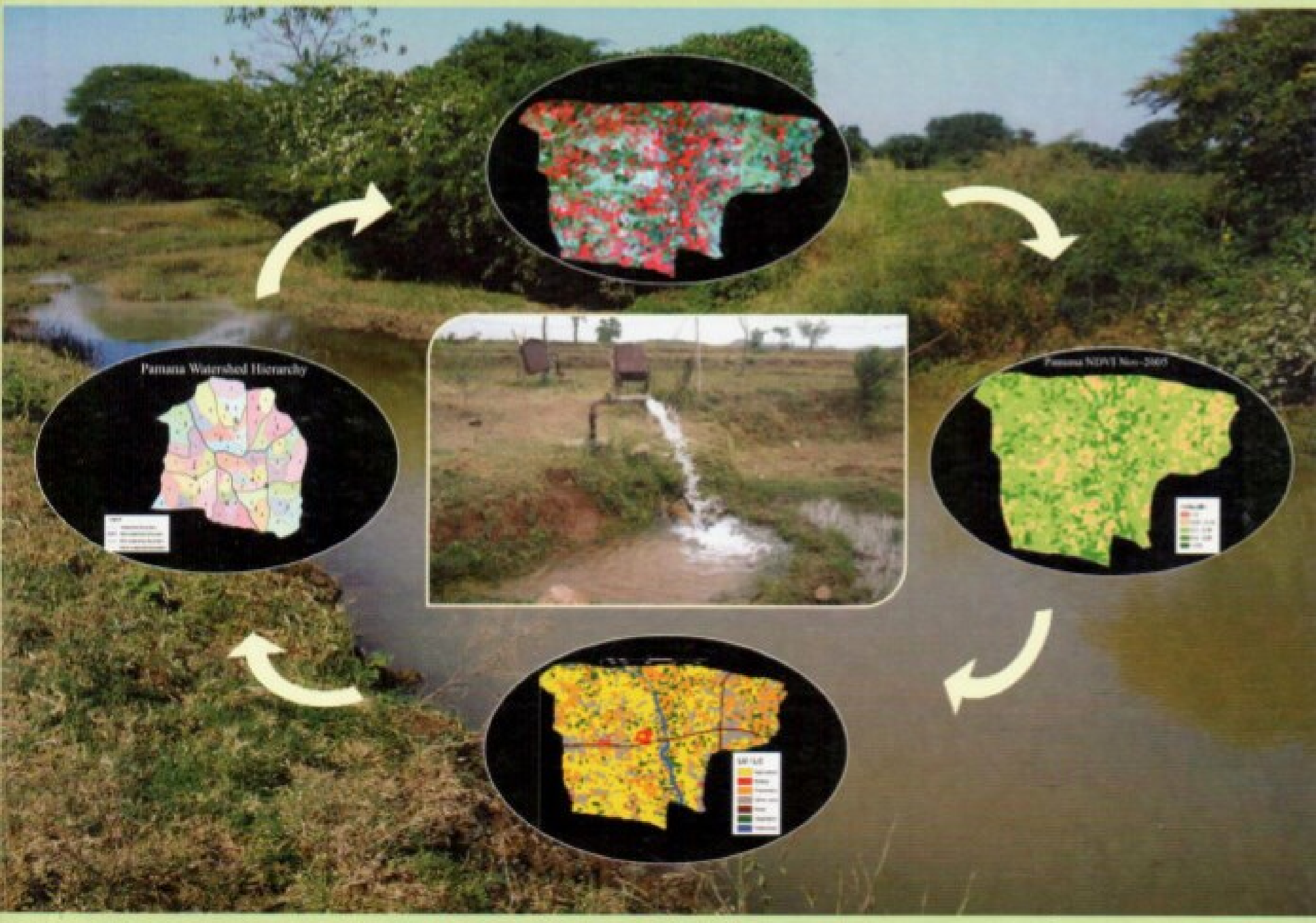
Natural Resource Management and Rural Livelihoods

Evaluation methodology for *Post-facto* assessment of watershed development projects

- a multi-disciplinary, multi-scale & multi-aspect approach



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February 2010


Geo-referencing check-dam


Setting GPS base-station


Initialization of spectro-radiometer


Measuring spectral reflectance


Collecting geo-referenced soil sample


Updating field boundary using GPS


Survey at farmer's field


Discussion with watershed committee

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Foreward

Watershed Development Program that had been implemented in India since the 5th Five Year plan (FYP) (1974-79), has been the accepted strategy for agricultural development in rainfed regions in India. To assess and evaluate the impact of watershed development projects on agricultural sustainability in rainfed regions, a study was undertaken in four treated and four untreated micro-watersheds in the Telangana region of Andhra Pradesh falling under hot and moist semi-arid climate in Peninsular India. In view of the divergent conclusions published based on earlier impact studies on several watersheds, it was deemed fit to undertake the study of a few treated watersheds in this region to understand the critical issues that determine the sustainability of watershed projects.

Selected micro-watersheds were located in four villages in the districts of *Rangareddy* and *Nalgonda* in Andhra Pradesh. The study used tools of Geomatics – GIS (Geographical Information System), remote sensing and DGPS (Differential Global Positioning system) along with conventional methods like soil survey and analysis, PRA (Participatory Rural Appraisal) and socio-economic survey, etc. to assess and evaluate sustainability of Watershed Development Programme (WDP). In all, fifty-one *sustainability indicators* (SI) were constructed to assess the impact of WDP and a methodology was developed to enable a quantitative evaluation of various aspects of sustainability of agricultural production system, viz., agricultural *productivity*, economic *viability*, livelihood *security*, environmental *protection* and social *acceptability*. This publication covers a detailed account of methodology and results of case studies. Application of GIS and remote sensing techniques has facilitated analysis of *inter-* and *intra-* temporal variations in the impact of WDP across the selected watersheds. The study was carried out under the *ICAR National Fellow* scheme awarded to the first author in February 2005. Authors strongly feel that the evaluation methodology described in this publication would be highly useful to the watershed project implementation agencies for development of watersheds and undertaking corrective measures as and when required. Further, funding and evaluating agencies will also find this book very useful to undertake an objective evaluation of ongoing and concluding projects.

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Authors

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Authors

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Acronyms/ Abbreviations

ADG	Additional Director General
AER	Agro Ecological Regions
AESR	Agro Ecological Sub-Regions
Agri.	Agriculture
AMC	Agriculture Market Committee
B:C	Benefit Cost ratio
BC	Backward Caste
BVC	Bivariate Correlation
CCT	continuous contour trench
CD	Check-Dam
CDE	Centre for Development and Environment
CEC	Cation Exchange Capacity
CESS	Centre for Economic & Social Studies
CG-WDP	Common Guidelines for Watershed Development Program
CLUMA	Centre for Land Use Management
COSTED	Committee on Science & Technology in Developing countries
CPR	Common Pool Resources
CRIDA	Central Research Institute for Dryland Agriculture
CSFD	French for the French Scientific Committee on Desertification
CSO	Central Statistical Organisation
CSWCRTI	Central Soil & Water Conservation Research and Training Institute
CV	Coefficient of Variance
DAC	Department of Agriculture & Cooperation
DDG	Deputy Director General
DDP	Desert Development Program
Dept.	Department
Dev.	Development

DFID	Department for International Development
DGPS	Differential Global Positioning System
DHA	Dehydrogenase Assay
DOLR	Department of Land Resources
DOA	Department of Agriculture
DPAP	Drought Prone Area Development Program
DORD	Dept. of Rural Development
DST	Department of Science & Technology
DWACRA	Development of Women & Children in Rural Areas
EAS	Employment Assurance Scheme
EC	Electrical Conductivity
FAO	Food and Agriculture Organisation
FESLM	Framework for Evaluation of Sustainable Land Management
FL	Farm Level
FYM	Farm Yard Manure
FYP	Five Year Plan
GIS	Geographical Information System
GOI	Government of India
Govt.	Government
GP	Gram Panchayat
GPS	Global Positioning System
GRF	Gunegal Research Farm
ha	Hectares
HH	House Hold
HHL	House Hold Level
HRF	Hayathnagar Research Farm
IBN	International Biosciences Network
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crop Research Institute for Semi-Arid Tropics

ICSU	International Council of Scientific Unions
ID	Irrigated Dryland
IFPRI	International Food Policy Research Institute
IIED	International Institute for Environment & Development
IIPS	International Institute for Population Sciences
INM	Integrated Nutrient Management
IRDP	Integrated Rural Development Programme
IRS	Indian Remote Sensing Satellite
ISRO	Indian Space Research Organisation
IVLP	Institute Village Linkage Program
IWDP	Integrated Watershed Development Project
IWG	International Working Group
JRY	Jawahar Rozgar Yojana
LADA	Land Degradation Assessment in Drylands
LMP	Land Management Practices
LPG	Liquid Petroleum Gas
Mandal	Mandal – an Administrative unit
MBC	microbial biomass carbon
MDO	Mandal Development Officer
MOA	Ministry of Agriculture
MOEF	Ministry of Environment & Forestry
MOF	Ministry of Finance
MORD	Ministry of Rural Development
MRO	Mandal Revenue Officer
MWR	Ministry of Water Resources
MWS-WDP	Micro Watersheds - Watershed Development Program
Naala	River-catchment
NAARM	National Academy of Agricultural Research Management
NABARD	National Bank for Agriculture and Rural Development

NBSS&LUP	National Bureau of Soil Survey & Land Use Planning
NDVI	Normalised Differential Vegetation Index
NGO	Non Government Organisation
NRAA	National Rainfed Area Authority
NNRMS	National Natural Resource Management System
NRDMS	Natural Resources Data Management System
NREGS	National Rural Employment Guarantee Scheme
NRM	Natural Resource Management
NRSC	National Remote Sensing Centre
NWDP	National Watershed Development Program
NWDPRA	National Watershed Development Project for Rainfed Area
OC	Organic Carbon
OC	Other Caste
OM	Organic Matter
PACS	Poorest Areas Civil Society
PCA	Principal Component Analysis
PDS	Public Distribution System
PIA	Project Implementing Agency
PRA	Participatory Rural Appraisal
PROGRESS	an NGO in Hyderabad
PSB	Public Sector Banks
PSU	Public Sector Undertaking
Pvt.	Private
RRB	Regional Rural Bank
RS	Remote Sensing
S&WC	Soil and Water Conservation
SAT	Semi-Arid Tropics
SC	Scheduled Caste
SHG	Self Help Group

SI	Sustainability Indicators
SMW	Standard Meteorological Week
SOI	Survey of India
SPSS	Statistical Package for the Social Sciences
ST	Scheduled Tribe
Tehsil	Sub-district revenue division
TMW	Treated Micro Watershed
TRYSEM	Training of Rural Youth for Self-Employment
UNCCD	United Nations Convention to Combat Desertification
UNESCO	United Nations Educational Scientific & Cultural Organisation
USD	U.S. Dollar
USLE	Universal Soil Loss Equation
UTMW	Untreated Micro Watershed
VAO	Village Administrative Officer
WARASA	Watershed Areas' Rainfed Agricultural Systems Approach
WASSAN	Watershed Support Services and Activities Network
WC	Watershed Committee
WDF	Watershed Development Fund
WDP	Watershed Development Program
WDSCA	Watershed Development in Shifting Cultivation Areas
WL	Watershed Level
WOCAT	World Overview of Conservation Approaches and Technologies
WPI	Wholesale Price Index

1. Introduction: Watershed Development and Evaluation

Rainfed agro-ecological regions (AER) which encompass the semi-arid tropics (SAT) and hot dry and moist sub-humid regions of India, extends over 76.74 million ha (mha) out of a total geographical area of 90.4 mha in the states of Andhra Pradesh (AP), Maharashtra, Karnataka and Tamilnadu in Peninsular India. Watershed-based development has been an important component in the schemes for economic planning for development in the region. In order to improve agricultural productivity, livelihood security and rural lifestyle, improved land management practices (LMP) have been propagated under watershed development program (WDP). According to Census of India - 2001 conducted by Government of India (GOI), out of 288.34 million persons in the four states, over 180.99 million lived in rural areas and were involved in agriculture and allied activities. In 2009 it was estimated that the total population in the four southern states would be 317.47 million persons with over 188.56 million living in rural areas alone. In Andhra Pradesh an estimated 83.17 million persons were living in rural areas with over 5.34 million persons in the two districts of Nalgonda and Rangareddy alone. Hence watershed development projects have the potential to benefit this large volume of population in the state and other parts of the country and improve their livelihood status and protect the natural resource base in the region.

Rainfed AER encompassing Peninsular India receives an average annual rainfall of 500 mm (300-800 mm), which occur in 52 - 55 rainy days. Over 50 percent of this rainfall occurs by way of thunderstorm that lasts for a few hours. Considering such a rainfall pattern, it is essential to harvest, store and use rainwater for undertaking agriculture and other allied activities for the rest of the year. Intensive rainfall events induce severe soil erosion in bare or sparsely vegetated land that is common in the region. Watershed Development Program (WDP) is undoubtedly, crucial not only for increasing agricultural productivity from rainfed regions but also managing and conserving the natural resource base of rainfed regions on which millions of small and marginal farmers subsist. Soil and Water Conservation Structures (S&WC) viz., check-dam, stone weirs, contour bund, live bunds, vegetative cover, key-line plantation, grass way, etc., were planned to provide impediments to overland - runoff which induce soil erosion and depletion of nutrients from agricultural fields. Structures were laid to guide runoff to designated farm ponds and tanks for water harvesting on the surface, besides impounding water for facilitating deep percolation for groundwater recharge. Thus, WDP was considered the most comprehensive program for achieving agricultural and ecological sustainability in the rainfed regions in India. A hallmark of WDP was the implementation of improved land management practices (LMP) for each aspect of agriculture and rural life in the rainfed regions.

