), Gender Development Organisers (GDOs), Watershed Development Facilitators (WDFs), and Community Organisers (COs). A District Field Coordinator (DFC), who was part of the consultant's team, supervised the work in each district.

Under this programme, a total of 4,480 borewells were drilled. Of these, 3,462 were successful with yield above 1,500 gph, at 77 per cent success rate*** in 470 villages, covering about 14,000 households across seven districts (Table 6.2). In the APWELL Project, farmers own and maintain the borewell irrigation systems constructed as part of the project. Under each well, the farmers formed Water User Groups (WUGs) for construction, operation, and maintenance of the borewell systems. Women WUG members formed Self-Help Groups (SHGs) for thrift and credit activities, and gradually initiated land and water-based agriculture and other supplementary income-generating activities. On an average each well/WUG has four households covering 10 acres of land, i.e., an average of 2.5 acres. The average cost of a well was about Rs.1.4 lakhs of which about 14 per cent was contributed by the farmers (Table 6.2). Clusters of WUGs were formed into Borewell User Associations (BUAs), which in due course were legally registered, for training, conflict resolution, procuring agricultural inputs, marketing, agro-processing, and groundwater management. Important components of the project included: groundwater resources development where feasible, land-and-water management by the users, extension and training, activities for gender integration, environment management, and monitoring and evaluation.

The project clearly demonstrated that PGM is a viable concept if introduced in conjunction with groundwater development, agricultural production, institutional development, and capacity building of farming communities. The implementation process followed by the APWELL Project achieved certain important results, which are good lessons for future projects:

- The intense community organization efforts to form and nurture WUGs assured the involvement of the farmers from the very inception of the project activities within the village.

- Compulsory inclusion of women as members of WUGs and forming SHGs helped to mainstream women farmers into the management of groundwater systems.

- At the end of project implementation, the assets created were handed over to the WUGs. Thus, the project had a distinct exit policy woven into its concept.

- The WUGs contributed 15 per cent of the cost (excluding administrative charges). This ensured greater sense of ownership among them.

*** 75 per cent is the acceptable success rate.

- Every member of the WUG was given a pipe outlet on his/her land, assuring equity in water distribution and reducing water conveyance loss.

- Intensive capacity building through training, exposure visits, and demonstrations assured quick adoption of sustainable water management and agricultural practices.

- Well-trained and strongly-motivated staff of the Government and NGOs working closely with farmers is necessary for the successful implementation of PGM.

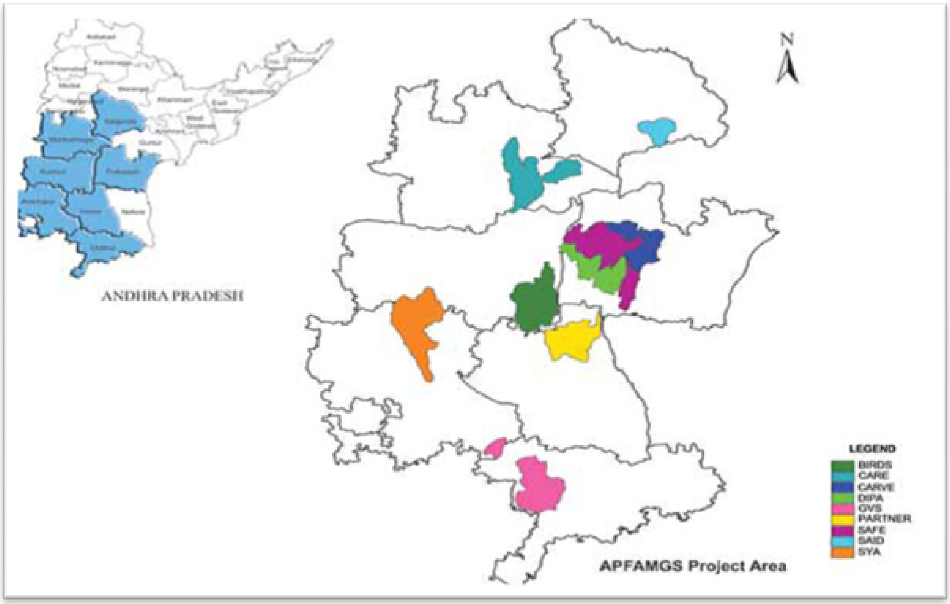
APWELL to APFAMGS

On the recommendation of the Mid-Term Review Mission[†††], the APWELL gradually initiated a number of pilot activities related to water conservation, including WSD in two villages, PHM in all clusters with more than 10 successful groundwater irrigation systems, an experiment with people-controlled groundwater system in upper Gundlakamma sub-basin in Prakasam District; artificial recharge measures in two watersheds (with technical inputs from the National Geographical Research Institute (NGRI)), and introduction of drip and sprinkler irrigation, and eco-farming through application of low-cost bio-fertilizers and bio-pesticides. The APWELL Project also conducted water quality testing in fluoride-endemic areas. During the final year of the APWELL Project, it was decided that the Indo-Dutch development assistance agreements were not to be extended to new projects. Instead, the Dutch Government approved a far smaller capacity building initiative to support farmer-managed groundwater systems for implementation through a network of NGOs in the seven APWELL districts. This was called the APFAMGS, for which funding was provided directly by the Royal Netherlands Embassy (RNE) till June 2004, after which it was transferred to the FAO.

The APFAMGS Project was implemented in the same seven districts (Map 6.1) as that of the APWELL, covering 650 habitations in 66 HUNs. It works in partnership with groundwater-dependent farmers, and empowers farmers with the knowledge and skills to monitor the groundwater system and take up appropriate interventions towards its management. The APFAMGS Project adopted a sub-basin approach for selecting habitations, unlike the APWELL which selected villages with exploitable surplus of groundwater. Thus, the approach to groundwater management shifted from water sharing to water management. Moreover, its infrastructure and incentive-centred approach has transformed it into a scientific knowledge-intensive approach.

[†††] AP Groundwater Bore Well Irrigation Schemes (APWELL): Mid-term review mission report, Netherlands Economic Institute, 1997

Map: 6.1: Location Map of the Operational Area under the APFAMGS (APWELL) Project



The philosophy of the APFAMGS Project is: "farmers' understanding of groundwater dynamics makes the difference". This is achieved through the process of enabling primary stakeholders to involve in PHM for sustainable use of groundwater resources using hydrological boundaries as an operational unit. The APFAMGS Project is implemented through a network of Community Based Organizations (CBOs) including nine field level partner NGOs and two international resource agencies. The main objective of the project is to "equip groundwater farmer users with the necessary data, skills and knowledge to manage groundwater resources available to them in a sustainable manner, mainly through managing and monitoring their own demand". The basic premise is that self-generated scientific data and knowledge will enable farmers to make appropriate farming choices using groundwater. The farming communities make informed decisions using hydrological data developed on the Geological Information System (GIS) platform.

Elaborate institutional arrangements with equal representation of men and women were made to implement the programme. The main activities taken up include:

- Awareness generation on the emerging groundwater crisis, and treating groundwater as a "common good" at the habitation and hydrologic unit level.

- Demystifying the science of hydrology through participatory learning, practising and establishing a new relationship between farmers and groundwater.

- Participatory planning and sharing of information through CWB workshops for evolving common strategies that limit damage to the groundwater system without sacrificing individual interest.

Additional steps include:

- improving crop water efficiency.
- reducing chemical pollution.
- groundwater governance transcending individual holdings and habitations without being coercive through voluntary choices such as reduced pumping, preventing construction of new wells, crop diversification, reduced application of chemical fertilizers/pesticides, etc.

A comprehensive institutional structure integrating technical and social components was established. At the village level a GMC is the key institution of the farmers - both men and women. A network of GMCs is formed at the hydrological unit level, viz. the HUN. These two are critical for providing a "demonstration effect" of the learning's from the project to the larger community of farmers beyond the project area. The HUNs have a legal status, allowing them to receive funds as well as carry out business activities. Making the farmers water literate is the core of the approach. The first step in this direction is to enhance the farmer's capacities to collect and analyse data on their own.

GMC Meeting

Capacity building and training activities are part of project components. Formal and informal techniques such as technical training related to recording rainfall, measuring draft from observation wells, cultural shows, practical training, exposure visits, exchange visits, and workshops are included. These capacities are used in the PHM exercise. In PHM, the farmers volunteer to monitor water levels from 2,026 observation wells (one well for every sq km) every fortnight. Daily rainfall measurement is collected from rain gauge stations from 190 rain gauge stations established for every 5 sq km in the project area. The collected information is shared with the farmers for taking farming decisions. Discharge measurements are also carried out to understand the pumping capacity in 700 monitoring observation wells. This is accomplished by measuring the time taken to fill a drum of known capacity; additionally, the discharge farmers also measure the drawdown. Based on these measurements, the farmers have a good understanding of the pumping capacity of the wells, well performance, water requirement for different crops, and the ways and means to increase water use efficiency.

The success of demystifying science is reflected in the CWB, which helps farmers to collectively make land use plans, depending upon water availability. The CWB is taken up at the village level before the starting of each season and aggregated at the HUN level. Using rainfall data and assumed run-off coefficient (10 per cent), the contribution of rainfall to groundwater recharge is estimated. The net availability of groundwater is estimated by adding or deducting the previous season's balance. There may either be positive or negative water balance in each season, depending on the recharge and draft. Based on the crop's water requirements and the net available groundwater, crop areas are decided in a collective manner.

By following local measures, the volunteers explain the area under each crop with the available groundwater. They estimate the area that can be devoted to paddy if the entire water is used for paddy crop or other crops, or a combination of different crops. The estimates show that in 59 of the 63 HUNs, groundwater balance is deficit. The CWB also identified over-exploited aquifers, and water-harvesting measures such as injection wells were taken up in these aquifers. In some areas, abandoned open wells were also used to trap the flood flows and transfer them to the aquifers. Though there is no coercive mechanism to force the farmers to adopt collective decisions, a survey was conducted after every season on the extent to which collective decisions were made and discussed in the GMC. The data on actual cropping pattern is used to arrive at the actual draft; however, there is always a difference between estimated and actual draft. Though individual farmers' decisions are respected, the GMCs and HUNs are able to act as pressure groups to advocate change in cropping patterns, use of sustainable agricultural practices, and water saving technologies in some places.

A hydrological database has been generated and is used for managing groundwater in 559 out of 650 habitations. In fact, the data generated is the property of the GMC and is being sold to outside agencies for the purpose of research. More than 4,000 farmers are trained to read maps and more than 10,000 farmers can handle hydrological equipment. It is assessed that some of the achievements have surpassed the targets (FAO, 2008). During the field visits, we have observed the farmers presenting crop water budget estimates and taking the water table measurements.