As India envisages sustaining an agricultural growth rate of 4.0 to 4.5 per cent in order to reduce food insecurity and poverty, while increasing rural purchasing power, benefit accrued from implementing improved LMP under WDP needs to be evaluated so that necessary corrections or emphasis could be affected if essential.

2. Watershed Development Program (WDP) in India

Watershed Development and Management Program was initiated during 1980s to address these limitations of the rainfed AER (Planning Commission, 2001). One of the primary reasons, in favour of watershed-based development in rainfed AER, is the enormous cost of major water projects like the under-construction Narmada river-valley project. Hence, emphasis was shifted to augmenting water resources through small and decentralized projects and the WDP for rainfed regions in rural India, have remained the accepted strategy for rural transformation. The Watershed Projects have been undertaken under six major national programs, viz., Drought-Prone Area Program (DPAP), Desert Development Program (DDP), National Watershed Development Project for Rain-fed Area (NWDPRA), Watershed Development in Shifting Cultivation Areas (WDSCA), Integrated Watershed Development Project (IWDP) and Employment Assurance Scheme (EAS) etc. by four Central Ministries of Govt. of India namely, Ministry of Rural Development (MORD), Agriculture (MOA), Environment & Forestry (MOEF) and Water Resources (MOWR). Significantly, 70 percent of funds for watershed development in India were spent under these six major programs. There were also, a lot of commonality in the WDP undertaken by these four ministries, in view of which, a inter-ministerial sub-committee was constituted in 1999, to evolve a common approach and principles for undertaking of WDP in India.

Government of India drew an ambitious 25-years Perspective Plan for an holistic and integrated development of rainfed areas in the country on watershed -basis, for covering an area of approximately 63 mha at an estimated cost of Rs. 76,000 crore or USD 1520 m (Planning Commission, 2005). However, experts like – Dr. M.S. Swaminathan(2001, 2005) and Dr. C.H. Hanumantha Rao (1994) besides others, had expressed their reservation in the manner in which the project was being implemented, although several modifications were implemented in the programme since its inception in the year 1983. A Technical Committee Report submitted to the Department of Land Resources (DOLR-MORD) in January 2006 (Parthasarathy, 2006), estimates that at current level of outlay, it may take 75 years to complete watershed treatment in India. The Committee opined that if S&WC measures needed to be completed by 2020, the Government must allocate Rs. 100,000 million (20 million USD) annually for the purpose, for the next 15 years.

Undoubtedly, WDP is essential for rainfed agriculture and since 1983 three generations of watershed projects have been implemented in the country. The Ministry of Rural Development (MORD) followed the Hanumantha Rao (1994) Committee recommendations and implemented all WDP under those guidelines between 1994-2001. In 2000, Ministry of Agriculture (MOA) revised its' WDP guidelines and the National Watershed Development Project for Rainfed Areas - *NWDPRA Guidelines* came into being (MOA, 2001). These guidelines were intended to be common guidelines to make WDP more participatory, sustainable and equitable (Information Box 1). However, MORD revised its' 1994 guidelines in 2001 and again in 2003, naming it the *Hariyali Guidelines* for WDP (MORD, 2003).

Till the 8th Five – Year Plan (FYP), a total of 16.5 mha of land was treated with watershed projects. From April 1995, MORD implemented the DDP, DPAP and IWDP projects under the Common Guidelines as recommended by the Hanumantha Rao (1994) Committee. Between 1995-96 and 2007-08, over 45,062 projects were sanctioned under the above-mentioned three programs with a view to treat over 32.29 mha at a cost of 77386 million rupee *(http://india.gov.in/sectors/agriculture/watershed_development.php 2009).* Besides these National Bank for Agriculture and Rural Development (NABARD) established a Watershed Development Fund (WDF) in 1999-2000 to enable the various states in the country to access credit for treatment of land under the WDP.

Information box 1

Chronology of Watershed Development Program in India
1951 - Soil & Water Conservation works initiated
1956 – Forty-two micro–watersheds developed by Central Soil & Water Cons. Research & Training Institute (CSWCRTI) Dehradun, on experimental basis
1974- Demand-driven watershed development & management based on participatory-approach initiated by CSWCRTI. NGOs joined the program in 1985 to promote partnership with people
1983 - Forty-seven Model Watersheds implemented
1987-88 - National Watershed Development Program for Rainfed Areas (NWDPRA) (MOA, 2001)
1989- Integrated Watershed Development Projects (IWDP) taken up by National Wasteland Development Board (NWDP) to develop wastelands on watershed basis
1991 – Launch of National Watershed Development Program in Rainfed Areas (NWDPRA) by Ministry of Agriculture and Co-operation (MOA, Govt. of India)
1994 – Technical Committee *(Prof. Hanumantha Rao)* recommended common guidelines for DDP, DPAP & IWDP (MoRD)
2003 – New *Hariyali* guidelines to simplify procedures & to involve *Panchayat Raj institution.* (Local self-govt.) in planning, implementation & management of economic development activities (MORD)
2005- WARASA *Jan Sahbhagita* -Guidelines for Common Approach for Watershed Development (MOA & MORD)
2006 –Tech. Comm. Report *(Parthasarathy, 2006) From Hariyali to Neeranchal* advocated an enlarged & reformed watershed program in India with financial allocation of Rs. 10,000 crore / year (USD 2223 million) till 2020 (MoRD)
2006 – Setting up of National Rainfed Area Authority (NRAA)
2008 – Common guidelines for WDP to address emerging issues of groundwater recharge & convergence to create critical mass of investments in rainfed areas under 11th FYP (2007 – 2012)

Andhra Pradesh where the present study was undertaken is the fifth largest state in India and a major contributor to the food basket of the country of which rainfed agriculture is an important component. With a net sown area accounting for 10.84 mha with a cultivable waste of 0.6 mha, fallow area of 2.7 mha (current fallow) and other fallow accounting for 1.5 mha according to the Land Use Statistics of 2007-08 (DOA, 2008), agriculture is critical for the economic development not only for the state but also for the region and the nation. In 1997, a massive programme for development of all degraded lands in the state was launched and under the *Ten - Year Action Plan* for development of wastelands, degraded lands (i.e., dryland which are being cultivated under rainfed conditions) and degraded reserve forests, over 10 mha of degraded and wastelands (1.72 mha. by Forest Dept., 0.45 mha. by Dept. of Agriculture and 7.82 mha by the Dept. of Rural Development), were to be developed with an outlay of about 40000 million rupee at the rate of 1.0 mha, annually. During the period about 5.4 mha were to be developed through 12,890 watershed projects by the Dept. of Rural Development (DORD), Govt. of AP.

3. About this Study

The study was undertaken in four project villages where watersheds were developed by various agencies in northern Telangana semi-arid and dry sub-humid tropics identified as AESR 7.2 (Velayutham *et al.*, 1999). For assessing or determining the impact of WDP, the situation in four treated watersheds were compared with that of four untreated watersheds located in the vicinity within each village taken as control although not in a strict sense in view of the implementation of other developmental activities in the village. The impact of sustainability of WDP was evaluated in each watershed at three levels - household, field and watershed during 2005 to 2009 and the outcome were compared annually with the situation prevalent during the preceding year in the respective watersheds. For evaluation, valuation of economic returns from a unit land area (ha) was estimated across the watersheds annually and the results have been discussed at length in a later section of this publication.

Review of progress under WDP

Despite its' importance to the agricultural sector in particular and the Indian economy in general, progress under WDP till the 10th FYP was limited. A number of studies undertaken in the last 25 years have indicated several flaws in the implementation of the programme (Amita Shah *et al.,* 2004, Planning Commission, 2001, 2005; Kerr & Sanghi, 1992; Kerr *et al.,* 2002; Hanumantha Rao, 2000; Joshi *et al.,* 2005, Samra, 1997; Sreedevi *et al.,* 2004; Samra & Eswaran, 2000, Venkateswarlu, 1999. Based on all these studies, the Govt. of India in 2008, announced a comprehensive set of guidelines for watershed development in the country that came into effect from 1st April 2008 (Planning Commission 2008a, 2008b;Govt. of India, 2008) which supersedes all earlier guidelines for WDP in the country, in view of the critical role that WDP could play in conserving and enriching the natural resource base of rainfed regions in the country.

Besides these studies, a few were undertaken to review the Policy on WDP in Andhra Pradesh (Oliver Springate – Baginski *et al.,* 2004), watershed development program in India (Hanumantha Rao, 2000), sustaining rural livelihood (Ratna Reddy 2003; Ratna Reddy *et al.,* 2004) and a World Bank Review of Watershed Experience in Andhra Pradesh (World Bank, 2001). Most of these evaluation studies were conducted by independent consultants who evaluated the watershed projects using qualitative information alone owing to non-availability of authentic baseline data provided by the respective Project Implementing Agency (PIA). This proved to be a serious lacuna, as most of these valuable studies could make only general recommendations rather than provide concrete suggestions that could help the PIA to undertake effective corrective measures to make the watershed projects sustainable. To address this shortcoming, the present study was undertaken to demonstrate the use of Geo-informatics tools to evaluate WDP in the country. Use of Information Technology including Geo-informatics has helped to overcome the bottleneck of lack of quantifiable baseline data, a general problem faced by all earlier projects in the country. Using these tools, it was possible to construct sustainability indicators and develop a methodology for quantitative evaluation that was applied to evaluate eight micro-watersheds in four villages in Telengana region in Andhra Pradesh, as described in this publication. The present study was undertaken to evaluate these watershed projects that had been implemented under the 1994 guidelines of Hanumantha Rao Committee and the NWDPRA guidelines of MOA (2001), in order to, identify critical indicators of sustainable development in rainfed agriculture. The lessons learnt from this study would presumably help in effective implementation of the Integrated Watershed Development Projects (IWDP) under the new Common Guidelines for Watershed Projects implemented by Govt. of India in April 2008.

Objectives

One of the main objective of the study was to develop a methodology for assessment and evaluation of WDP based on performance indicators using tools of Geo-informatics – GIS, remote sensing, Differential Global Positioning System (DGPS) and Total Station along with conventional methods of study like soil analysis, PRA, socio-economic survey, etc. Another objective was to identify essential aspects of WDP through identification of critical indicators (Kaushalya et al., 2007, 2009). This task was accomplished through application of two statistical techniques - *Bivariate Correlation technique* and *Principal Component Analysis.* Critical indicators were used as Minimum Data Sets for evaluation of WDP. Outcome of this study was compared across the selected watershed villages, both spatially and temporally and the results of this *post-facto* assessment and evaluation are presented here.

4. Study Area

As already mentioned, four villages were selected in AESR 7.2 to assess and evaluate the watershed projects developed between 1999-2002 in the districts of Rangareddy (RR) and Nalgonda of Telangana region in AP (Figure 1 & 2). The watershed projects had been developed under NWDPRA guidelines by the Departments of Agriculture (DOA) and of Rural Development (DORD), AP State Govt. besides an NGO called PROGRESS. The four villages covered over 6000 ha of agricultural land and their geographical location has been indicated in Table 1. About 440 farm households were surveyed for socio-economic information each year. Five hundred and fifty soil samples were analysed for 12 physico-chemical and biological properties. In each of the four villages selected for the study, 7, 11, 13 and 19 micro-watersheds were delineated of which one treated and one untreated micro-watersheds covering an area around 100 ha were selected for evaluation of impact of watershed projects on agricultural sustainability.

Table 1 : Study Area

S. No.	Dist.	Name of Agency	Name of Watershed	Location (SOI Toposheet No.)	Funding Agency
1	Rangareddy	DPAP, Govt of AP	Dontanpalli, Shankarpalli Mandal	56 K / 3	MORD
2	Rangareddy	PROGRESS - NGO	Pamana, Chevella Mandal,	56 K / 3	MORD
3	Rangareddy	DOA	Chintapatla, Yacharam Mandal, near Ibrahimpatnam	56 K / 12	MOA
4	Nalgonda	DPAP, Govt of AP	Gollapalli, Chintapalli Mandal,	56 L / 13	MORD

Selection of watersheds

Pamana village from which a micro-watershed was selected for the study is located within Chevella watershed ($78^0$7’30"E & $17^0$16’45"N). WDP was implemented under DPAP program in 1999 (Table 1). The village area could be delineated into 16 micro-watersheds (MWS - catchment of first-order stream). Under WDP, ten check-dams were constructed in two of the sixteen micro-watersheds within Pamana in a planned manner. For implementation of WDP, a *watershed committee* was formed consisting of stakeholders (farmers belonging to the respective watersheds) and *seed money* was sanctioned to the village administration (*Gram Panchayat*) for undertaking various programs with the guidance of officials from the State Dept. of Agriculture. Villagers constructed the soil and water conservation structures (S&WC) for which they were paid wages from the DPAP fund.