However, the farmers are yet to be trained on using the GIS. About 300 FWS have been established to train the farmers and equip them with technical and non-technical aspects of groundwater management. HESA, a decision-making tool for groundwater management, is being adopted and supported by recharge and discharge factors. Crop plans and management of groundwater is based on this analysis and observations. This is the same sequence used for Agro-Ecosystem Analysis in the classical FFS approach (FAO, 2008). The focus of FWS is on the active and lead farmers who can apply them directly on farm and also share them with a larger audience. The FWS has successfully created the first batch of over 10,000 farmers who have already emerged as trainers to other farmers both under the project as well as for the Government-run FFS. Such a training and adaptation has demystified hydrology, which is a hidden source, and helped the farmers in understanding the resource availability and dynamics.

Sharing of information across HUs resulted in evolving common strategies, limiting the depletion of the groundwater table. Some of the important achievements include reduction in groundwater pumping in a number of HUs. In 14 of the 63 HUs, groundwater pumping has been reduced significantly, while in nine others the reduction was moderate.

Overall, despite the reduction in pumping in a number of HUs, it is not significant enough to have a drainage basin-level impact. Reduced water pumping has a direct bearing on area under paddy, as paddy is water-intensive and the most preferred crop. In all, except in four HUs, the area under paddy cultivation has come down ranging from a few acres to several hundred acres. The farmers' experience showed that they incur crop losses whenever they do not follow the collective advice due to water scarcity. Crop diversification has taken place in favour of pulses, oil seeds, fruits, vegetables, flowers, etc. The farmers try to offset the losses due to reduction in paddy by growing other high value crops. The risks associated with commercial crops such as monoculture, reduced area under food crops, and loss in soil fertility, are also being addressed simultaneously. Water saving devices such as sprinkler and drip irrigation have been introduced for crops such as groundnut, sunflower, Bengal gram, chillies, and horticultural crops. It is estimated that groundwater pumping was reduced by more than 8 per cent (equivalent to 5 mcm per year) over the project area due to water-saving techniques. The experience of APFAMGS proves that a comprehensive approach could benefit the farming communities, though in a limited way at present.

Impact of APFAMGS:

Several impacts, on expected lines, are reported by the Project. Though some of the claims require technical verification, these impacts are:

- Empowerment of the community to collect, analyse and use data and knowledge related to water;
- Change in perception of groundwater from private property to that of a common good;
- Shift from cultivation of irrigated water intensive crops to less water intensive Irrigable Dry (ID) crops;
- Reduced losses from irrigated crops and increased profits from rain-fed or less water-intensive cash crops;
- Reduced groundwater draft;
- Increased groundwater recharge;
- Reduced use of chemical inputs;

- Increased use of organic methods of farming; and
- Reduced migration.

III. Social Regulations in Water Management at the Community Level (SRWM)

An action research project called "Social Regulations in Water Management at the Community Level" (SRWM) was initiated in 2004 in three villages in AP by the Centre for World Solidarity (CWS), in partnership with local grass-root NGOs. Another village in Warangal was added during 2007. The project aims to promote local regulation and management of groundwater resources with equitable access to all families in the communities. The project is expected to develop models to equip the community with drought mitigation preparedness strategies through better water management and regulations at the community level; and to support Community Based Organisations (CBOs) and *Panchayat Raj* Institutions (PRIs) in prioritizing the needs of the community for drinking water, irrigation, and other uses, based on the principles of equity. Specific objectives of the project include:

- To develop the capacity of the community and NGOs on CWB, water supply and demand, and water balance assessments.
- To strengthen the role of PRIs and water communities, to decentralise decision making, and creating the authority to enforce the rules, regulations and norms.
- To regulate water demand to ensure that everyone has access to at least the basic minimum of water for drinking and household purposes.
- To ensure regulatory mechanisms in irrigation practices that fit/relate with organisational structures such as NRM committees of *Gram Panchayats*, Watershed Committees (WSC), etc., and develop appropriate linkages to other Natural Resources Management (NRM) sectors.
- To crystallize facilitating mechanisms for social regulation of water resources and advocate the Government for wider replication and policy change.

The project is being implemented in four villages from three districts covering 715 households at an estimated cost of about Rs.2.5 million per year over three years from AEI, Luxembourg. The four project villages include Madirepalli and CR Pally in Anantapur District, Mylaram in Medak District and Enabavi in Warangal District. In all the four villages, rain-fed agriculture is the norm, but groundwater is an important contributor to irrigation on 6 to 42 per cent of the land. Groundwater provides the much needed life-saving irrigation during prolonged dry spells. Since 2009, as many as

15 more villages, which are spread in Anantapur, Chittoor and Nellore districts, were added in the project.

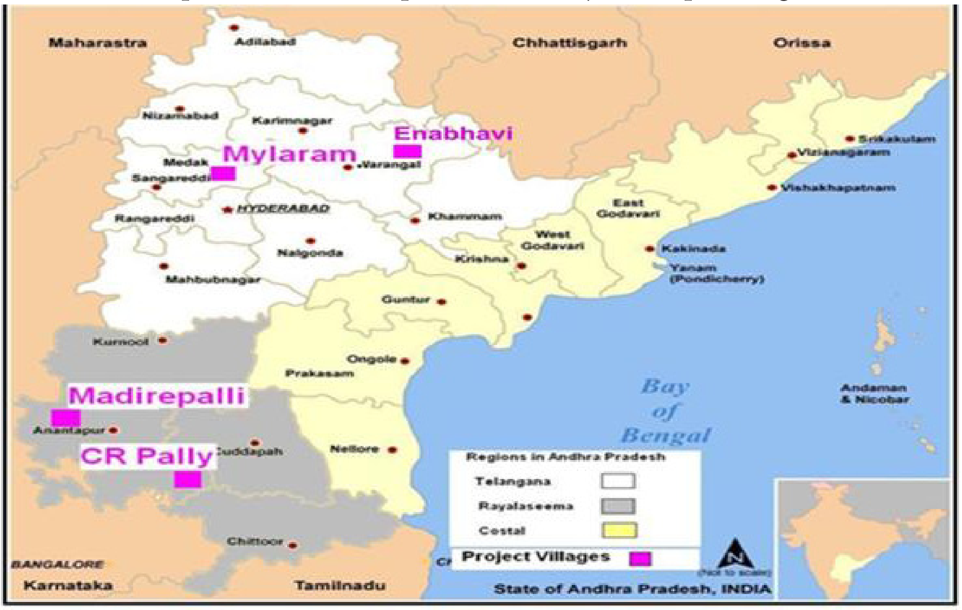
Prior to the 1990s, open wells with electrical centrifugal pumps were used to extract groundwater in the programme villages. Farmers started drilling borewells during early 1990s - the number of borewells grew rapidly in these villages over the last 15 years - and the shallow open wells gradually dried up due to declining groundwater levels. Due to indiscriminate drilling of borewells and unscientific groundwater exploration, many borewells failed either at the time of drilling or during later years. Furthermore, drilling borewells as deep as 300 ft at a closer spacing resulted in the drying up of the shallow, open dugwells, and shallow borewells due to well interference. This phenomenon resulted in huge loss of investments to farmers and seriously affected the livelihoods of farmers dependent on irrigation.

Assessing the village level Resources

The project interventions began with a participatory assessment of water resources in the project villages. Participatory Rural Appraisal (PRA) methods were used to map the resource status and the existing water utilization pattern for different purposes, such as drinking, domestic, and for irrigation. Growth of groundwater-based irrigation and trends in the groundwater levels over a period of time were thoroughly discussed and analysed in community level meetings, wherein women and men from all households participated. A series of such meetings and interactions helped to arrive at the crux of the issues, i.e., frequent failure of borewells and increasing debts of farmers due to investment on new borewells.

Competition between neighbouring farmers often leads them to drill borewells as close as two meters apart. For instance, in Madirepalli Village, three neighbouring farmers dug 13 borewells in an area of 0.5 acres over a period of four years in competition to tap groundwater. The project realized that there is need for changing the mind-set of the farmers from "competition" to "cooperation" and to increase the "water literacy" among the farmers for efficient use of water.

Map 6.2: Location Map of SRWM Project Sample Villages



A number of training programs, exposure visits and awareness-raising meetings were organized by the grass-root partner NGOs supported by CWS in the project villages. Further public awareness and education was carried out through posters, pamphlets and wall-writings. PHM of rainfall and groundwater levels in selected borewells was done regularly and shared and discussed at village meetings in order to increase the understanding of farmers on the behaviour of groundwater in relation to rainfall.

A volunteer from the community measured rainfall from a simple manual rain gauge station installed in the villages and recorded the static water levels in 10 sample borewells using an electronic water level indicator. This data was displayed on a village notice board and updated periodically.

The first three years (from a total of seven years) of intensive grass-root work and facilitation has resulted in the community realizing the ill-effects of indiscriminate drilling

Officials interacting with GMC

Measuring Water Level

Displaying Water level data in the Village Notice Board

of borewells and use of groundwater. The community evolved and agreed on the following "social regulations" and interventions in the village:

- No new borewells to be drilled in the village;
- Equitable access to groundwater for all the families through well sharing;
- Increasing the groundwater resources by conservation and recharge; and
- Efficient use of irrigation water through demand-side management.

Small groups of farmers were formed in all the project villages between a borewell owner and a set of about two to three neighbouring farmers, who did not own borewells. The borewell owners were motivated to share water by explaining that drilling new wells in the vicinity of their wells may render theirs dry due to competitive extraction. Instead, sharing a portion of water from his well helps his neighbours, while securing his access to water and thus livelihood. Sharing water with neighbours is a "win-win" situation, benefiting both the borewell owners and water receivers.

Sharing the Resource at the Village Level

Sharing of groundwater resource by well owners with other farmers is the prominent feature of the PGM in villages. The practice is of significance in an over-exploited area like Anantapur. For instance, Madirepalli Village of Singanamala Mandal has basically granitic terrain. The dugwells are very deep - sometimes more than 35 feet - and dry. The farmers in the village are practicing groundwater management by sharing and conserving the resource through micro-irrigation and its augmentation through construction of recharge structures. Before the interventions, the farmers were given training on PHM, and are provided with the required equipment. However, there was slackness in practicing it.

The villagers express gratefulness to the local NGO (RIDS) which created enough awareness among them about the futility of drilling new bores and the advantages of sharing water. Most of the farmers reported that earlier, they drilled numerous borewells of various depths. Most of these were drilled without scientific investigation, and huge money was invested in the hope of getting enough water. They believe that the efforts of the NGOs would ultimately pave the way for changing the groundwater scenario in their village. This change of practices occurred over a period of time, and also with the cost attached to the lessons learnt. Between 2004 (before the intervention) and 2010 (after the intervention), there was significant change in the attitude of the farmers, with substantial physical gains (Table 6.3). For instance, two of the open wells and 16 of the borewells were revived after the intervention. The area under irrigation also increased substantially, i.e., 31 per cent in the case of Kharif and 158 per cent in the case of *Rabi* crops. This was possible mainly due to water sharing, reduction in the cultivation of water-intensive crops (paddy), and increase in area under micro-irrigation. Groundwater recharge has been enhanced through renovation of recharge structures such as percolation ponds, check dams, etc. A notable achievement is that 78 farmers are sharing water with well owners and getting critical irrigation for their irrigated dry crops. The area under *Kharif* paddy has declined by 31 per cent, while *Rabi* paddy is totally stopped; direct irrigation is used only in the case of paddy.

Earlier, the villagers drilled a large number of bores individually in their lands in the hope of having an irrigation source. For instance, a farmer, *K. Subbanna,* drilled 26 bores but only one was successful and is functioning to this day. Most of the bores went dry or were low-yielding. The farmers earlier resorted to growing paddy and other water-intensive commercial crops but subsequently switched over to Irrigable Dry (ID) crops such as sunflower, groundnut, etc. After the intervention, the farmers decided not to drill new borewells and share the water from the successful bores with other farmers. Water is being shared between brothers, among farmers irrespective of caste and between small and big farmers in the village. The villagers constructed 28 recharge structures and helped to augment the yields of the successful bores. The number of farmers sharing bores increased from eight in 2004 to 78 in 2010-11. The recharge structures constructed during the past 2-3 years reportedly revived/rejuvenated some of the defunct borewells and are presently irrigating about one to three acres per well. Earlier, farmers used the flood irrigation method, but now they are adopting micro-irrigation methods such as drip and sprinkler irrigation for the ID crops.

Table 6.3: Impact of SRWM Project in Madirepalli Village

Details	Before (2003-04)	After (2010-11)	Change/ Impact
Area under cultivation (acres)	767.5	767.5	---
No. of functional open wells	2 (59)	4 (59)	Increased
No. of functional borewells	53 (75)	69 (79)	Increased
Area irrigated	Kharif: 213 Rabi: 127	Kharif: 280 Rabi: 328	Increased by 31% in Kharif and 158% in Rabi
Number of observation borewells	0	10	Increased
Number of sharing groups formed	01	69	Increased
Number of farmers sharing water	08	78	Increased
Area under paddy (acres)	Kharif: 74 Rabi: 73	Kharif: 51 Rabi: 0	Kharif: -31% Rabi: -100%
Area under direct irrigation (acres)	314	51	-84
Area under micro-irrigation (acres)	26	557	Increased
Construction of recharge structures	0	28 (percolation tanks, check dams and recharge pits)	Increased recharge of wells
Cropping pattern	Paddy for regular consumption through very low-yielding BWs	Switched over to ID crops like groundnut, green chilli, sunflower, etc.,	Better financial returns; conserved resource.

Note : Figures in brackets are the total number of wells.
Source : Rural Integrated Development Society (RIDS) (2011).

Key Achievements of the Project in Madirepalli Village:

- Gradual change in thinking among the community, recognizing groundwater as a scarce and CPR;

- Enhanced resource availability through rejuvenating and taking up new water harvesting activities;
- Created drinking water access to fulfil the entire community's and cattle's needs; however, these impacts are local and do not take the scale impacts (Syme *et al*., 2011);
- All 69 individually-owned irrigation borewells came under the water-sharing system providing water access to 78 new farmers;
- 268 acres of rain-fed lands brought under protected irrigation by sharing water from borewells using micro-irrigation systems; this corresponds to 44 per cent of the total well irrigated area in the village during 2010-11;
- Relative extraction of groundwater reduced from 125 to 80 per cent of the annual available groundwater from the year 2004-2005 to 2010-2011; and
- Farmers changed from water-intensive crops to water-saving crops.

Though there was a deeper crisis in agriculture in Madirepalli Village due to higher groundwater dependency, the existence of traditional regulatory practices in Gonchi seepage channels and motivated village leadership contributed to better results of the project in Madirepalli compared to the other project villages. While Madirepalli was successful in expanding the water-sharing system to many borewells, there was a significant change in cropping pattern (from water-intensive crops to water-saving crops) in Mylaram Village. The project was also successful in building a community level institution, called Water Resources Committee, in CR Pally, which took up the agenda of groundwater management and regulation. From 2009, electricity efficiency measures such as formation of Distribution Transformer (DT) level farmers groups; installing capacitors on all pump-sets; and regularizing unauthorized electric connections to agricultural pump-sets helped to reduce low voltages at pump-sets, and contributed to reduction in motor burnouts in project villages.

IV. Andhra Pradesh Drought Adaption Initiative (APDAI) Project

The APDAI pilot project is being implemented in two phases due to different modes of financing. Phase I of the pilot program (April 2006 - June 2007), financed by a World Bank-executed trust fund, initiated activities in six villages in three Mandals of Mahbubnagar District. Phase II of the pilot implementation was started in November 2007 and the project was expanded into an additional nine villages in Mahbubnagar District and initiated activities in 10 new villages in Anantapur District. In addition, there is an option to pursue pilot initiatives outside the 10 selected villages in Anantapur. The implementation of the APDAI Phase II is being supported by the Japan Policy and

Human Resources Development (JPHRD), the Climate Change Initiative Grant (CCIG), and the World Bank. The pilot activities are implemented by the Society for Elimination of Rural Poverty (SERP) in collaboration with District Collectors in the pilot districts, and under the oversight of the Principal Secretary, Department of Rural Development (DoRD) through the Office of the Commissioner, Rural Development (CRD).

The drought adaptation pilot is rooted in the strength of the CBOs and is implemented by the federation of women SHGs (*Mandal Mahila Samakhyas* - MMSs) in convergence with various Government departments. The pilot initiative relies on pooling existing experience and expertise of NGOs, research institutes, and CBOs into a consortium of supporting agencies led by WASSAN to facilitate the action research on the ground. As part of APDAI initiatives, a new approach was introduced to secure rain-fed crops through sharing groundwater for critical irrigation, and involving communities for management by developing social regulations. WASSAN is the lead technical agency for this pilot.

The APDAI approach of community groundwater management aimed at two shifts:

1. From individual farmer approach to area-based approach for irrigation; and

2. From groundwater as private property to groundwater as common property.

It aimed at building a case for enabling policy support and investments on critical/ protective irrigation and water sharing, focusing on rain-fed farmers. The envisaged model included an approach to facilitate a common understanding between owners and non-owners of borewells, to share the groundwater. It also provided for incentivising for sharing and initiating social regulation for controlling the competitive digging of borewells. Further, farmers were supported with pipeline networks for transportation of water to rain-fed farms and linkage with micro-irrigation systems that contribute to maximize the groundwater use efficiency. The pilot was taken up during 2006-07, initially in Chellapur Village of Mahbubnagar District. Later it was extended to eight villages in Mahbubnagar, Anantapur and Ranga Reddy districts. The main objectives of the initiative include:

- Stopping the competitive digging of borewells ;
- Providing access to the groundwater for rain-fed crops for protective/critical irrigation, which improves their productivity;
- Reducing water loss by adopting effective irrigation systems and methods;
- Reducing the cultivation of water-intensive crops (paddy) under borewells and motivating the farmers for alternative crops to improve water productivity;

- Enabling village level institutions for Community Managed Groundwater Regulations, including monitoring of groundwater level and borewell yields;
- Improving the groundwater recharge, in the long run through convergence; and
- Ensuring food and fodder security for household needs.

Implementation Process

The process is initiated with participatory analysis of agriculture under rain-fed conditions and the need for protective irrigation in order to make crop production viable. These exercises are usually carried out with the entire village and also with farmers in small groups. Area-based approach involves organising farmers under Common Interest Groups (CIGs) for a rain-fed patch. In each patch, well owners are convinced to share their water with the surrounding farmers. Once consensus is reached on water regulations and sharing the cost of pipeline installation, an agreement on groundwater regulation is signed by all the farmers in the patch in the presence of a *Tahsildar* on a bond paper for Rs.100.

As per the agreement, all the borewells will be pooled through a common pipeline network and water will be shared among all, irrespective of ownership. No new borewells will be dug for at least the next 10 years. The cropping pattern will be decided on the basis of crop plans linked to the availability of water in agreement with members of the CIG while giving priority to food and fodder crops and a reduction in the area under paddy. One borewell a day will be rested on rotation, thus reducing water pumping by about 20 per cent. While water is shared to protect the *Kharif* crop of non-owners, the acreage of borewell-owning farmers is ensured; and a general fund is created for the maintenance of pipeline, repairs, etc., within the CIG.

The water from the borewells of the farmers willing to share is interconnected to one main pipeline, which is distributed to the identified rain-fed patch of land. This involves:

- Preparation of a pipeline network plan:
  - o Identification of borewell points;
  - o Levelling survey using hydrometer for main pipeline, sub-lines and outlets;
  - o Plot-wise area measurement and location of pipeline on the field; and
  - o Preparation of a detailed map showing the individual plot and total patch area boundaries and the pipeline network.
- Preparation of pipeline design and detailed estimation of the pipeline network.

- Work Execution:
  - o Calling quotations from reputed PVC companies;
  - o Placing a work order to the short-listed company; and
  - o Execution of work by CIGs and *Grama Samakhyas*, with the support of WASSAN.
- Evolving crop planning and regulation mechanisms:
  - o Restriction of water-intensive crop area for each farmer owning borewells ;
  - o Forming outlet-wise groups for water use;
  - o Appointment of one or two persons for water distribution;
  - o Formation of water regulation committee at village level;
  - o Outlet-wise scheduling of water distribution at the time of critical irrigation; and
  - o Developing a common fund for pipeline maintenance by collecting water charges from the water users of the pipeline network.

As there was no threat of new borewells in the vicinity that may lead to the drying of their own borewell, the farmers agree to pool their borewells and share the water. This would avoid competitive borewell digging, unnecessary investments, and loss of capital. The borewell owner is assured of earlier cropped area but with less water-requiring crops. The water thus saved will provide critical irrigation to a rain-fed patch, which includes lands of both borewell owners as well as others. If any one of the borewells fails, there is a back up arrangement as they are pooled. There was also motivation in terms of getting access to micro-irrigation system (sprinklers and drips) at subsidy, through linkage with the Andhra Pradesh Micro-Irrigation Project (APMIP). This was intended to increase the groundwater use efficiency. The APDAI has also extended up to 90 per cent support for pipeline network required for water sharing.

Impact of the Pilot

- Able to provide protective irrigation for selected rain-fed patches in the pilot villages;
- Ensured timely sowing, especially during delayed monsoons (because of assured water supply);
- Increase in cropped area under the pooled borewells ;
- Incremental returns on crop yield;
- On an average, about 25 to 30 per cent of the pumping hours were saved through resting of wells, resulting in saving both the groundwater and power consumption;

- Micro-irrigation system and pipelines have reduced the labour time for irrigating the crop (seven hours to one hour);
- It also increased water use efficiency; and
- Arresting competitive digging of borewells.

Experience in Gorantlavaripalle:

Gorantlavaripalle in Nallacheruvu Mandal has 113 families and the total cultivated area is 270 acres. There are 26 borewells, 60 families having irrigated lands, and 40 families without any source of irrigation. Normally, paddy is cultivated under borewell irrigation. Farmers with borewells also have dry-lands, which are at a distance of more than one kilometre from the borewells, while farmers without any water source have lands nearer to the borewells.