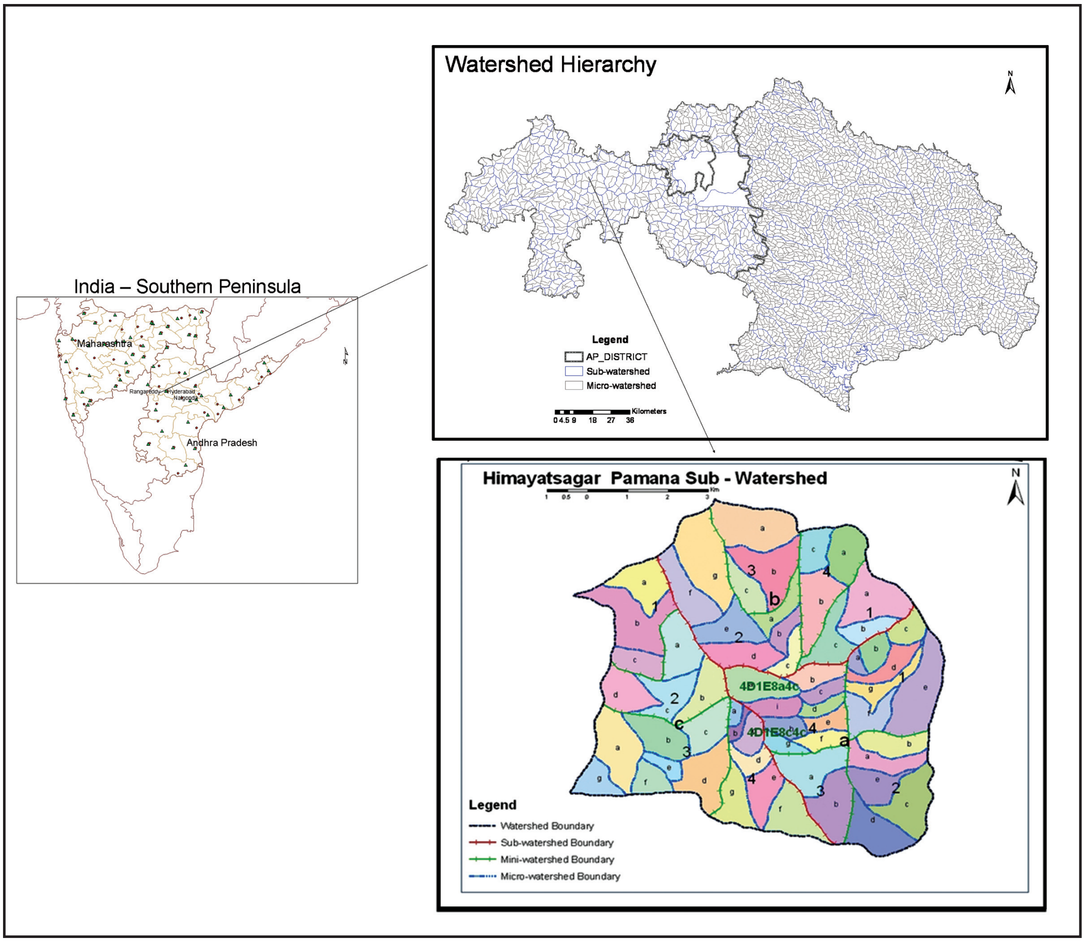


Figure 1: Location of Study area

To assess and evaluate WDP in Pamana, GIS and remote sensing techniques were used to supplement information generated from actual field survey, soil analysis and socio-economic survey. Database were initially created in *MS-Access* and subsequently developed into *Dot net* application. Thematic maps of the resources in the respective watersheds were drawn using *ArcGIS*. Multi-spectral data from IRS satellite were procured for pre-project period i.e., 1998 and post-project periods, i.e., 2005, mapped and analysed for land use and land cover change. The imageries were interpreted to derive various sustainability indicators and to understand the processes of LULC change.

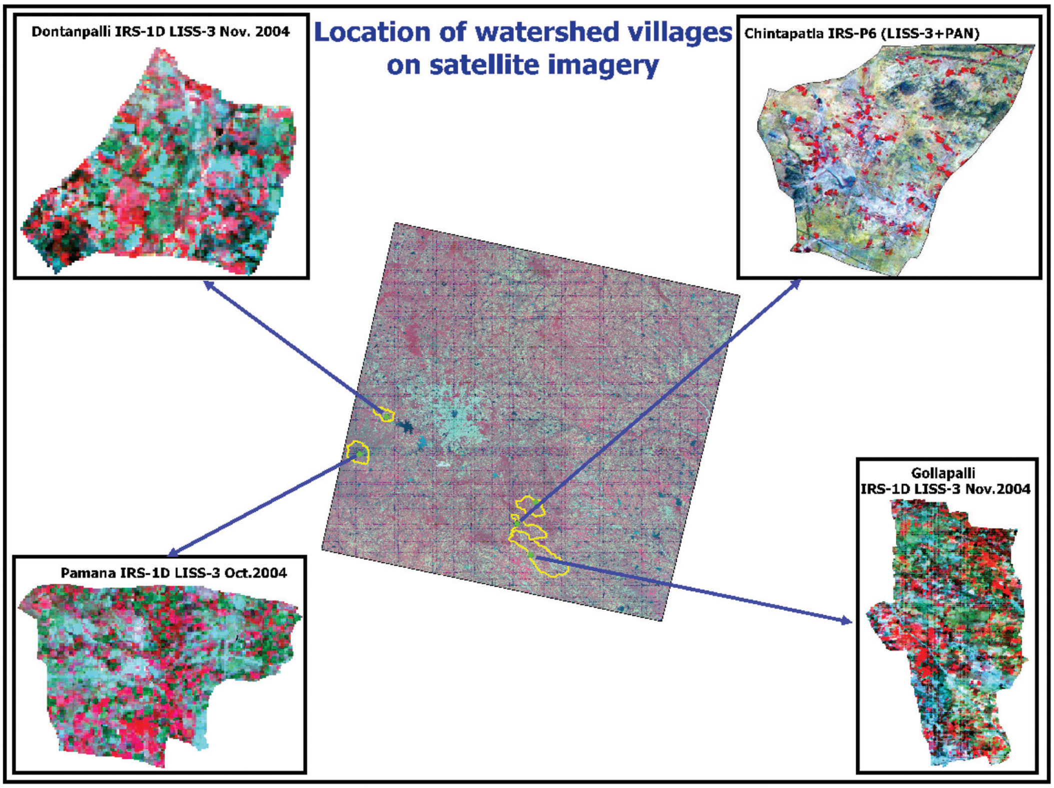
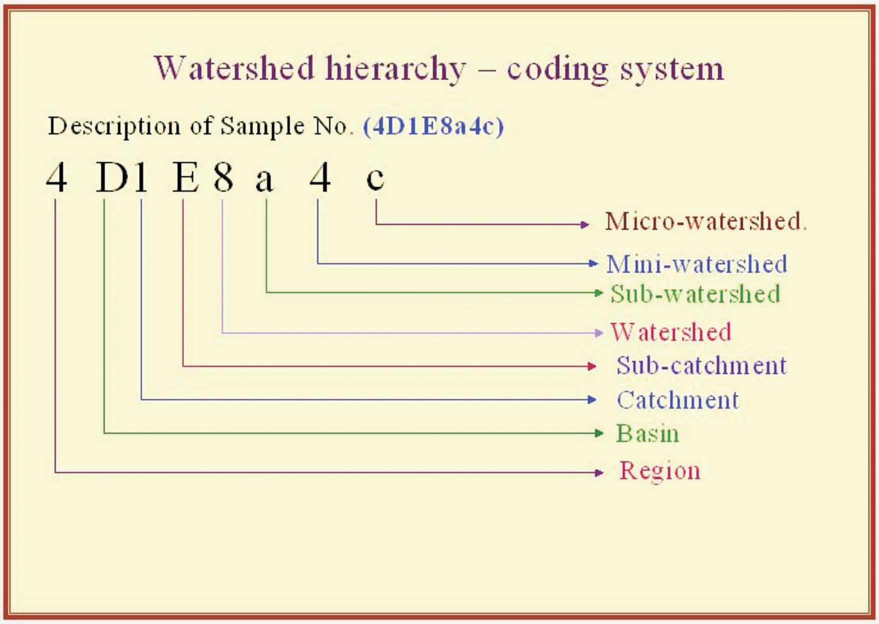


Figure 2: IRS satellite imagery indicating location of selected watershed villages

In Pamana, as in other cases, two micro-watersheds – one a treated micro-watersheds (TMW) where S&WC measures were undertaken and another an untreated micro-watersheds (UTMW) where WDP interventions were not implemented although other activities may have been implemented, were selected for developing an assessment and evaluation procedure for WDP. Watershed hierarchy was delineated and micro-watersheds identified for the study. A watershed coding system developed at CRIDA during 1996-1997 under the ICAR – Institute Village Linkage Program (IVLP) was used (Information box 2). It is heartening to note that since then this method of coding stream network has been accepted as a standard practice to identify stream network hierarchy in the country and used by AIS& LUS (2002) to prepare an atlas for the country. The stream codification methodology evolved is as follows: for e.g., Pamana TMW is denoted as 4D1E8a4c which signifies the following drainage hierarchy levels: **4** – Southern Water Region, **D** - Krishna River, **1** – Musa River, **E** – Himayatsagar sub-catchment, **8** – Watershed No. (4th order stream catchment), a **-** sub-watershed code (3rd order stream catchment), **4 -** mini-watershed (2nd order stream catchment) and **c -** micro-watershed (1st order stream catchment).

Information box 2



Watershed hierarchy – coding system developed for Pamana

Socio-economic survey was conducted using structured questionnaire for measuring the sustainability indicators. Soil sampling and analysis for 12 physico-chemical and biological parameters were undertaken. Satellite data of IRS 1D LISS-III of 16 Nov. 1998 and IRS – P6 data of 4 Nov. 2005 were interpreted using ERDAS Imagine (Ver. 8.7) and land use land cover and degradation maps were prepared for developing sustainability indicators. Finally, an assessment and evaluation methodology was developed for undertaking an integrated evaluation of sustainability of WDP in all the selected watersheds.

Pamana watershed

Pamana village is located towards southwest of Hyderabad Urban Agglomeration (HUA) at approximately a distance of 70 km from the city centre. The village has 280 farm households who own over 1100 ha of farmland. In most of the cases landholding size range between 1-2 ha and significantly, there are no landless persons in the village. The village is located in the Himayatsagar catchment and Figure 3 indicates the regional watershed hierarchy of the watershed.

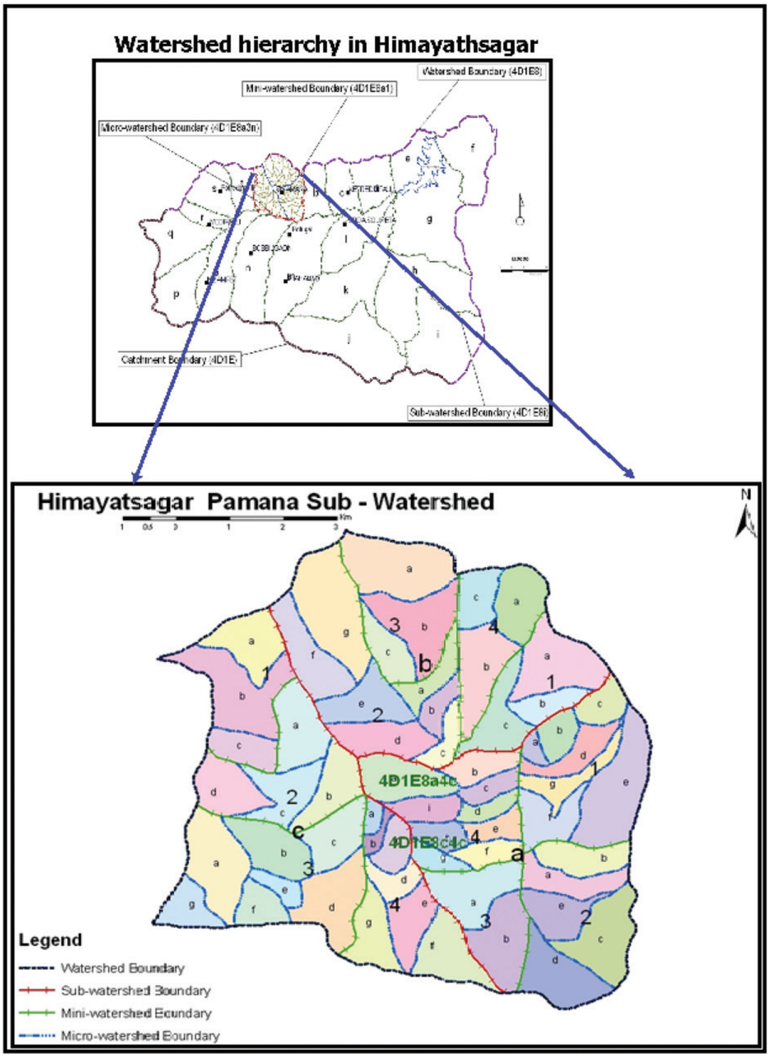


Figure 3: Watershed hierarchy of Pamana village, Chevella mandal in Himayatsagar catchment in Rangareddy district.

Watershed development program was initiated in the village in two phases. During the implementation of first phase from 1994, ten check-dams were built in a micro-watershed. In 2005, four concrete check-dam structures were built in a second micro-watershed under DPAP scheme. A treated micro-watershed (TMW) of 133.52 ha area and another untreated micro-watershed (UTMW) 101.8 ha were selected for assessment and evaluation of sustainability of WDP. The second phase of WDP in Pamana was implemented by a NGO called *PROGRESS*, which was active in the region. The NGO painstakingly facilitated creation of social structures like *Watershed Committee* (WC) that was entrusted with the task of overseeing maintenance and construction of S&WC structures and bunds created under the WDP besides formation of *Watershed Association* (WA) and *Self-Help Group* (SHG) where all farmers were stakeholders and were involved in the decision-making process an aspect vital for sustainability of WDP.