To facilitate groundwater sharing, all the farmers in the village were organized into five groups, based on the contiguity of the land. Thus, the village area was divided into five blocks. Each block consists of farmers with and without wells. All the groups passed a resolution agreeing to network the 26 borewells through a single pipeline. The farmers in their groups identified those with water and without water and came to an agreement regarding who would share water with whom. A committee was formed with two representatives from each group (one with water source and the other without water source) and a representative from the Village Organisation (VO). Based on the agreement, WASSAN facilitated the MMS to undertake the following surveys:

i. Ground levelling survey - This was completed in October, 2008;
ii. Pumping water level - This was completed in November, 2008;
iii. Static water level survey; and
iv. Discharge measurement.

The last two surveys should be done once in a month. After the above surveys, a plan and a budget estimate were prepared for networking the borewells and distribution pipes. They also framed norms and regulations and signed the agreement, with the *Tahsildar* as a witness, on a Rs.100 stamp paper. The plan and estimates were discussed in a meeting organized by the MMS. It was estimated that the cost of networking and distributing water to dry-land crops would cost about Rs.8 to 12 thousands per acre. Based on the discussions in the MMS, it was proposed that the cost should be shared in the following proportion: 25 per cent as initial farmer's share; 25 per cent as subsidy from the programme; and 50 per cent as loan to the farmer (either from bank or the VO).

However, farmers conveyed their inability to bear these costs due to frequent droughts in the recent years. A meeting was organized in the village in June, 2009 with the farmers, staff of MMS, WASSAN, and the Project Directors of District Water Management Agency (DWMA) and District Rural Development Agency (DRDA). It was agreed that farmers would first pay a membership fee of Rs.1000 per acre and another Rs.1000 per acre after obtaining the crop yields. The canal digging work was initiated in July, 2009, and was completed in December, 2009.

All the farmers under the borewell network prepared a crop plan for *Kharif*, 2010. They agreed to decrease the area under paddy and other water-intensive crops, such as sugarcane, under the borewells. For efficient functioning of the networking system they agreed to appoint one *Neerugatti* (waterman) with the following responsibilities:

1. Encourage every farmer to take up crop cultivation;
2. Inform the farmers about their turns for water sharing;
3. Collect annual fees of Rs.1000 per acre after the yields are obtained;
4. Out of the amounts collected the share of the waterman is 20 per cent and the remaining 80 per cent is allocated for repairs and maintenance - this amount is deposited into the bank account of the committee; and
5. Bring at once to the notice of the committee members regarding leakages and repairs.

V Community Based Groundwater Management: A Comparative Assessment

In this section we assess the impact of the CBGM institutions at the household level. This is based on the quantitative and qualitative data collected from the sample households from the sample villages. Impact assessment is carried out at the two levels, viz. well owners and water-sharing farmers across farm sizes. Impacts are assessed not only between different types of institutions but also with and without institutions, i.e., using the control village. Three indicators, viz. access to irrigation, access to critical irrigation, and moving towards less water-intensive crops are assessed. Besides, awareness and perceptions of the farmers regarding the role and effectiveness of the institutions is also gauged.

Access to irrigation has gone up in all the sample villages, including the control village. It may be noted that the sample households include only those farmers having wells or those sharing water from well owners and hence, the proportion of area irrigated is on the higher side. The increase is the highest in the control village at 213 per cent (Table 6.4). The difference between the control and other sample villages is that the increase in area under irrigation is mainly through sharing of wells in the villages with institutional arrangements while in the control village, irrigation under own wells has gone up substantially. Across the size classes, increased access to irrigation is more among marginal and small farmers in three of the sample villages, including the control village (Table 6.5). On the other hand, the large farmers gained more in the case of Thaticherla Village where APFAMGS is working. It may be noted that water sharing is neither new nor attributed to the groundwater institutions alone, and sharing has been practiced in all the sample villages prior to the advent of these institutions. Even in the control village, well sharing has been practiced, though on a limited scale between relatives, in the recent years. The role of institutions becomes clear in terms of other impacts such as reduction in individual wells, availability of critical irrigation and reduction in the cultivation of water-intensive crops.

Table 6.4: Changes in Percentage Area under Well Irrigation by Well Status

Status	Thaticherla (APFAMGS)			Madirepalli (SRWM)			Gorantlavaripalle (APDAI)			Rajupalem (Control)		
	O	WS	All	O	WS	All	O	WS	All	O	WS	All
Before	56	30	49	49	8	31	77	18	59	32	0*	22
Present	76	83	78	60	63	62	92	64	83	66	77	69
%Change	36	176	59	22	688	100	19	255	41	138	-	213

Source: Field Survey

Note: *Though there was the practice of sharing wells before 2004, there was no area covered as the groups became defunct, consequent to the drying up of wells. Hence, the changes are not entirely due to increased well-sharing activity; instead it is due to the revival of borewells under water sharing.

O-Owned well, ***WS***- water sharing, All- both owned well and water sharing together

Table 6.5: Changes in Percentage Area under Well irrigation by Farm Size

Status	Thaticherla (APFAMGS)			Madirepalli (SRWM)			Gorantlavaripalle (APDAI)			Rajupalem (Control)		
	MF	SF	LMF	MF	SF	LMF	MF	SF	LMF	MF	SF	LMF
Before	50	62	25	25	39	30	8	66	80	17	14	41
Present	79	79	75	70	58	59	69	85	90	73	69	66
%Change	58	27	200	180	49	97	763	29	13	329	393	61

Source: Field Survey

Note: ***MF***- Marginal Farmer, ***SF***- Small Farmer, ***LMF***- Large and Medium Farmers

The number of households sharing water has gone up in all the sample villages (Table 6.6), and the increase is substantially higher among the villages with groundwater institutions than in the control village. On the other hand, the number of wells almost doubled in the control village as against the moderate increase in the institutional villages. The number of functional wells has also gone up in all the sample villages. This could be due to the better rainfall conditions after 2004 when compared to severe drought conditions (three successive droughts) between 2001 and 2004. Most of the dugwells dried up during this period and a few of them revived after 2004. More importantly, investments in new wells is marginal in the sample villages where social regulation is in place (Madirepalli and Gorantlavaripalle), whereas in the case of APFAMGS village (Thaticherla), the number of borewells has gone up by 20 per cent, as there is no regulation.

Table 6.6: Changes in Access to Wells and Access to Water

Village	Total No. of HHs (Population)	Period	Water Sharing HHs	Area under Paddy (acres)	Area under Irrigation (Acres)	Source of Irrigation			
						Dugwells		Borewells	
						No.	Area (acre)	No.	Area (acre)
Thaticherla	265(1155)	B	45	132	168	24 (0)	0	30 (15)	38 (22)
		A	148	55	329	24 (0)	0	36 (31)	159 (48)
Madirepalli	173 (725)	B	8	180	254	59 (2)	4	75 (53)	200 (79)
		A	78	50	491	59 (4)	16	79 (69)	390 (79)
Gorantlavaripalle	113 (487)	B	10	128	140	34 (0)	0	82 (40)	90 (64)
		A	42	80	188	34 (0)	0	84 (46)	138 (73)
Rajupalem	374 (1414)	B	25	150	199	9 (6)	14	40 (35)	95 (48)
		A	44	150	249	9 (4)	8	79 (62)	150 (60)

Source : Field Survey (PRA/FGD Methods) and village Records

Note : Figures in brackets are functional wells and percentage of area in the case of area.
B-Before, ***A***-After

Improved groundwater conditions in the sample villages under groundwater institutions are also evident from the availability of irrigation during critical periods. The number of farmers reporting availability of groundwater during critical periods has gone up in all the institutional villages, while the number has gone down in the control village (Table 6.7). However, this is limited to well owners in two of the villages. In the case of Gorantlavaripalle (APDAI), even the well-sharing farmers have reported that they have received critical irrigation. The marginal and small farmers are the main beneficiaries in terms of receiving critical irrigation in the institutional villages (Table 6.8), whereas in the control village, the proportion of marginal and small farmers receiving critical irrigation has come down. This indicates that groundwater institutions have improved the source sustainability and helped in protecting the crops to a large extent. This would have been possible due to the reduction in the area under water-intensive crops (paddy) in two of the institutional villages (Table 6.9). However, the APFAMGS village, along with the control village, reported an increased area under paddy. The reduction in area under paddy in the institutional villages is more among large farmers, while the increase in area under paddy is more among marginal and small farmers (Table 6.10). This is mostly compensated by groundnut crop. In all the sample villages, no crop area has declined substantially. The decline is more in the villages with social regulation. This reflects the improved access to critical irrigation. In the absence of any social regulation, the farmers do not seem to follow conservation methods, though they tend to reduce their risk of investing in new borewells as they are familiar with the groundwater situation due to the interventions of the APFAMGS.

Table 6.7: Availability of Irrigation during Critical Periods of Crop Growth by Well Status (Percentage of Farmers)

Availability/ Status	Thaticherla (APFAMGS)			Madirepalli (SRWM)			Gorantlavaripalle (APDAI)			Rajupalem (Control)		
	O	WS	All	O	WS	All	O	WS	All	O	WS	All
Before	23	0	14	0	0	0	60	28	51	34	0	23
Present	36	0	22	10	0	50	77	67	74	20	0	13
% Change	**60**	-	**60**	-	-	-	**29**	**140**	**46**	**-43**	-	**-43**

Source : Field Survey.

Note : O-Owned well, WS- water sharing, All- both owned well and water sharing together

Table 6.8: Availability of Irrigation during Critical Periods of Crop Growth by Farm Size (Percentage of Farmers)

Availability/ Status	Thaticherla (APFAMGS)			Madirepalli (SRWM)			Gorantlavaripalle (APDAI)			Rajupalem (Control)		
	MF	SF	LMF	MF	SF	LMF	MF	SF	LMF	MF	SF	LMF
Before	18	10	0	0	0	0	0	56	67	27	32	0
Present	27	20	0	17	75	50	50	79	67	5	16	21
% Change	**50**	**100**	**0**	-	-	-	-	**41**	**0**	**-83**	**-50**	-

Source : Field Survey

Note : MF- Marginal Farmer, SF- Small Farmer, LMF- Large and Medium Farmers

The perceptions of the farmers in the institutional villages indicate high awareness about the institutions (Table 6.11). While the membership is limited to well owners in the case of APFAMGS villages, even the well-sharing farmers are members in the other two villages. As a result, institutional membership is quite low in the APFAMGS village.

However, in all the villages, most of the sample farmers participate in the field or farmer schools (Table 6.11) participation rates range between 73 and 100 per cent among sample villages. On the other hand, participation in crop water budgeting is as low as 40 per cent in the APDAI village (Gorantlavaripalle). It was observed that all the farmers who participated in crop water budgeting exercise followed the recommendations in the social regulation villages while fewer farmers followed the recommendations in the APFAMGS village.