Chintapatla watershed

Chintapatla village is located in Yacharam mandal in the border of Rangareddy and Nalgonda districts. It is drained by the Shaslervagu River (Figure 4) which is numbered as 4D1F3a in the National Watershed Atlas (AIS & LUS, 1988). The area extent of the village is 2237 ha that is owned by over 400 farm-households. Land holding sizes ranged from 0.5 to 5 ha. The village has essentially red shallow gravelly soils (fine mixed *Typic Rhodustalfs*) and most of the land belongs to *LCC III e* to *VIII.*

Major crops grown were paddy, sorghum, castor, horse gram and vegetables, which included tomatoes. Although *Kharif* (June - Sept.) is the main cropping season, crops were also grown during *Rabi* (Nov. - Feb.) and summer seasons wherever assured water was available for irrigation. This trend of exploiting groundwater for growing paddy and other vegetable crops for market was seen to have increased since 2004 when the Govt. declared free electric power supply to the farming sector. Livestock was seen to be an important component of agriculture in the village as there were over 250 buffaloes that were milked and the produce was sold to dairy federations in the region. Poultry was however, restricted to backyards alone.

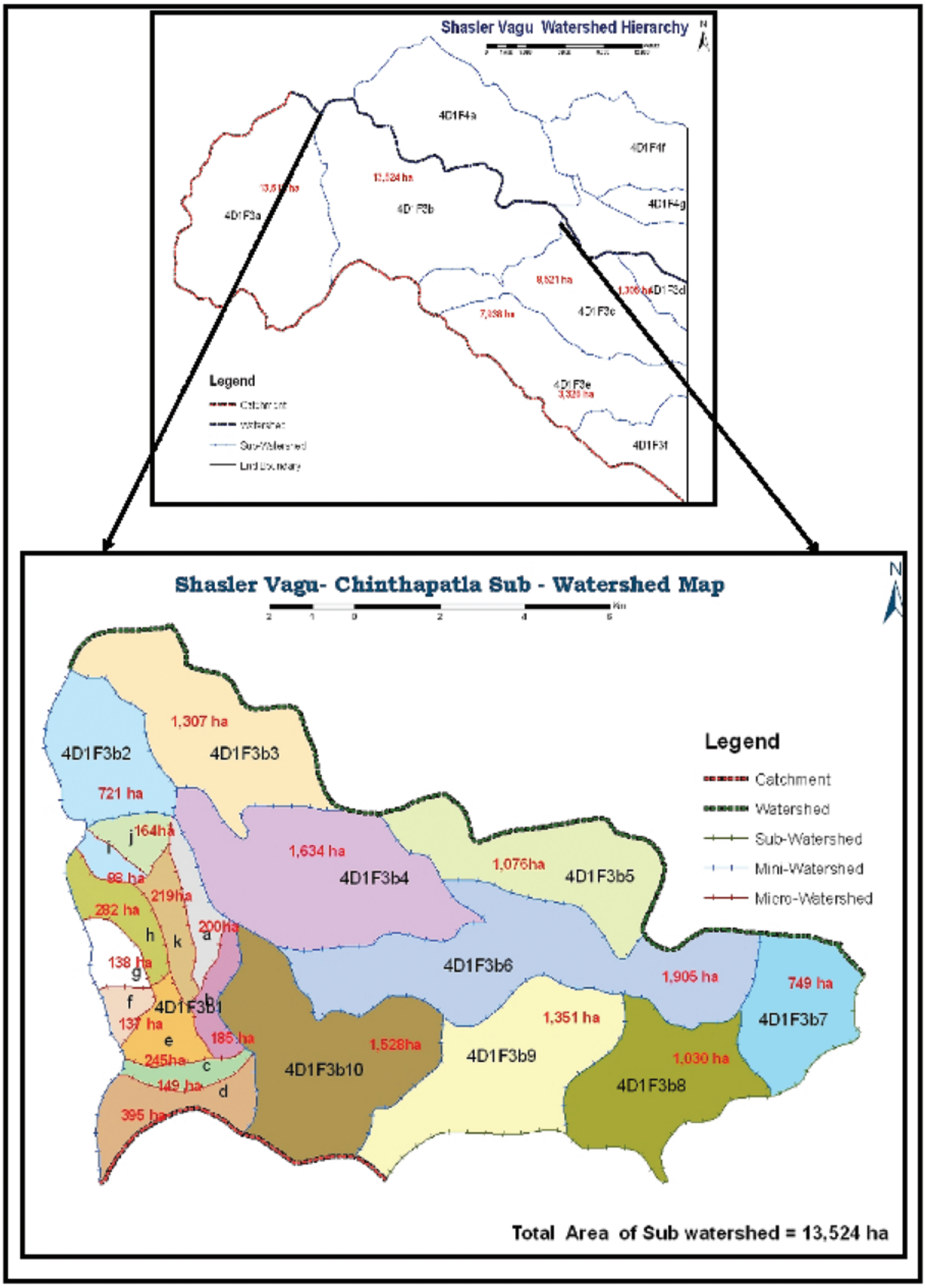


Figure 4: Watershed hierarchy of Chintapatla village, Yacharam mandal, Rangareddy district.

WDP was initiated in the village in 1994 - 1995 under the DPAP program. Three check-dams were built in the watershed along with small concrete structures and large stone and mud structures. Continuous contour trenches (CCT) were also dug around steep slopes to facilitate infiltration of water for groundwater recharge. Stone-weir and rubble structures were constructed to impede overland flow of water and for halting soil erosion.

The villagers in Dontanpalli realised the benefits of WDP as their crops grew well in lower reaches of the check dam and their bore-wells did not fall defunct owing to fall in groundwater table, as was usual prior to the launce of WDP in the village. After the launch of the WDP, groundwater recharge was evident from the level of water - table in the village besides halting of soil erosion and increase in crop yield. It was seen that the paddy yield in particular, rose from 1500 to 2000 kg ha^{-1}.

Dontanpalli watershed

This village is located in Shankarpalli mandal at the border of Rangareddy and Medak districts at the junction of three mandals - Shankarpalli, Moinabad and Chevella. Thus, geographically Dontanpalli is located in the peri-urban belt of Hyderabad where large-scale land use and land cover changes are occurring. Agricultural land use was seen to rapidly change as land was being converted into urban and industrial use and the impact of these recent changes was clearly visible on the state of agriculture in the village.

Dontanpalli watershed is located in the Osmansagar catchment and is denoted as 4D1E7 in the National Watershed Hierarchy Atlas (Figure 5). Dontanpalli village has a total area of 696 ha encompassing the area under seven hamlets namely, Maharajpet, Kakarlakunta, Pilligondla, Irrigutta Tanda, Dontanpalli, Ponnagutta Tanda and Goplaram. While Dontanpalli is a revenue village, the seven hamlets have a combined *Panchayat* (village council) located at Maharajpet. This decentralized administrative setup is a factor that has been working against the interests of residents of Dontanpalli village. There are 410 farm households in the seven hamlets and a majority of them belong to marginal and small category of farmers.

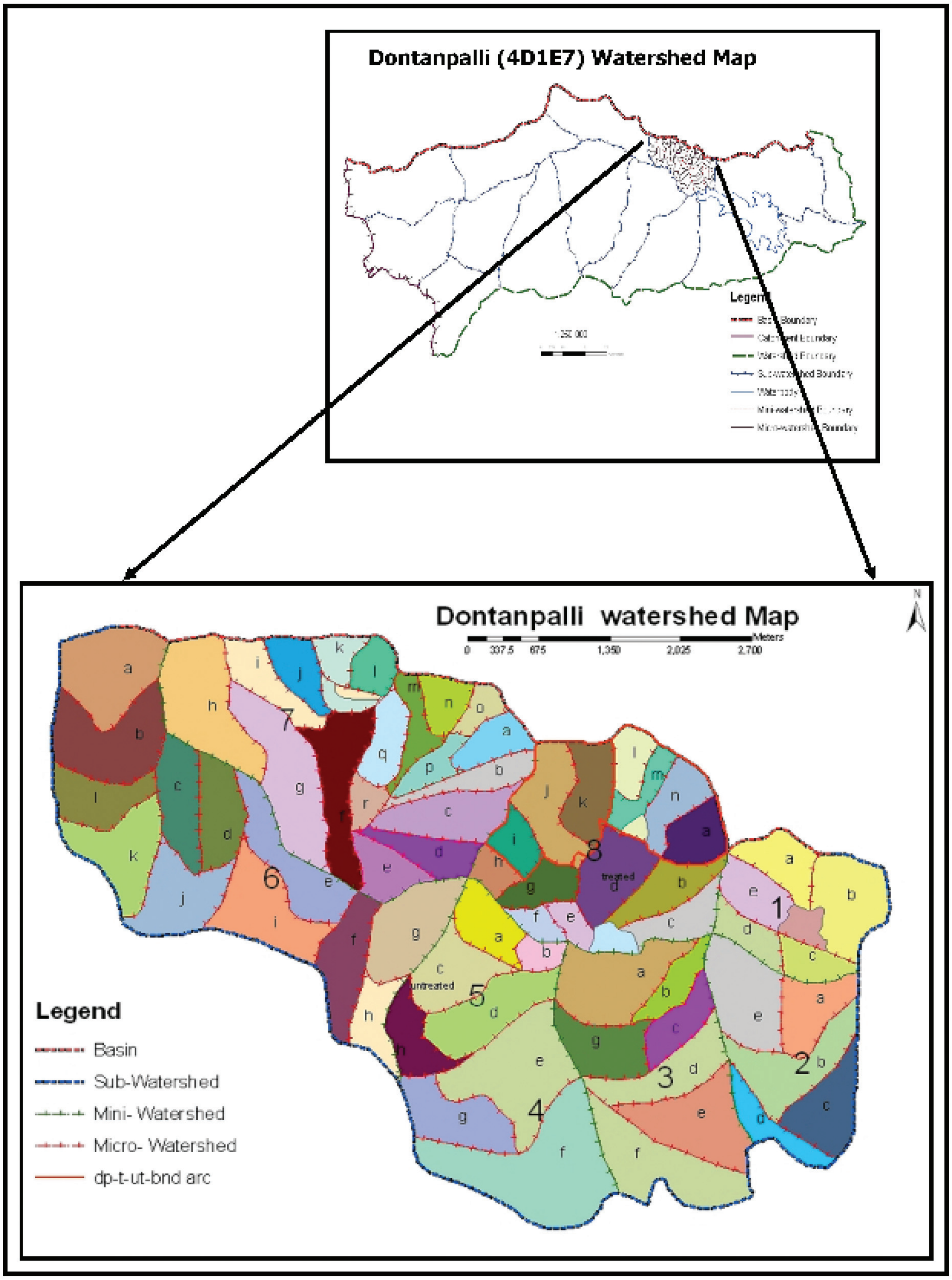


Figure 5: Regional watershed hierarchy of Dontanpalli watershed, Shankarpalli mandal, Rangareddy district.

The soil is essentially red shallow loam (fine mixed *Typic Haplustalfs*) and the land predominantly belongs to *LCC III e s*. Dominant crops grown during *Kharif* season were sorghum, paddy and vegetables while red gram, tomatoes and chillies were grown during *Rabi* season. Since the last decade, floriculture had been developed in the area, which was seen to be profitable owing to proximity to Hyderabad. During the last decade several large plantation orchards were developed by non-residents essentially city-dwellers who had bought land from the small and marginal farmers and consolidated them into large holdings. The dispossessed farmers of the village worked in these mango, guava and grapes orchards as labour. Department of Agriculture, Govt. of Andhra Pradesh implemented WDP in the village under DPAP scheme in 1995-96. Under the program six check-dams were constructed and several CCT were dug to impend overland water flow to facilitate infiltration. The WDP was officially concluded in 2001.

Gollapalli watershed

This village is located in Chintapalli mandal of Nalgonda district and is drained by Peddavagu River. The Peddavagu Watershed has been denoted as 4D2B2 (Figure 6) in the National Watershed Atlas (AIS&LUS, 1988). Gollapalli was a part of Kurmed village with a combined *Panchayat* located at the latter till a decade ago. The two have been administratively bifurcated in the last decade although the state highway connecting Hyderabad with Nagarjunasagar had physically divided the two earlier when drainage lines got truncated owing to construction of state highway. Although Gollapalli is now a separate revenue village its' *Panchayat* is still located at Kurmed and many farm households own and cultivate their land in either or both villages, that makes the assessment and evaluation of development projects like WDP, challenging.

Gollapalli village extends over 509 ha which belongs to over two hundred and twenty-five farm households. Although a majority of farmers are small and marginal, there are a few who have large landholdings. Soils are essentially red gravelly loam soils (loamy, skeletal, mixed *Typic Rhodustalfs*) and the land belongs to *LCC III e s*. Major crops grown were cotton, paddy, maize, sorghum, castor, vegetables which included tomato, carrot, onions, garlic, etc., and red gram. There are a few mango and orange orchards belonging to large farmers who have consolidated their holdings by buying a few landholdings belonging to small and marginal farmers in the village.

In 2007-08, the boom in real estate had boosted land price that induced several farmers to sell their land for non-agricultural use instead of continuing to practice rainfed agriculture. However, the subsequent economic slump in second-half of 2008 has dampened the market price of land in the region and agriculture has seen resurgence.