Table 6.9: Shifting Away from Paddy Crop by Well Status (% area)

Crops/ Status	Thaticherla (APFAMGS)			Madirepalli (SRWM)			Gorantlavaripalle (APDAI)			Rajupalem (Control)		
	O	WS	All	O	WS	All	O	WS	All	O	WS	All
Before												
No Crop	11	9	10	13	61	34	13	29	18	13	32	19
Paddy	11	4	9	63	4	38	23	4	17	14	0	10
Groundnut	7	4	6	24	35	29	29	46	34	11	0	8
After												
No Crop	9	9	9	5	2	4	3	0	2	14	12	13
Paddy	16	22	18	17	4	12	21	4	16	19	6	15
Groundnut	7	0	5	65	94	78	37	71	48	4	3	4
% Change												
No Crop	-17	0	-12	-63	-97	-89	-75	-100	-88	10	-64	-29
Paddy	50	400	100	-73	0	-69	-7	0	-7	36	0	55
Groundnut	0	-100	-20	173	171	172	28	54	39	-67	0	-56

Source : Field Survey
Note : O-Owned well, WS- water sharing, All- both owned well and water sharing together

Hence, the number of farmers growing paddy has increased in some cases, while in others, a decline was noticed. It is observed that a large number of farmers have started growing groundnut in Madirepalli.

The main benefits perceived due to the institutions are awareness about groundwater, followed by crop methods, and groundwater irrigation methods (Table 6.11). Among the reasons for non-participation is the absence of tangible benefits followed by non-feasibility. While 70 per cent of the non-participating farmers felt that there are no tangible benefits in the APFAMGS and APDAI villages, only 35 per cent of the farmers perceived this reason in the case of SRWM village (Madirepalli). This perception is

Table 6.10: Shifting away from Paddy Crop by Farm Size (% area)

Crops/ Status	Thaticherla (APFAMGS)			Madirepalli (SRWM)			Gorantlavaripalle (APDAI)			Rajupalem (Control)		
	MF	SF	LMF	MF	SF	LMF	MF	SF	LMF	MF	SF	LMF
Before												
No Crop	13	4	13	50	19	36	38	15	10	30	18	9
Paddy	8	13	6	15	55	36	0	16	40	3	12	13
Groundnut	13	0	0	35	26	28	62	31	20	3	6	16
After												
No Crop	11	13	0	5	10	0	0	3	0	13	14	13
Paddy	24	17	6	10	16	10	0	16	30	10	14	22
Groundnut	8	0	6	75	68	84	92	40	40	3	4	3
% Change												
No Crop	-20	200	-100	-90	-50	-100	-100	-80	-100	-56	-22	33
Paddy	200	33	0	-33	-71	-73	0	0	-25	200	17	75
Groundnut	-40	0	0	114	162	200	50	29	100	0	-33	-80

Source : Field Survey

Note : MF- Marginal Farmer, SF- Small Farmer, LMF- Large and Medium Farmers

greater among the well-sharing farmers when compared to the well owners. Similarly, 81 per cent of the sample farmers in the APFAMGS village have endorsed the benefits from groundwater institutions, while 100 per cent agreed about the benefits in the other two villages. Lack of benefits is attributed to the reason that farmers do not follow the suggestions of the management committee, as the institutions play only an advisory role. However, the sample farmers in APFAMGS and APDAI villages perceive that the advisories are being followed or adopted.

Overall, the performance in terms of physical indicators and farmers' perceptions appears to be better in case of Madirepalli Village (SRWM) where social regulation is in place; while the performance of APFAMGS where there is no regulation seems to be poor. The APFAMGS initiative is the oldest among the three models. In fact, during the field work, the APFAMGS interventions were terminated, as the NGOs were waiting for the extension of the project. Hence, the poor performance of APFAMGS raises the issue of institutional sustainability (Reddy *et al.*, 2011), and this is applicable even for the other two initiatives. The difference between the other two initiatives is that the APDAI initiative is backed by the DoRD, while the SRWM is NGO-driven. The better performance of SRWM could be due to the intensive approach it has adopted in promoting water

Table 6.11: Farmers' Perceptions on Community Based Groundwater Management

Awareness on Groundwater Management Practices	Details of Perceptions	Thaticherla (APFAMGS)			Madirepalli (SRWM)			Gorantlavaripalle (APDAI)		
		O	WS	All	O	WS	All	O	WS	All
APFAMGS/ SRWM/APDAI	Awareness	100	100	100	100	100	100	100	100	100
Membership	Yes	35	0	19	93	94	94	76	92	83
Participated in FFS	Yes	100	79	90	100	100	100	82	62	73
Benefits derived	Awareness on crops	100	71	87	100	100	100	82	77	80
	Groundwater methods	71	71	71	100	100	100	82	69	77
	Groundwater awareness	100	100	100	100	100	100	94	77	87
	All of the above	90	81	86	100	100	100	86	74	81
Reasons for not participating	No tangible benefit	59	86	71	33	38	35	59	85	70
	Not feasible	41	36	39	7	6	6	41	62	50
	Personal reasons	6	7	6	0	0	0	12	15	0
Participated in crop-water budgeting	Yes	100	43	74	100	100	100	65	8	40
Followed recommendations	Yes	82	29	58	100	100	100	65	8	40
Benefits from groundwater management	Yes	100	57	81	100	100	100	100	100	100
	Conduct of FSS/ FWS/CWB	100	100	100	100	100	100	100	100	100
	Management of groundwater	88	86	87	100	100	100	82	85	83
	All of the above	96	95	96	100	100	100	94	95	94
Reasons for lack of benefits	Institutions play only advisory role	18	29	23	100	94	97	18	77	43
	Farmers not followed GMC's suggestions	82	71	77	0	6	3	82	23	57

Source: Field Survey
Note: O-Owned well, WS- water sharing, All- both owned well and water sharing together

sharing - it has taken almost three years to organise the farmers and build awareness before initiating the well-sharing process. Besides, the SRWM worked with small groups of well-owning and well-sharing farmers, whereas the groups were bigger in the area-based approach followed by the APDAI.

CHAPTER VII

LESSONS FOR UP-SCALING

AP, arguably, has more experience in promoting community-based water management than any other Indian state. Even in the case of groundwater management, AP is the first state in the country to introduce community-based management way back in the 1990s. Unlike in the case of surface water, canals or tanks, there is no evidence of in *situ* institutional innovations in the case of groundwater. This is mainly due to the existing private (*de facto*) property rights on groundwater. Though these initiatives under study are still at a pilot stage, they can provide valuable insights for designing appropriate policies. However, the potential for up-scaling is linked to the specific hydro-geological and socio-economic settings and hence needs region-specific or flexible approach. Here we assess the strengths and weaknesses of the three institutional approaches and explore the possibilities for scaling up or policy lessons for bringing groundwater under community management.

The three models considered here have the common goal and objective of sustainable groundwater management. All the three institutions are led by NGOs with support from different agencies including the State Government. However, the approaches followed and the implementation modalities are different and can be grouped as: i) knowledge intensive; and ii) social regulation. These approaches have their advantages as well as disadvantages in terms of achieving their objectives and the sustainability of the initiatives (Table 7.1).

i) Knowledge-based Approach

The APFAMGS initiative is based on the principle of demystifying science through enhancing the capacities of the communities in terms of their skills and scientific knowledge. The focus is on facilitating or making communities assess the groundwater potential at the village level and estimating the available water before each crop season. These estimates are integrated at the hydrological unit level, providing the much needed scientific scale for assessing the groundwater. At the same time, the scale at which observation wells are monitored (village level) is more appropriate to the communities. For, official groundwater assessment is made based on the observation wells located at the Mandal (more than 30 villages) level and does not reflect the situation at the village level. Crop water budgets are prepared by the communities at the village level and the suggested cropping pattern for the season is provided (based on the groundwater availability) to the community. These details are shared across the villages within the hydrological unit.

Table 7.1: Features of the Three Institutional Models

Features	APFAMGS	SRWM	APDAI
Initiative (Funding)	External (FAO)	External (AEI, Luxembourg)	State Government (DoRD)
Implementation	NGOs (BIRDS)	NGOs (CWS+Partners)	Govt.+NGO WASSAN+Partners) *Mahila Samkhyas*
Years of existence	8	7	2
Groundwater situation	Scarce	Scarce	Scarce
Project scale	Big (650 villages)	Small (19 villages)	Small (8 villages)
Key features	Information	Informal regulation	Formal regulation
Scale of operation	Hydrological unit	Vicinity of wells (within a village)	Area based on the wells (within a village)
Institutional approach	Influencing community through generation of intensive scientific information	Regulating community through awareness and incentives	Regulating community through semi-scientific information-based awareness and incentives
Operational modalities	All well owners with focus on information. Followed an extensive approach	Small groups of well owners and dry land farmers. Followed an intensive approach	Larger group of well owners and dry land farmers covering specific location. Focus on incentives
Farmers' contribution	Nil	20 per cent towards micro-irrigation	75 per cent
Awareness on ground water situation	High	High	High
Participation in management	Limited to well owners	High	High
Practicing recommendations	Moderate	High	Low
Key to success	Professional approach	Leadership and incentives	Incentives
Impacts on access to water	Moderate	High	Moderate
Nature of key impact	Reduction in over exploitation of groundwater	Conservation of water and sharing of water	Conservation and sharing of water
Impact on equity	No	Yes	Yes
Scalability	Good	Poor	Moderate
Sustainability	?	?	?

Source: Field Survey (PRA/FGD Methods) and Reports

The "do-it-yourself" approach with relatively better scientific or technical inputs has clearly improved the awareness of the well owners. The initiative is highly successful in demystifying science and needs to be considered at the policy level to promote institutional linkages for generating such information at the village level. While such an awareness has helped in checking further expansion of groundwater development, i.e., new wells, it has failed to encourage other conservation practices such as increased investments in recharge structures or equity by sharing the water with un-irrigated farmers. Though our sample village does not provide any evidence on the reduction in water-intensive crops (paddy), it has been achieved in other places (Reddy, 2012). The limited impact is mainly due to the reason that neither social regulations are imposed, nor economic incentives are provided, for adopting such measures. In fact, the farmers feel that the APFAMGS merely plays an advisory role without any incentives or disincentives to follow the advisories. The result is a lot of useful information generated at the appropriate scale, helping only the well-owning farmers while the farmers hitherto not having wells are dissuaded from digging new wells (through information-based awareness)-there is no incentive for them to support the initiative; in fact, they are not even members of the committee.

Our qualitative research indicated that farmers are very much interested in having institutional arrangements in the lines of APFAMGS for managing groundwater. However, sustainability of the APFAMGS initiative is a big question mark in the absence of linkages with formal institutions, and policy or legislative backing of the movement[††]. Moreover, the exit protocol is not clearly defined. In a number of villages, the activities of the APFAMGS came to a standstill during the two years' gap (2009-11), due to the delay in the extension of the project. One suggestion made by the farmers in this regard is to bring the initiative under the groundwater department's purview so that the process would go on in the long run (Reddy *et al.*, 2011).

ii) Social Regulation Approach

The other two models, viz. the SRWM and APDAI, have adopted social regulation to manage groundwater. Though awareness building and data generation by the village communities are important components, the process is not so systematic. The most important aspect of these two models is to bring consensus among the communities to share water between well owners and others. Incentives such as reduced risk of well failure as no new wells are allowed, subsidies for micro-irrigation, provision for protective irrigation to the dry plots of the well owners, and the irrigation backup they get in the event of well failure, are put in place. Besides, there is provision for water harvesting

[††] Though HUNs are registered bodies and can take up activities like input procurement, output marketing etc., they are yet to be functional in these activities.

structures to increase recharge, and distribution losses are reduced through pipeline supply of water and increased water use efficiency through promotion of micro-irrigation (subsidies).