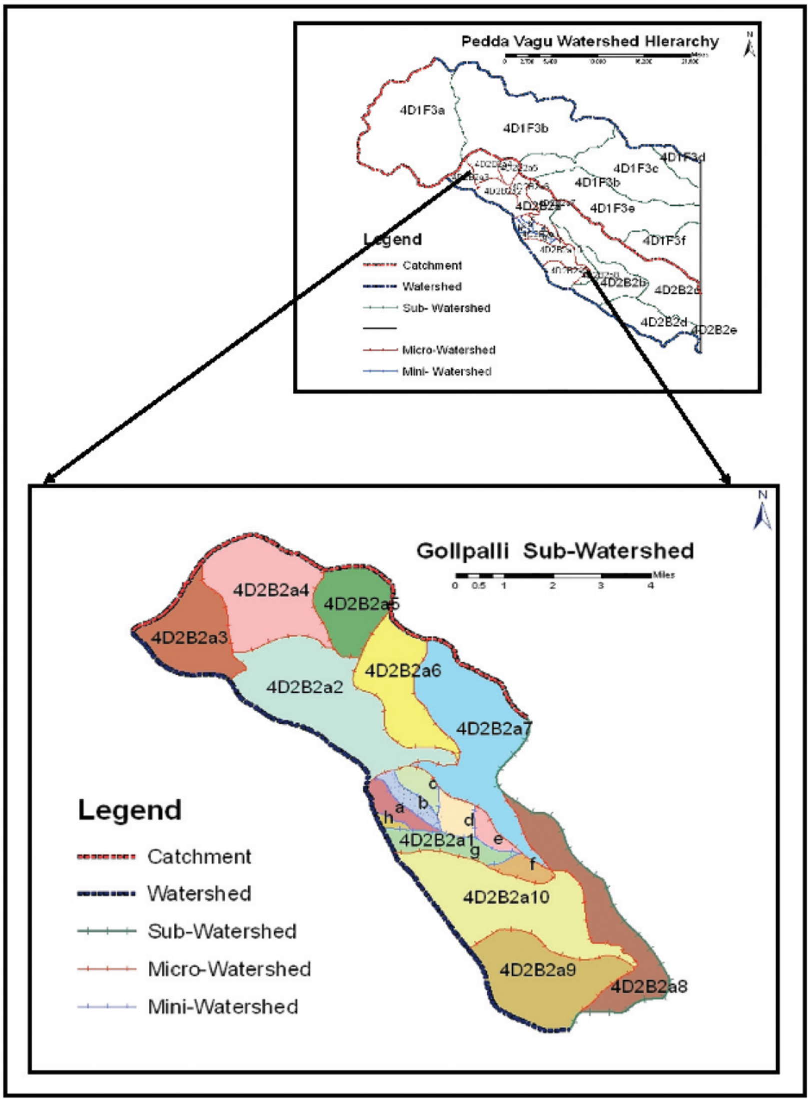


Figure 6: Nested micro-watersheds of Gollapalli village, Chintapalli Mandal, Nalgonda District

Natural resource base

The region forms part of the Deccan plateau with craggy hillocks and stone outcrops and ideally suited for WDP. The soils are predominantly *Alfisols* and associated mixed red soils while Pamana has some *Vertisols* and *Inceptisols*. Climate is typically semi-arid to dry sub-humid with rainfall ranging from 650-800 mm that is mainly received during southwest monsoon (June – Sept.). The lithology is made up of igneous rocks – granite with large fractures that have been used for tapping groundwater. The natural vegetation is typically semi-arid deciduous and thorny scrub – *babool* (*Acacia nilotica* and *Acacia arabica*), *neem (Azadirachta indica)*, tamarind *(Tamarindus indica),* guava *(Psidium gujava), sapota (Achras zapota),* palmyra palm *(Borassus flabelliafera),* custard-apple *(Annona squamosa),* gooseberry *(Emblica officinalis), ber (Ziziphus mauritiana),* agava, cactus and grasses *(Sehima-Dichanthium).*

Cropping system till the 1990s included rainfed cereal crops like sorghum (*Sorghum bicolor*) and pearl millet or bajra (*Pennisetum americanum*), besides castor bean – a non-edible oil crop (*Ricinus communis*) and pulses – pigeon pea (*Cajanus cajan*), green-gram (*Vigna radiata*), black-gram (*Vigna mungo*), horse-gram (*Macrotyloma uniflorum*), cluster-bean or guar (*Cyamopsis tetragonoloba*) and cowpea (*Vigna unguiculata*). However, since 1990s and with implementation of WDP, there has been a major shift in cropping systems. Irrigation through bore-wells resulted in large areas being brought under paddy (*Oryza sativa*) cultivation. Other dominant crops include maize (*Zea mays*), groundnut (*Arachis hypogaea*) and cotton (*Gossypium hirsutum*); the last two preferred by farmers for its' high value although low rainfall have often caused crop failure. Cultivation of castor, pearl millet and cowpea are waning. Area under oilseeds like sunflower (*Helianthus annuus*), sesame (*Sesamum indicum*) and safflower (*Carthamus tinctorius*) is on the rise. Horticulture crops like mango (*Mangifera indica*), grapefruit (*Citrus paradisi*), lime (*Citrus aurantifolia*), sweet orange (*Citrus sinensis*) and grapes (*Vitis vinifera*) are gaining. Cultivation of vegetables viz., tomato (*Lycopersicon esculentum*), chilli (*Capsicum annuum*), brinjal (*Solanum melongena*), okra or *bhindi* (*Abelmoschus esculentus*), cucurbits and carrot (*Daucus carota*) are preferred by farmers over other crops owing to market demand and easy accessibility to Hyderabad. Fodder grass such as napier (*Pennisetum parapareum*) and *para* grass (*Panicum muticum*) are in great demand.

5. Current situation in the study area

Since 2005 there have been many policy changes that have had a large impact on the way rainfed agriculture is being carried out in the region. One of the major policy issue that has positively impacted agriculture in the country especially in rainfed areas is the implementation of National Rural Employment Guarantee Scheme (NREGS) since 2007-2008. The scheme has provided livelihood security at household-level and the much- needed cash for purchase of inputs like seeds and fertilizer to undertake agricultural operations at field-level. This extraneous infusion of cash liquidity at the village-level has had a positive impact on rural livelihood and rainfed agriculture as noticed in the study area. During occurrence of drought in August 2009, dryland crops like castor and sorghum wilted in the field for want of rain while farmers were able to save paddy crop in the treated micro-watersheds through irrigation by tapping groundwater sourced at a depth of 240 ft while shallow bore wells dried up. During this period the NREGS brought relief to the farmers and helped minimize hardships due to drought that continued till mid- September 2009. Presently NREGS encompasses all villages in the study area (Photo 1 - 4). For instance in Pamana village over 60 to 70 adults hold NREGS cards and earn Rs. 100 day^{-1} under the scheme. The activities carried out are removing silt from check dams, land levelling, and bunding across slope in farmer’s fields, clearing of bush, etc. However, farmers have ignored cultivation of live bunds and reinforcement of bunds with vegetation despite incentives and distribution of seeds by Govt.

To maintain check dams in Pamana village, the Golconda Grameena Bank has granted one lakh rupees to a group of ten farmers. Besides this the *Gram panchayat* has petitioned the Govt. for monetary support for constructing a *kunta* (small tank) towards the southeast direction of the village for storing runoff and wastewater to support agriculture as they village does not have any tank for this purpose. In Pamana, social organisation is vibrant. At present over 26 SHG with 15 members each, is functioning in the village. Besides this, there is one association for the handicapped, six farmers’ associations and two watershed committees. Each household has at least one person in any one of these structures.

Besides NREGS, the state Govt., has launched a housing scheme called *Indiramma Pathakam* under which scores of houses have been constructed and distributed in the villages. For instance, in Pamana over 192 houses were sanctioned at a cost of 50,000 rupees each of which 150 have been completed and the rest are under construction. In addition to these, the pension scheme for old, handicapped and widow have brought relief to people in the villages. Health and immunization program have also been emphasised and mid-day meal and Anganwadi schemes have contributed significantly.

Apart from NREGS – a policy intervention by Govt. of India to provide livelihood security to farmers in rural areas in the country which has largely been welcomed notwithstanding its' large financial implication to the country, another policy intervention of the Congress-led Govt of Andhra Pradesh to provide free electricity to farmers since 2005, has adversely affected groundwater table due to overexploitation, thus undermining the benefits accrued through WDP in the state. This decision to provide free electricity to farming sector in the state has lead to an increase in area under paddy cultivation even in unsuitable marginal land that has accelerated the drastic fall in groundwater table. Despite the imposition of restriction on cultivation of irrigated dryland (ID) crops by the state govt., it could not be implemented rigorously. During the drought situation in August 2009, the necessity for developing assured sources of irrigation in the rainfed regions was amply clear and hence WDP would remain the bedrock for development of rainfed agriculture in the country.

Photo 1: Effectiveness of check-dam in 2006 in Pamana village, Chevella mandal, Rangareddy district and impact of drought in 2009

Photo 2: Efficacy of WDP in Pamana as evident from stream flow

Photo 3: Visit to Chintapatla village to assess drought situation in August 2009

Photo 4: Tribal farmers in Chintapatla treated watershed in March 2009

Climatic condition, change in land use, cropping pattern and status of water resources in study area

Analysis of historical rainfall data in Andhra Pradesh indicates that 65% is received during southwest monsoon while 24% precipitation occurs during northeast monsoon, 9% during summer and 2% in the winter season. The importance of southwest monsoon rainfall to the Telangana region is evident from the fact that 76% of the annual rainfall is received during this season while Coastal Andhra and Rayalaseema regions receive 59 and 56% only. The northeast monsoon contributes only 13% in case of Telengana while it accounts for 30% in case of Rayalaseema region and 29% in case of Coastal Andhra. Annual rainfall variability is high i.e., 30-40% in Telangana region and in Rayalaseema and moderately lower (20-30%) in case of

Coastal Andhra (CRIDA, 2009). Analysis of rainfall data indicated that the amount of rainfall is changing in Rangareddy affecting the production systems when compared to Nalgonda. Although the minimum and maximum temperature is not varying in Rangareddy, the minimum temperature in Nalgonda like the rest of eastern half of AP is increasing which is impacting the production systems. The range of relative humidity was seen to be low in Rangareddy when compared to Nalgonda district.

Analysis of rainfall data during 2005 indicated that the southwest monsoon set in on Telengana region on June 25 and the total rainfall received in the region was higher than the normal. For instance, in case of data obtained from CRIDA's research farm located at Hayathnagar, annual rainfall in 2005 was recorded as 1086 mm when compared to the normal (1971 – 2000) of 742 mm. Sowing of the crops in this area commenced during 26th Standard Meteorological Week (SMW) (June 25 – July 1) and was fairly completed within the next two weeks; however, a few crops were sown till the 29 SMW. The southwest monsoon withdrew from the region by the October 31, 2005 (CRIDA, 2006).

In 2006, the southwest monsoon set in on June 10 over Hyderabad and Rangareddy and the southwest monsoon rainfall received at HRF was 685 mm or 92% of the normal for the station. Sowing of most of the crops commenced during the 24th SMW while some of the crops were sown till the 30-31 SMW due to an intermittent dry spell during 26-29 SMW. Soil moisture stress in the early establishment stage of the crop resulted in stunted growth of sorghum. The southwest monsoon also withdrew earlier by a period of 10 days from the normal date. In 2007 the southwest monsoon set in on June 13, 2007 over Hyderabad and during the season, a total rainfall of 719 mm was recorded in HRF. Sowings of most crops commenced during the 23 SMW week owing to good pre-monsoon rainfall and were completed during 24-26 week. However, rainfall in the month of July was deficit by 82.2 % and the southwest monsoon withdrew one week in advance. In 2008 the southwest monsoon set in on June 9 as a very weak system resulting in light rainfall occurrence during 12 –13th June. By the end of the season the annual rainfall received at HRF was 1088 mm and most of the crops could be sown only during the 26 – 30th SMW owing to low monsoon activity. The southwest monsoon also withdrew earlier by a week (CRIDA 2009, p 7). In 2009 the vigorous pre-monsoon activity lead to a weakening of southwest monsoon and as a result the *Kharif* cropping season was lost. The revival of monsoon in September has shored up the water deficit, but the loss of cropping season has endured.

Figure 7 depicts the rainfall variability recorded in Gunegal Research Farm (GRF) of CRIDA located 10 km to the north of Chintapatla village, one of the study area. It is evident that rainfall during the southwest monsoon could range from 300 to 1000 mm while the 4-yr moving average of southwest monsoon rainfall ranges from 450-600 mm. The CV of rainfall seasons vary; while variation in Pre-monsoon could be 47%, for southwest monsoon it could be 31% and for Post-monsoon as high as 66%. Data of number of rainy days in the station from 1967 was analysed which indicated a decreasing trend (Figure 7). The CV for pre-monsoon showers was 36%, 23% in case of SMW and 42% in case of post-monsoon showers. Due to such variability in monsoon that is the bedrock of rainfed agriculture in the area, WDP have been implemented and have been welcomed by farmers.

Positive impact of WDP could be discerned in case of Chintapatla Village (Figure 8) as a result of drop in the number of migrations from the treated micro-watershed (TMW) in the village when compared to that from the untreated micro-watershed (UTMW) taken for this study as control.