Social regulation appears to be effective in terms of stopping new borewells as well as a larger number of households, especially the marginal and small, benefiting from sharing water with well owners. This not only helped in increasing the cropped area, but also provided protective irrigation to a number of plots during critical periods, thus saving the crops. This also resulted in equity in the distribution of water and overall improvement in welfare. However, there are differences between the two models of social regulation in terms of their effectiveness: the SRWM appears to be more effective when compared to APDAI. One reason could be that the SRWM is older, followed an intensive approach, and worked with smaller groups of farmers compared to the APDAI initiative. Though APDAI mostly follows the SRWM approach, it has adopted a broader (area-based) and formal approach involving the department. Besides, groundwater management is one of the pilots under the APDAI and hence, there are chances of dilution as far as the departmental involvement is concerned.

Despite the formal approach, participation and rule following is limited in the APDAI. People indicated that there are no tangible benefits from the initiative, and 50 per cent of the farmers felt that the institutional arrangements are not feasible. This view is more conspicuous among those sharing wells. This sceptical nature could be due to the larger contribution (75 per cent) from the farmers, which is substantial (total costs are Rs.8 to 10 thousand per acre). On the other hand, the approach of peoples' contribution could provide the much needed ownership and sustainability*. It is observed that the formal process of entering an agreement with the witness of the Tahsildar has also discouraged some villages from joining the initiative.

The formal approach of APDAI appears good on paper, as it follows an integrated approach of drought adaptation. The integration also involves various departments such as rural development, groundwater, agriculture, etc., but the feasibility of such integration is doubtful. The approach involves the existing institutions such as the Mahila Samakhyas, which provide the assurance of sustenance in the medium run at least. However, at the same time, there is also a danger of acquiring the stamp of a Government programme where people look for freebies rather than regulation and contribution.

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* Of late people contribution in Government Programmes has lost its importance, as people are increasingly considering Government Programmes as welfare measures rather than developmental. Hence, their contribution is treated as negative rather than as ownership.

On the whole, the social regulation approach seems to work better for sustainable groundwater management when compared to the knowledge intensive approach. Water use and sharing through regulation has increased the area under protective irrigation in an equitable manner.

The knowledge intensive approach is not designed to address equity. In the absence of any regulations, formal or informal, the farmers do not have any incentive to follow the good practices in the given policy environment. Encouraging sharing of water between well owners and others would result in achieving the twin objectives of conservation and improved access with equity. How to attain this on scale needs serious consideration at the policy level.

Sustainability of these initiatives is a major concern in all the approaches. None of the approaches have a well-defined exit protocol, while the APDAI appears to be well placed in this regard as its process involves a number of departments and formal institutions. At the same time, it requires strong leadership at the village level to implement and take the initiative forward, especially in the context of peoples' contribution. In the case of SRWM, its present success is mainly due to the commitment of NGO partners in the absence of any contribution from the farmers. Besides, in the absence of contribution, the financial sustainability of the initiatives would be a big concern, especially once the external funding stops. The weak sustainability of APFAMGS initiative was already evident during the no fund phase. Hence, fund flows appear to be critical for the success of the initiatives. The initiatives may continue in some of the villages due to strong leadership and commitment of the local NGOs even beyond the present funding, as they are at a smaller scale. Thus, scaling up these initiatives requires much more planning and designing.

Limitations of these Models

All these models suffer from limited scientific knowledge application at the ground level. The APFAMGS, which focuses on "demystifying" science, does not follow a rigorous scientific approach towards groundwater recharge and balance estimation, water budgeting based on crop water requirement, etc. Similarly, the well-sharing and social regulation models do not integrate technical inputs for estimating the groundwater availability. Moreover, they do not consider scale impacts at a watershed or basin scale, as the positive impacts observed in the study locations may be causing negative impacts downstream. Unless the impacts are considered at a scale of a hydrological unit, it is difficult to assess the real impacts.

Due to the short duration of these interventions, we are not able to provide hard core evidence to support some of the impacts that are measured in terms of farmers' perceptions. In the absence of long term data, the issue of attribution is also a problem. The changes in groundwater balance could be due to rainfall and other climatic fluctuations. Therefore, it is necessary to keep these limitations in view while considering scaling up of these initiatives.

Policy Directions for Scaling Up

The assessment of the three models indicates that CBGM is neither simple nor easily forthcoming. It calls for a lot of effort, working through complex rural dynamics at various levels. The reason is that appropriate policies to support or encourage such initiatives are not in place. Often, the existing policies work towards achieving opposite objectives rather than going in tandem with the participatory initiatives. The three approaches have proved that communities are capable of managing groundwater in a sustainable manner. The communities are also capable of understanding and using the technical aspects of hydro-geology. However, since groundwater is widely considered as a private property, there are no incentives for managing it at the community level. Furthermore, there are no economic incentives or disincentives for managing groundwater in a sustainable manner. Hence, unless wide-ranging policy changes are brought in, these initiatives remain as models rather than being adapted at a wider scale. Creating demand for these initiatives is as important as demand management of groundwater, and the demand management models cannot be effective as long as policy environment is supply-sided.

Some of the important policy interventions for promoting CBGM on a wider scale include:

- ▲ Need for dispelling the notion of groundwater as private property and making it a common property in the real sense. This calls for wide-ranging legislations and legal support.
- ▲ Establishing or moving towards community-based property rights on groundwater with proper distribution of rights to potential users.
- ▲ Moving towards aquifer planning at the hydrological unit level to start with and then to watershed or river basin scale.
- ▲ Creating hydrological information at a much smaller scale appropriate for short-term farming decisions. This could be attained through creating low cost infrastructure at the village level and providing training at the local level to take up the responsibilities on a regular basis with the necessary economic incentives.
- ▲ Water sharing at the village level needs to be promoted as a first step in this direction. Existing wells could be linked and termed as common property.

- Incentives to conserve and manage water resources rather than exploit the resources such as free power and support prices for water-intensive crops like paddy.
- The present policy distortions of free power, and the input and output pricing policies need to be rationalised to match conservation objectives.
- Regulation through pricing is the most effective instrument, but is hardly adopted at the policy level. In the absence of realistic pricing, water use efficiency remains a dream.
- As long as water rights are linked to land, water sharing is the best option to achieve equity. Encouraging and strengthening the existing traditional group wells in AP through differential and higher incentives in electricity tariffs, subsidies for micro-irrigation kits, etc., would help improve the equity and sustainability of groundwater.
- Andhra Pradesh Water Land and Trees Act (APWALTA) bans drilling new wells in villages notified as over-exploited. The Government may encourage only new wells on group sharing basis in villages/micro-basins that are identified as critical and semi-critical with respect to groundwater development. Strengthening and enforcing the existing regulations like APWALTA could be a starting point in this direction.
- Delinking land and water rights need to be treated as an important policy goal, at least in the long run.

Thus, the experience of the three models reveals that wide ranging policy changes are required to scale up the achievements of these small scale initiatives. Replication of these models could be possible with high transaction costs, but the sustainability of these initiatives remains uncertain in the present policy environment.

The most important lessons from these models include:

i) creation of information at the appropriate scale through community involvement; and

ii) generating demand for demand management of groundwater with the help of this information.

However, the conclusions drawn here are based on the experience of a few villages and hence cannot be generalised. While these findings provide some insights, there is a need for better understanding of such initiatives through a large scale systematic research covering the existing initiatives across the country.

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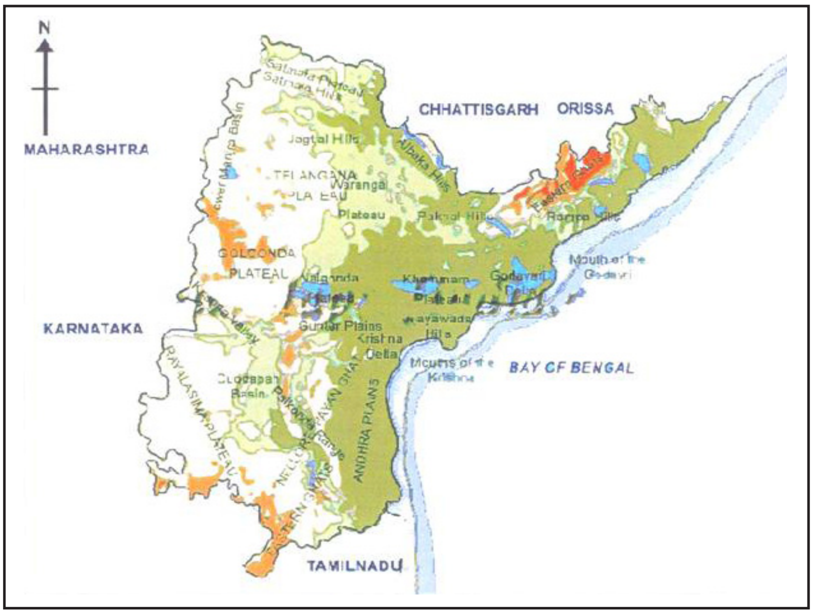
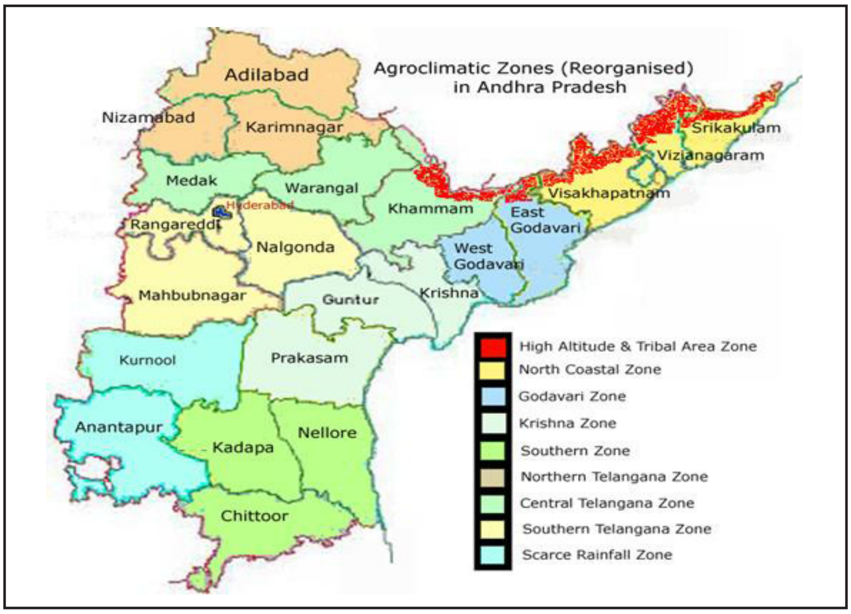
Annexure