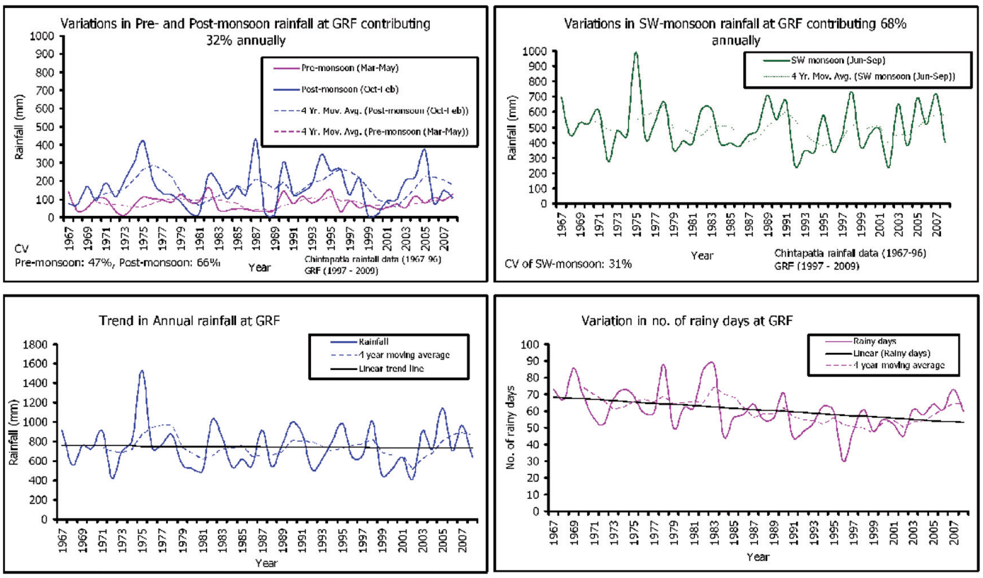


Figure 7: Variations in rainfall and number of rainy days at Gunegal Research Farm (CRIDA) near study area.

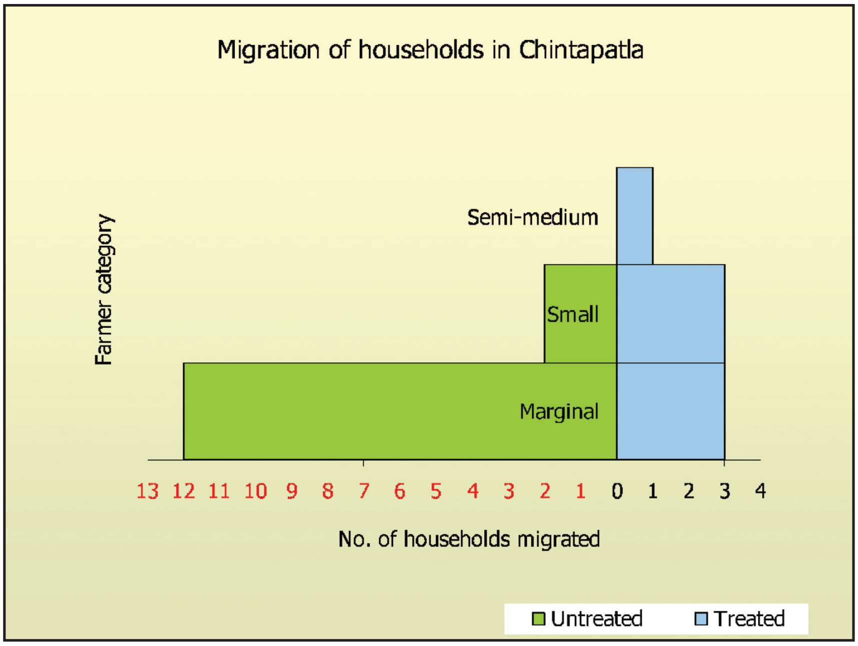


Figure 8: Migration pattern in Chintapatla (2007) (Sample size in TMW and UTMW was 82 and 58 households respectively)

Photo 5: Efficacy of WDP in Dontanpalli village, Shankarpalli mandal, Rangareddy district (Aug. 2008)

Photo 6: Efficacy of check-dam in Dontanpalli

Photo 7: Impact of WDP on land use pattern in Dontanpalli in March 2009

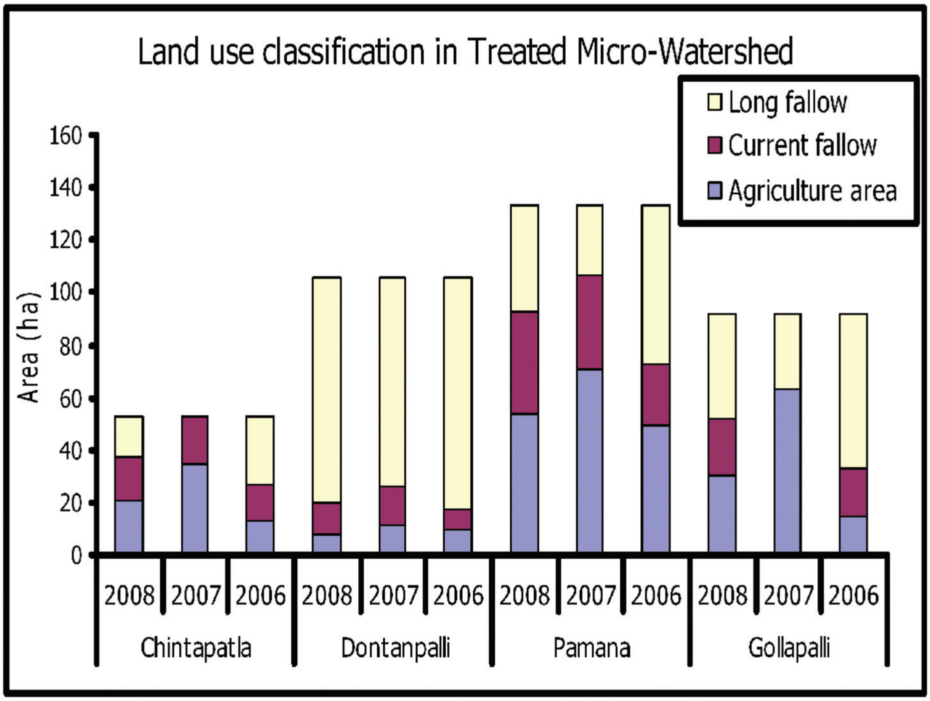
Since 2005, there has been a change in the composition of crop cafeteria in the region through partial replacement of traditional crops like sorghum and castor with paddy, vegetables – tomato, carrot, *brinjal* (egg-plant), cash crops like *chilli* and coriander, besides fruits - grapes, guava, custard apple, gooseberry, etc. This is a welcome trend as it increased economic returns from agriculture making it economically viable and increasing livelihood security among farmers. Development of forward linkages like setting up of food – processing units or development of faster mode of freight transport and adequate storage facility etc., are essential for sustaining this development (Photo 5 - 7).

Photo 8: Farm pond in Gollapalli village

Photo 9: Preparation of land for horticultural plantation financed by Govt. of AP (Gollapalli - March 2009)

Photo 10: Output from dug well during summer in Gollapalli (March 2009)

Photo 11: Effect of drought in Gollapalli - August 2009



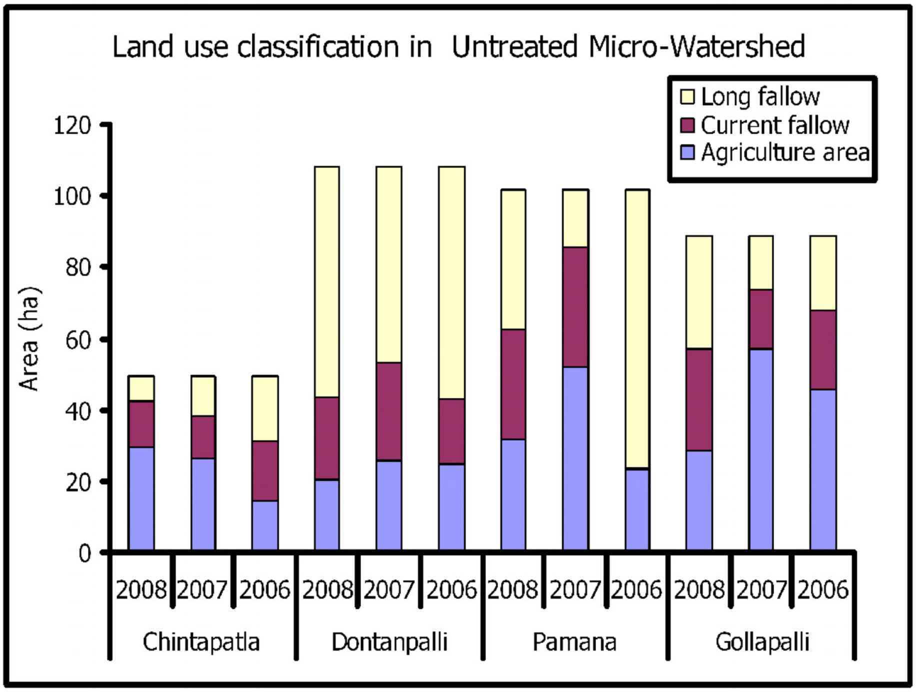


Figure 9: Land use intensity in selected micro-watersheds in study area (2006 -2008)

Area under agriculture had increased during 2008 in the selected watersheds as compared to that in 2006 due to cultivation of land under long fallow category; in fact in 2007 area under fallow shrunk due to favourable rainfall (Figure 9). In 2006, when the present study was initiated, bore-wells predominated the area due to supply of free electricity to farmers in the state. The number of bore-wells in Chintapatla was 400 in an area of 2226 ha in the village. In case of Pamana village there were 120 bore-wells in an area of 879 ha. In Dontanpalli the number of bore-wells were 300 in an area of 576 ha, followed by 70 in case of Gollapalli in 2061 ha. Besides this, the number of dug-wells in Chintapatla and Dontanpalli was over 100 in each village followed by that in Pamana - 80 and least in case of Gollapalli, i.e., 50. With the implementation of WDP it has been seen that the dug - wells have slowly increased in number in these villages (Photo 8 –11).

In Chintapatla village, over 320 ha of land was irrigated through bore-wells while tanks irrigated around 132 ha and dug-wells about 120 ha. In case of Dontanpalli, one tank and numerous dug-wells and bore-wells provided critical irrigation. Water output of dug-wells was good in the village as it is located near the Osmansagar Reservoir. In case of Pamana, bore-wells were more popular that irrigated 120 ha of agricultural land. In Gollapalli, despite its' vast extent, there were fewer number of bore-well and dug wells.

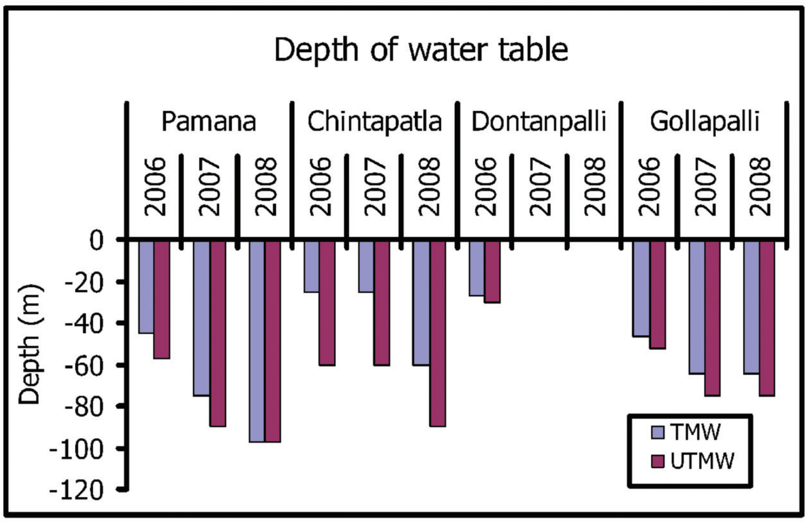


Figure 10a: Change in depth of water -table across watersheds (2006 - 2008)

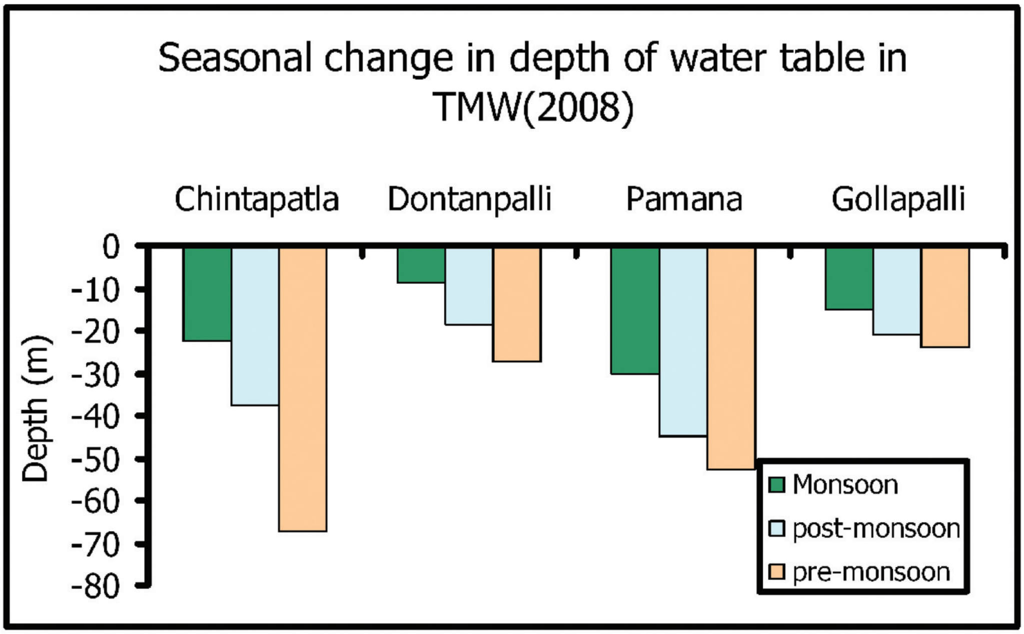


Figure 10b: Change in depth of water -table seasonally across watersheds in 2008

During the study in 2006, it was seen that in treated micro-watersheds (TMW) across the villages, the depth of water table ranged from 25.5 to 45 m with a minimum depth recorded in Chintapatla and a maximum in Gollapalli. During 2007 depth of water table ranged from 25.5 to 75 m across the villages and in 2008 it fell below 60 to 97.5 m. The fall was seen to be least in case of Chintapatla and most in case of Pamana where a number of high-value cash crops like vegetables; oilseeds and cotton were being cultivated using irrigation (Figure 10a & b). In untreated micro-watershed (UTMW), the depth of water table during 2006 ranged from 30 to 60 m with a minimum recorded in case of Dontanpalli and a maximum in case of Chintapatla. During 2007 the water table fell to 60 to 90 m across all the villages while in 2008 it fell further to 75 to 97.5 m. During 2008, minimum decline was recorded in case of Gollapalli and maximum in case of Pamana. The difference in depth of water table in TMW and UTMW indicates that WDP has helped in augmenting groundwater resource in treated watersheds however, the withdrawal is more than the recharge which is resulting in a general decline in water table. On the other hand in untreated watersheds, groundwater draft is continuing unabated leading to a continuous fall in the water table as seen in case of Chintapatla village (Figure 10a).