Map1: Physiographical Map of Andhra Pradesh



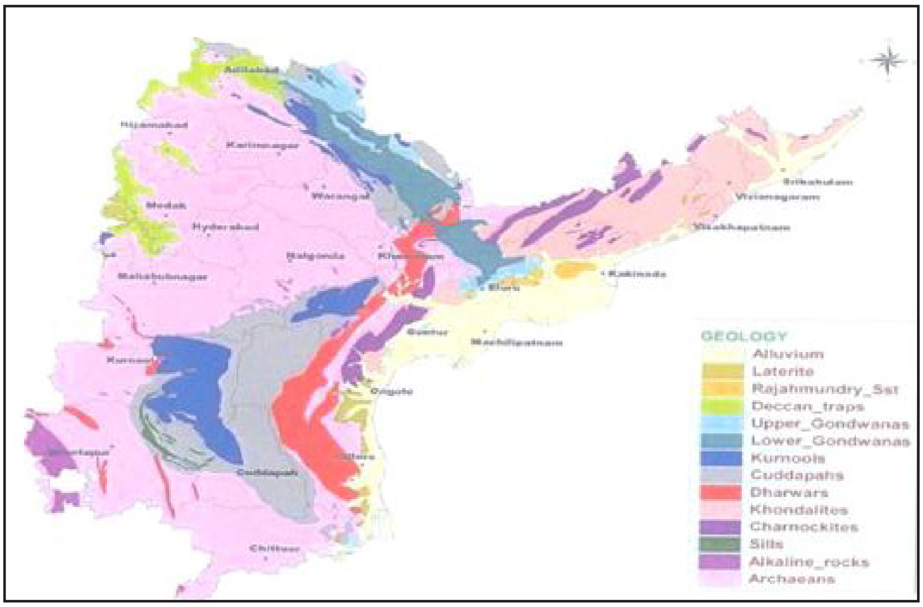
Source: GoAP, Department of Ground Water, Hyderabad.

Map 2: Agro-Climatic Zones of Andhra Pradesh



Source: Acharya N G Ranga Agricultural University (2008), Annual Report 2007-08, Hyderabad.

Map3: Geological Map of Andhra Pradesh



Source: GoAP (2008), Groundwater Resource Andhra Pradesh 2007, Vol-I, Department of Ground Water, Hyderabad, August.

Map 4: Major Aquifer Systems of India

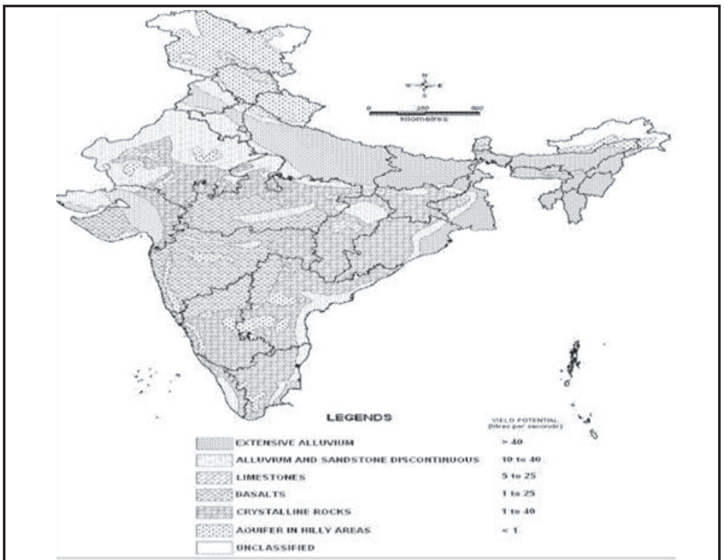
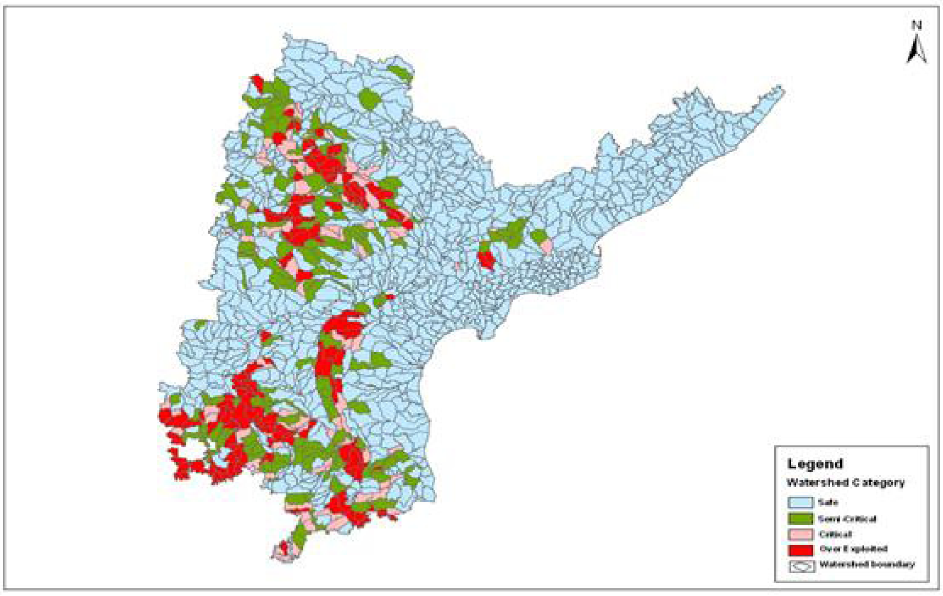


Figure 1. Major aquifer systems of India[10].

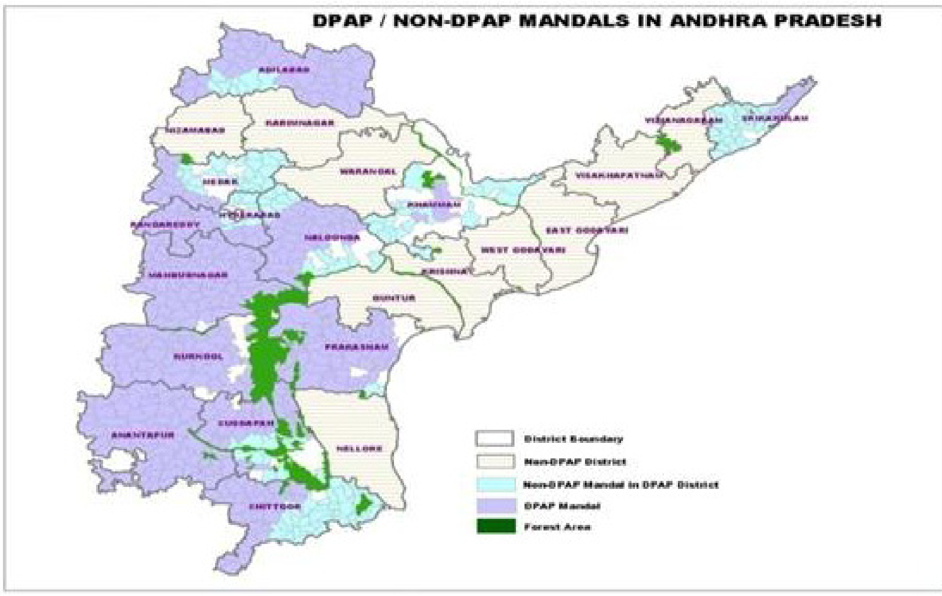
Source: GoI, CGWB, Ministry of Water Resources of India, New Delhi

Map 5: Status of Groundwater Development in Andhra Pradesh (2007)



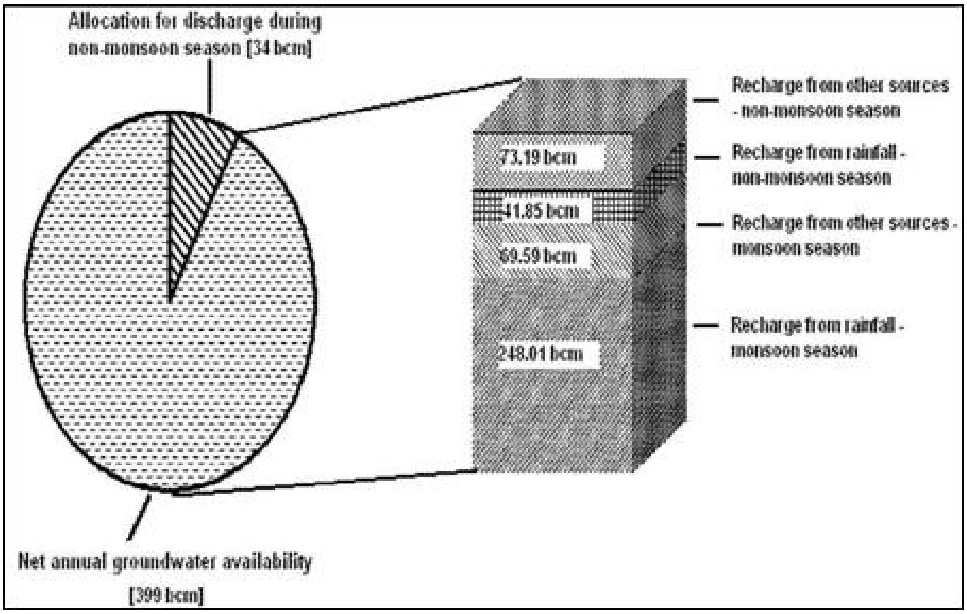
Source: GoAP (2008), Groundwater Resource Andhra Pradesh 2007, Vol-I, Department of Ground Water, Hyderabad, August.

Map 6: DPAP and Non-DPAP Districts of Andhra Pradesh



Source: GoAP, Commissioner of Rural Department (Watersheds), Hyderabad.

Figure 1: Annual Replenishable Groundwater Resources



Source: GoI, CGWB, Ministry of Water Resources of India, New Delhi

Table 1: Descriptive Statistics of Selected Variables

(N=22)

Variables	1985		1993		2002		2004		2007	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A ARF (in mm)	731.14	194.02	814.36	150.17	919.05	158.79	744.95	180.67	861.12	270.23
I I	126.61	19.18	127.62	18.99	128.97	19.81	127.91	19.50	133.22	20.52
CI	118.02	14.73	125.31	19.68	124.77	19.89	124.37	19.28	129.01	21.95
HDI	--	--	0.39	0.07	0.62	0.10	0.52	0.07	0.52	0.07
% Persons BPL	55.09	15.10	40.82	11.93	34.19	12.93	31.33	13.72	28.60	14.73
PCI (in Rs.)	--	--	7319.00	1264.49	9934.50	1697.68	19167	4314.19	22845.27	4787.88
Literacy Levels	27.69	6.37	41.64	7.25	58.69	7.00	58.69	7	58.69	7
Sugarcane (in ha)	7626.77	9644.85	13402.0	16473.2	16374.9	21927.4	16066.2	19977.9	19924.82	22955.04
Groundnut (in ha)	15019.27	12716.8	19475.7	15804.1	13631.0	13592.5	11634.9	12046.3	11276.77	12230.58
No. of Dugwells	2117.91	1933.52	937.36	896.06	513.05	696.95	546.77	1130.51	161.09	353.18
No. of Tubewells	614.09	556.87	1302.77	1210.13	1291.23	1147.41	2114.59	2354.85	594.50	651.87
No. of Agrl. Service Connections	2011	1869.67	4644.36	2718.03	5374	3475.52	2943.64	2110.43	3953.50	2239.61
No. of WSD	--	--	--	--	303.50	229.04	435.36	358.39	503.77	403.62
No. of Tanks	3590.50	2770.95	3632.50	2810.64	3747.41	2786.43	3747.41	2786.43	2717.68	2341.15
NIA Canals (in ha)	81540.41	92234.2	75409.8	84299.5	74972.1	81089.5	61180.8	76910.4	73761.55	80993.86

Table 2: Factors Influencing Groundwater Development in Command and Non-Command Areas (1985)

Variable	Command		Non-Command		Overall	
	Coefficient	VIF	Coefficient	VIF	Coefficient	VIF
Constant	-33.18 (-2.96)*		--50.741 (-2.033)**		-55.357(-2.587)*	
I I	0.096 (1.84)**	1.105	--	--	--	--
No. of Tubewells	0.002 (1.27)	1.120	--	--	--	--
% of BPL Population	0.161 (2.14)*	1.548	--	--	0.399 (2.257)*	1.572
Literacy Levels	0.564 (2.868)*	1.986	2.177 (3.021)*	1.606	1.379 (3.000)*	1.995
No. of Agrl. Service Connections	0.002 (2.412)*	1.491	0.015 (5.361)*	1.683	0.009 (5.664)*	1.490
No. of Tanks	--	--	0.004 (2.184)*	1.373	0.001 (1.094)	1.456
Groundnut	--	--	-0.001 (-1.762)**	1.233	--	--
R^2 (R Bar)	0.57(0.41) N=22		0.73 (0.66) N=22		0.74 (0.67) N=22	

Note: Figures in the brackets refer to the't' values and *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 3: Factors Influencing Groundwater Development in Command and Non-Command Areas (1993)

Variable	Command		Non-Command		Overall	
	Coefficient	VIF	Coefficient	VIF	Coefficient	VIF
Constant	-15.76 (-1.14)	--	-15.77 (-1.14)	--	--15.63 (-1.132)	--
II	0.186(1.790)**	1.559	0.185(1.776)**	1.559	0.184 (1.775)**	1.559
No. of Dugwells	0.003 (1.345)	1.115	0.003(1.342)	1.115	0.003(1.346)	1.115
No. of Tubewells	0.002(1.217)	1.521	0.002(1.224)	1.521	0.002(1.218)	1.521
HDI	47.342(1.919)**	1.348	47.738(1.931)**	1.348	47.434(1.920)**	1.348
NIA Canals	-0.000 (-3.930)*	1.492	-0.000 (-3.926)*	1.492	-0.000 (-3.931)*	1.492
R^2 (R Bar)	0.65 (0.55) N=22		0.65 (0.55) N=22		0.65 (0.55) N=22	

Note: Figures in the brackets refer to the't' values and *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 4: Factors Influencing Groundwater Development in Command and Non-Command Areas (2002)

Variable	Command		Non-Command		Overall	
	Coefficient	VIF	Coefficient	VIF	Coefficient	VIF
Constant	-4.227 (-0.178)		-72.546 (-1.693)	--	-41.885 (-1.097)	--
AARF	--	--	--	-	0.040 (-1.775)**	1.4911
II	-0.061 (-0.474)	1.544	0.617 (2.512)*	1.416	--	--
No. of Dugwells	-0.006 (-1.859)**	1.361	-0.003 (-0.527)	1.177	--	--
No. of Tubewells	0.008 (2.466)*	1.916	0.011 (2.572)*	1.547	--	--
Crop Intensity	--	--	--	--	.479 (2.390)*	1.841
HDI	24.605 (0.795)	1.875	51.600 (1.144)	1.232	110.886 (3.377)*	1.265
% of BPL Pop.	0.675 (3.320)*	1.523	0.178 (0.489)	1.325	--	--
No. of Watersheds	-0.038 (-2.890)*	2.026	-0.006 (-0.252)	2.026	--	--
NIA Canals	--	--	--	--	0.000 (-4.792)*	1.818
Groundnut	--	--	--	--	0.001 (2.409)*	1.870
R^2 (R Bar)	0.60 (0.40) N=22		0.64 (0.49) N=22		0.76 (0.68) N=22	

Note: Figures in the brackets refer to the't' values and *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 5: Factors Influencing Groundwater Development in Command and Non-Command Areas (2004)

Variable	Command		Non-Command		Overall	
	Coefficient	VIF	Coefficient	VIF	Coefficient	VIF
Constant	36.760 (2.091)**	--	177.744 (6.261)*	--	35.896 (1.435)	--
AARF	-	--	-0.115 (-4.502)*	1.727	-0.040 (-2.275)*	1.219
II	--	--	--	--	0.482 (3.236)*	1.023
No. of Tubewells	0.007 (2.245)*	1.930	0.004 (2.581)*	1.356	0.003 (2.366)*	1.143
PCI (constant prices)	0.001 (1.190)	1.286	0.000 (-0.322)	1.238	--	--
No. of Watersheds	-0.034 (-3.090)*	2.114	-0.038 (-2.667)*	2.132	--	--
No. of Tanks	-0.001 (-0.576)	1.379	-0.003 (-2.262)*	1.362	-0.003 (-2.457)*	1.291
NIA Canals	0.000 (-5.342)*	1.512	0.000 (-0.881)	1.444	0.000 (-4.895)*	1.361
R^2 (R Bar)	0.71 (0.60) N=22		0.71 (0.60) N=22		0.81 (0.75) N=22	

Note: Figures in the brackets refer to the't' values and *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 6: Factors Influencing Groundwater Development in Command and Non-Command Areas (2007)

Variable	Command		Non-Command		Overall	
	Coefficient	VIF	Coefficient	VIF	Coefficient	VIF
Constant	161.492 (3.341)*		-38.909 (-1.047)	--	67.707 (2.600)*	--
AARF	--	--	-.074 (-4.982)	1.603	-0.062 (-4.226)*	1.571
II	--	--	--	--	0.394 (2.425)*	1.115
No. of Dugwells	0.007 (.609)	1.19	--	--	--	--
No. of Tubewells	--	--	--	--	-0.011 (-1.774)**	1.515
Crop Intensity	--	--	0.735 (3.500)*	2.112	--	--
HDI	-192.377 (-2.5)*	2.05	--	--	--	--
PCI	--	--	-	---	0.000 (-0.076)	1.104
Literacy Levels	--	--	1.173 (2.207)*	1.376	--	--
No. of Agrl. Service Connections	--	--	0.003 (1.799)**	1.151	--	--
No. of Watersheds	-0.029 (-2.316)*	2.12	--	--	--	--
No. of Tanks	-0.006 (-2.823)*	1.76	--	--	--	--
NIA Canals	0.000 (-1.909)**	1.66	0.000 (-3.198)*	1.790	0.000 (-4.556)*	1.095
R^2 (R Bar)	0.49 (0.34) N=22		0.74 (0.67) N=22		0.74 (0.67) N= 22	

Note: Figures in the brackets refer to the't' values and *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 7: Factors Influencing Groundwater Development in DPAP and Non-DPAP Regions (1985)

Variable	DPAP			Non-DPAP		
	Coefficient	t	VIF	Coefficient	t	VIF
Constant	61.999	3.499		-30.675	-1.551	
No. of Dugwells	--	--	--	0.006*	7.498	1.069
II	--	--	--	0.225	1.961	1.085
AARF	-0.049**	-1.937	1.062	0.025**	2.230	1.112
No. of Agrl. Service Connections	0.004**	2.083	1.049	--	--	--
NIA under Project Canals	0.000*	-2.496	1.034	--	--	--
R^2 (R Bar)	0.65 (0.5) N= 12			0.92 (0.87) N= 10		

Note: *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 8: Factors Influencing Groundwater Development in DPAP and Non-DPAP Regions (1993)

Variable	DPAP			Non-DPAP		
	Coefficient	t	VIF	Coefficient	t	VIF
Constant	-15.249	-0.732		-0.495	-0.056	
CI	0.462*	2.671	1.388	--	--	--
AARF	-0.032*	-3.328	1.113	--	--	--
NIA Canals	0.000*	-4.838	1.394	--	--	--
Literacy Level	0.594*	2.502	1.131	--	--	--
No. of Agrl. Service Connections	--	--	--	0.003*	2.892	1.245
% of Population BPL	--	--	--	0.392	1.501	1.245
R^2	0.85 (0.77) N= 12			0.72 (0.64) N= 10		

Note: *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 9: Factors Influencing Groundwater Development in DPAP and Non-DPAP Regions (2002)

Variable	DPAP			Non-DPAP		
	Coefficient	t	VIF	Coefficient	t	VIF
Constant	-89.807	-1.209		-151.371	-3.033	
NIA Canals	-0.001*	-5.294	1.375	--	--	--
% of Population BPL	-0.558	-1.433	1.627	1.317*	4.953	1.321
CI	1.446*	2.307	1.208	--	--	--
Coverage of WSDP	0.060**	2.236	1.439	--	--	--
AARF	--	--	--	0.115**	2.225	1.791
No. of Tubewells	--	--	--	0.010**	2.078	1.409
II	--	--	--	0.168	1.386	1.249
R^2	0.82 (0.71) N= 12			0.91 (0.84) N= 10		

Note: *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 10: Factors Influencing Groundwater Development in DPAP and Non-DPAP Regions (2004)

Variable	DPAP			Non-DPAP		
	Coefficient	t	VIF	Coefficient	t	VIF
Constant	138.847	2.013		137.115	2.465	
AARF	-0.067*	-3.236	1.418	--	--	--
II	0.553	1.618	1.621	0.350**	2.158	1.032
HPI (2001)	-195.221*	-2.811	1.405	-198.943**	-2.140	1.497
NIA Canals	0.000**	-1.939	1.438	0.000*	-3.506	1.665
PCI	--	--	--	-0.001	-1.714	1.196
R^2	0.90 (0.84) N= 12			0.84 (0.72) N= 10		

Note: *, ** indicate level of significance at 5 and 10 per cent respectively.

Table 11: Factors Influencing Groundwater Development in DPAP and Non-DPAP Regions (2007)

Variable	DPAP			Non-DPAP		
	Coefficient	t	VIF	Coefficient	t	VIF
Constant	129.822	6.663		-3.262	-0.130	
AARF	-0.055*	-3.045	1.211	--	--	--
No. of Agrl. Service Connections	-0.005**	-1.964	1.212	0.004*	2.787	1.002
NIA Canals	0.000*	-3.241	1.166	0.000*	-3.274	1.001
II	--	--	--	0.263	1.586	1.001
R^2	0.76 (0.67) N= 12			0.79 (0.68) N= 10		

Note: *, ** indicate level of significance at 5 and 10 per cent respectively.

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