6. Methodology developed for *Post-facto* evaluation

The need for development of a comprehensive methodology for a *Post-facto* evaluation of WDP in rainfed regions has been felt for a long time; more so since the mid-term review of the 9th and 10th FYP in the country. The necessity to remove lacunae dogging the WDP has been felt for long. However, as evaluation studies undertaken earlier were unable to provide geo-referenced concrete solutions for implementation, necessary corrections could not be affected by the implementing agencies that proved detrimental to accruing economic returns in the short-run and ecological sustainability in the long run. The present study was undertaken precisely to address these lacunae. The primary objective of the study was thus, to use tools of Geo-informatics for making WDP sustainable. These tools could help in generating geo-referenced baseline data that could in turn support objective evaluation of WDP, a definite advantage over previous evaluation studies.

The present publication illustrates how GIS and Remote Sensing techniques could be used to generate baseline information for undertaking temporal monitoring of impact of WDP (Figure 11). As WDP encompasses a number of multidisciplinary aspects, a set of relevant sustainability indicators were identified for evaluation of each treated / developed watersheds in AESR 7.2 that encompasses Telangana region in AP. These indicators were identified based on the natural resource base conditions prevalent in the study area and the socio-economic condition of the farmers in the villages where the WDP had been implemented.

A framework was constructed to facilitate a quantitative evaluation of WDP. The entire process of *Post-facto* assessment and evaluation of WDP namely, identification of core issues that are either retarding or propelling the process of agricultural and economic development in a designated watershed, construction of relevant sustainability indicators and identification of critical indicators for evaluation of sustainability at various spatial - levels, namely, household, field and watershed - levels, etc., was developed and applied for evaluating eight micro-watersheds in Rangareddy and Nalgonda districts during 2005-2009 and the results of this work has been presented in this publication. The *Post-facto* evaluation methodology evolved from earlier studies conducted (Katyal et al., 1997; Kaushalya *et al.,* 2007, 2009) building up studies undertaken on sustainability issues namely, FAO (1993), Smyth and Dumanski (1993, 1995), Gomez *et al*., (1996) and Swete Kelly and Gomez (1998).

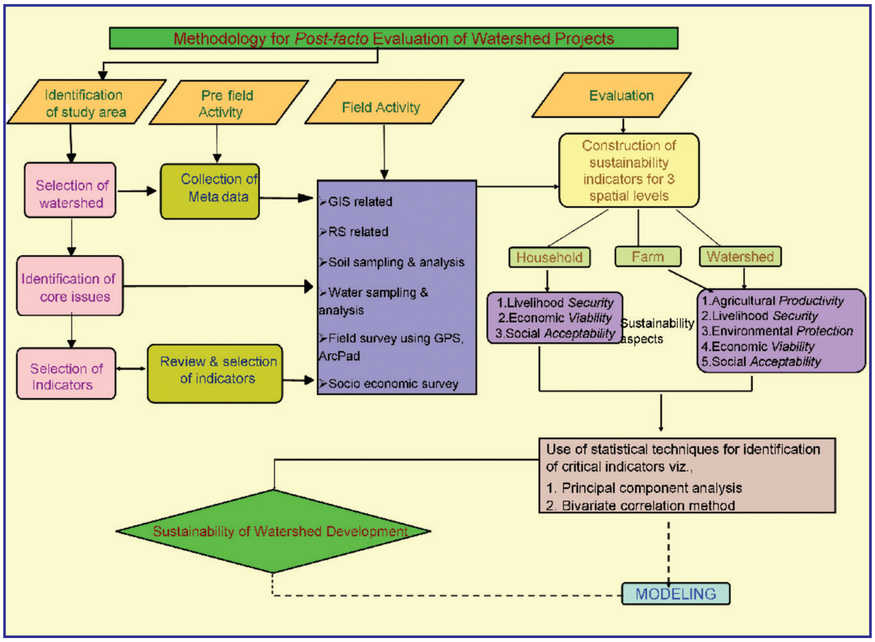


Figure 11: Methodology for *Post-facto* Evaluation of Watershed Projects

In 2005, reconnaissance survey was conducted in the selected watershed villages to identify sustainability indicators based on the core issues affecting rainfed agriculture in the region for initiating *Post-facto* evaluation of the watersheds. More than 550 geo-referenced soil samples were collected and analysed from 650 fields and 884 farm households were interviewed and socio-economic analysis was carried out. All data was archived in a geo-referenced database developed specifically for this purpose in accordance with the framework of National Natural Resource Database Management System (NRDMS) (DST, 2005).

Three of the four watersheds selected for the *Post-facto* evaluation had been developed by the Dept. of Agriculture, Govt. of AP under the DPAP program, while the fourth had been developed by an NGO named PROGRESS located at Hyderabad. In case of Chintapatla village, WDP was implemented under DPAP scheme by the

Dept. of Agri., Govt of Andhra Pradesh during the period 1994 – 1999. In Dontanpalli village, Agri. Dept., implemented WDP under DPAP scheme during 1995 - 2001. In Gollapalli, WDP was started in 1999 and concluded in 2004 while in Pamana village, an NGO named PROGRESS had implemented the program between 1994/95 and 2001.

After identification of core-issues that affected sustainability of agriculture, a suite of fifty-one indicators were developed out of which thirty –nine were used for evaluation of sustainability at household-, field- and watershed- level. The remaining 12 indicators would be used to undertake evaluation at village- and AESR- level. ***Sustainability Indicators*** based on the performance and state of various agricultural resources and production systems in the area, were constructed. In order to evaluate the impact of WDP on agricultural development, five aspects of sustainability were assessed namely, agricultural ***productivity***, livelihood ***security***, economic ***viability***, environmental ***protection*** and social ***acceptability*** (Smyth & Dumanski, 1995). Tools of GIS and remote sensing were used to evaluate the ***Performance*** of indicators like the Normalised Differential Vegetation Index (NDVI) and agricultural productivity besides the ***State*** of indicators like slope and soil nutrient gradient, besides several others as listed in Table 1. To this end, a matrix of indicators was developed in order to facilitate an impartial quantitative evaluation of the treated watersheds for which a scorecard was developed to quantify indicators that produced only qualitative information. Development of this evaluation methodology and its application for assessing the impact of WDP in eight treated and untreated micro-watersheds in Telengana region, have been described in this publication.

As mentioned earlier, the study followed an integrated approach by using modern tools of Geomatics, viz., GIS, GPS and Remote Sensing (RS) in addition to conventional techniques, like field survey and transact walk, civil survey using Total Station and topographical maps, soil sampling and analysis, socio-economic survey and Participatory Rural Appraisal (PRA). Under the Geomatics module, cadastral maps, topographical maps and satellite imagery of the selected watersheds were procured from various agencies - AP State Revenue Department and Map Sales Office; Survey of India (SOI) and National Remote Sensing Centre (NRSC), all of them located at

Hyderabad. Watershed hierarchy was identified and mapped using ***ArcGIS*** (Ver. 8.1). Catchments of 1st - order streams were nested into that of 2nd - order stream catchments which in turn, were nested into the 3rd - order stream catchments and so on. As the National Watershed Atlas (AIS & LUS, 1988) provides nomenclature for the five higher – orders of drainage network hierarchy in the country namely, Water Resource Region, River Basin, Catchments, Sub-catchments and Watershed; it was proposed by CRIDA in 1996 to further delineate the lower-end drainage network, viz., the 3rd, 2nd and 1st order streams and up-linking of them with the National Watershed Hierarchy (Katyal et al., 1996; Kaushalya et al., 2001) under the ICAR funded project - Institute Village Linkage Program (IVLP) in 1996. This method has since been accepted as a standard practice in the country with the All India Soil Survey and Land Use Planning adopting it for delineating the drainage network and micro-watersheds of the entire country.

For the study, watersheds in each of the selected villages were delineated into micro-watersheds. For instance in case of Pamana, micro-watersheds were delineated to

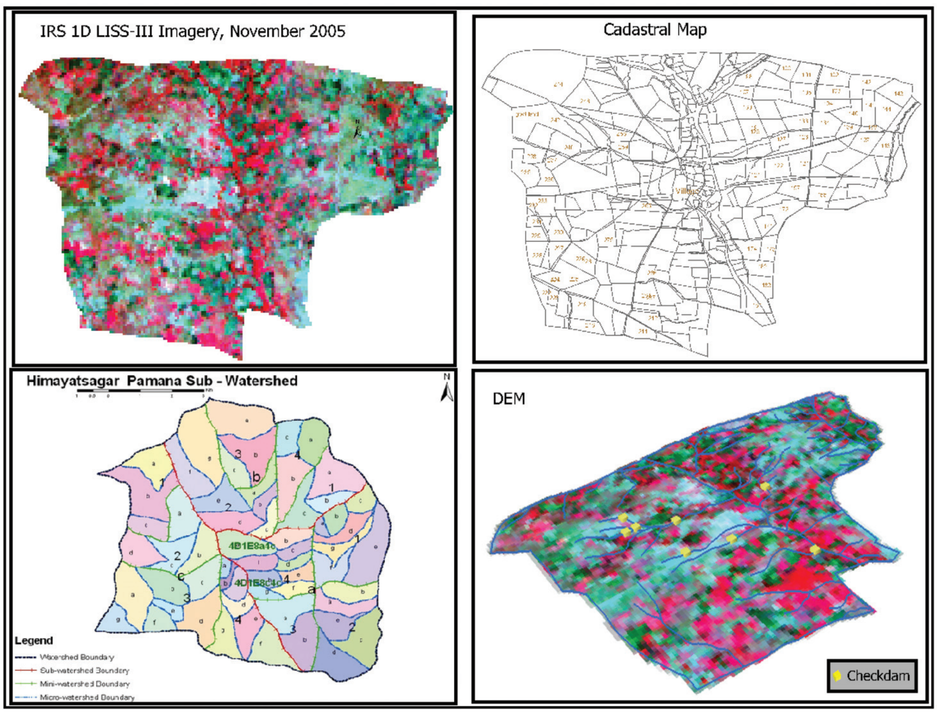


Figure 12: Digitization & delineation of watersheds using Arc GIS – Pamana Village, Chevella Mandal, Rangareddy Dist.

identify a treated or developed micro-watershed (TMW) where S&WC structures were located and an untreated micro-watersheds (UTMW) to be used as control, where no interventions were made. The nomenclature used to identify each of the selected micro-watersheds has been explained in Section 4. Micro-watersheds were delineated in a similar manner in other case of other villages also as illustrated earlier in Figures 3 – 6.

Watershed resource survey and household socio-economic survey were conducted using two structured questionnaires (Annexure 1 & 2) to measure the performance and state of sustainability indicators. Two databases – one for watershed information and another for household information - were created using ***MS-Access*** and linked to the GIS platform. Soil and water sampling and analysis for twelve physico-chemical and biological parameters were undertaken and the results were input into a Watershed Database. Satellite imageries of IRS -1D LISS-3 of 16 Nov. 1998, 17 March 2001, 16 Oct. 2004 and IRS – P6 LISS - 3 data of 4 Nov. 2005 were digitally interpreted using ***ERDAS Imagine*** (Ver. 8.7) (Figure 12) and land use, land cover and land degradation (Figure 13), NDVI maps (Figure 14) and soil fertility status (Figure 15) were prepared and the results were integrated for evaluation of the WDP in the selected villages and presented in this publication.

Identification of core issues that affect agriculture in the villages

After completion of reconnaissance survey of selected watersheds and discussion with key informants, core issues that impact agriculture in the selected watersheds were identified. These issues were related to several aspects of rainfed agriculture in the region viz.,

- *Availability of water resource* - water harvesting, utilization and safe disposal
- *Soil fertility status* – physical, chemical and biological characteristic
- *Vegetative cover* - forest area, scrubland, rangeland, CPR, environmental integrity
- *State of agriculture* – area, production, productivity

- *Social structure in the village* – mobilization of people, water user's group, social fencing, awareness, enhancement of technical skills, empowerment, food security, etc.
- *Economic structure within the village* – source of livelihood, gainful employment, quality of life, dependence on government aid, etc.
- *Institutional support* – Government initiatives and support, economic policy, macro- economics, socio-political conditions, etc.

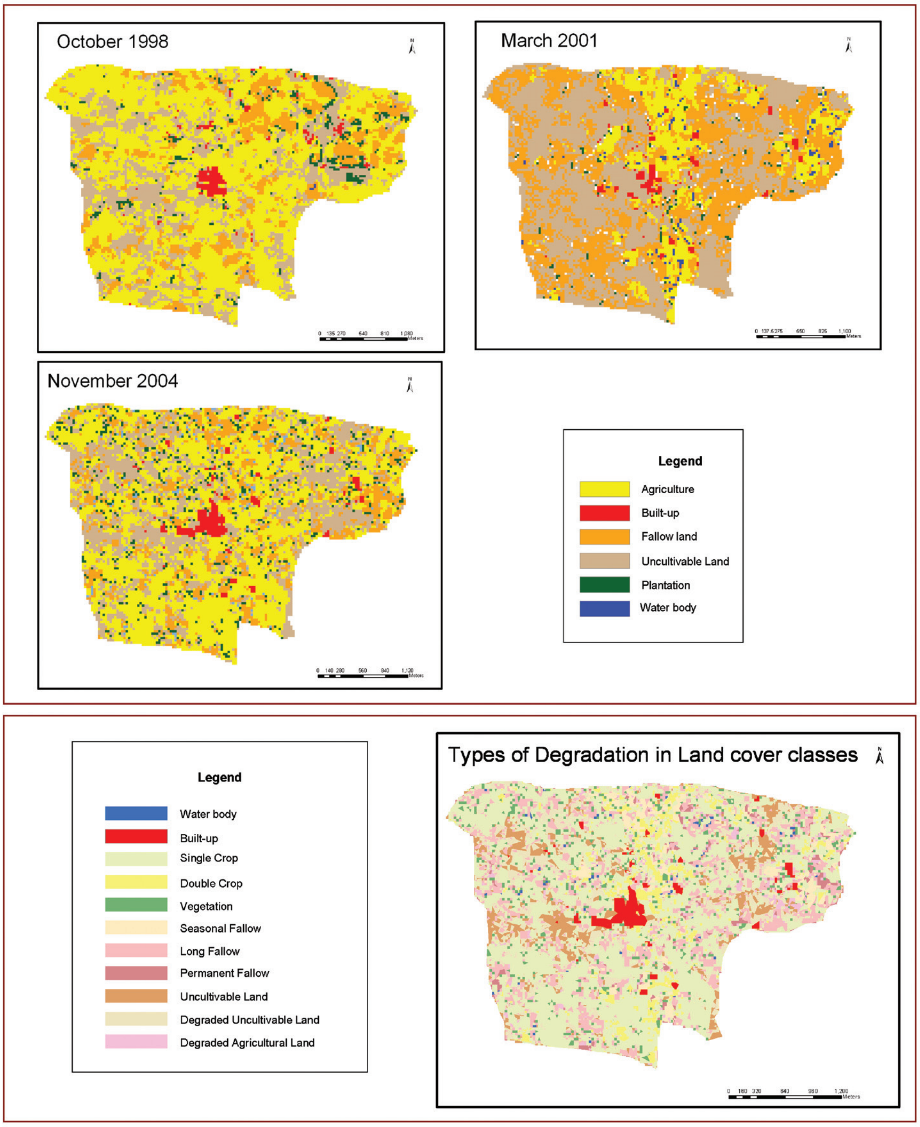


Figure 13: Land use land cover & degradation of land cover in Pamana

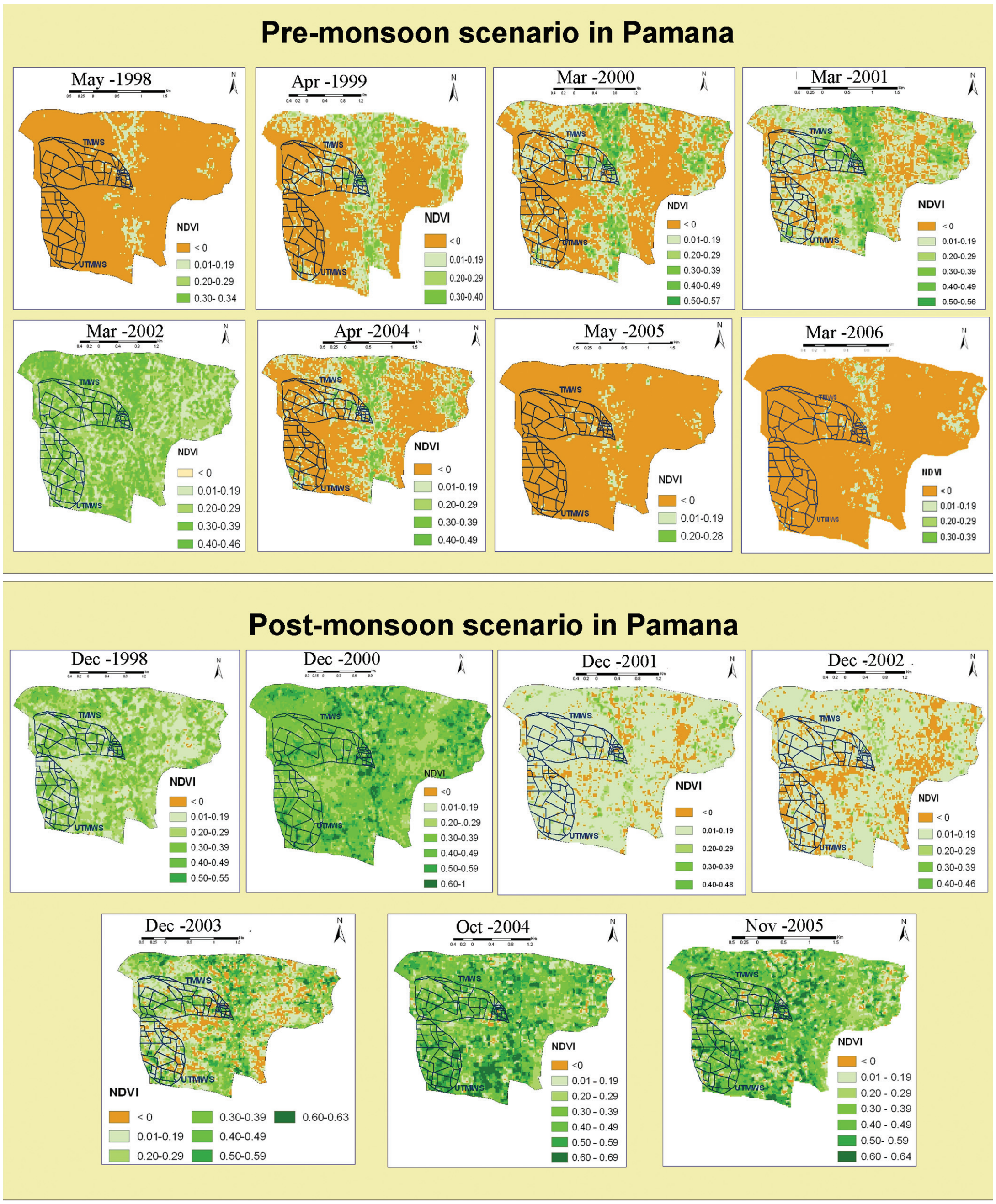
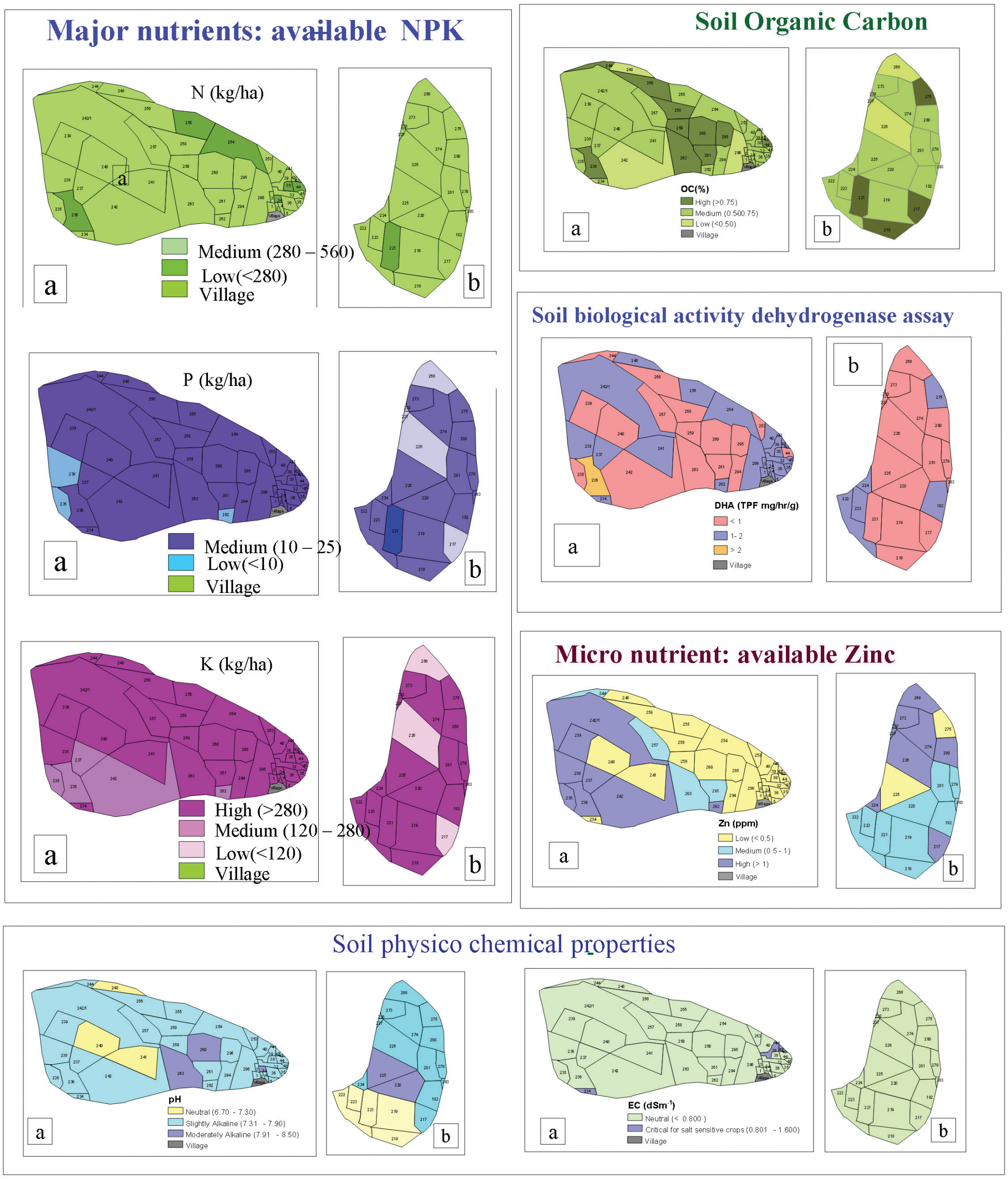


Figure 14: NDVI mapping in pre- & post-monsoon season in Pamana



a – TMW & b - UTMW

Figure 15: Soil fertility status at Pamana watersheds

Selection of indicators

In order to study the diverse aspects of rainfed agriculture and the impact of WDP on the core issues impacting rainfed agriculture in the study area, sustainability indicators were used. Although, initially this number was considered large, it was soon realised that in order to avoid overlooking any crucial source of information during the evaluation study, it was essential. After collection of all pertinent data, statistical analysis using *Bivariate Correlation (BVC)* and Principal Component Analysis (*PCA)* were undertaken to identify the critical indicators essential for carrying out a detailed study, thus solving the problem of multiplicity of indicators, if any. After four years of evaluation studies, it has been possible to identify ***a minimum dataset of relevant indicators*** for each spatial-level – household (HH), Field (FL) and watershed (WL) that could be used to evaluate and also to implement WDP projects for sustainable development, in future.

7. Construction of Sustainability Indicators

Sustainability is a vast subject, however, there is a consensus among researchers that there are five pillars of sustainability, namely *productivity, viability, security, protection* and *acceptability* (Smyth & Dumanski, 1995). Under the ***Framework for Evaluation of Sustainable Land Management*** (FAO, 1993) developed by an International Working Group (IWG), a procedure was recommended to evaluate sustainability of current and alternative land-use systems. This was an extension of the ***Framework for Land Evaluation*** put forth by FAO in 1976 except that evaluations were based on indicators of performance over time, rather than land suitability as indicated by FAO (1998). While initiating this study, the FESLM approach was found suitable and hence it was adequately modified and adapted to the present study. The adaptation required development of relevant indicators and a methodology to undertake a quantitative evaluation of impact of WDP in the study area.

Construction of sustainability indicators was based on deductive analysis. For instance, issues of natural resource availability viz., soil, water and vegetation affect diversity and intensity of land use, and thus have an impact on the *economic viability* of agricultural enterprise in the watershed or the village as a whole. Land quality and land use practices of farmers' impact the *livelihood security* of the farmers while better awareness among farmers have a positive impact on the *environmental protection* of the natural resources on which rainfed agriculture is based. *Economic* *viability* of the agricultural operations could be understood by analysing the issues that affect societal value of farmland besides impacting the risk-buffering capacity of the community and equity among them. Rural livelihood options and human well - being are vital for *social acceptability* of projects like the WDP without which sustainable development is unthinkable. These issues guided the construction of the fifty-one sustainability indicators used for this study.

Due to the multidisciplinary nature of evaluation procedure for WDP, a multitude of ***performance*** and ***state*** indicators were constructed. Several of these could be measured directly, viz., *soil fertility level* (N, P, K) or could be expressed quantitatively like *size of landholding,* while others could be indicated only qualitatively viz., *migration, awareness among farmers, adoption of crop contingency plans*, *farm OM recycling*, etc. In order to analyse all these aspects that could influence sustainability of WDP, thirty-nine indicators were used as listed in Table 2. A scorecard was developed to quantify the qualitative data that lead to the development of a composite evaluation procedure that was objective. Hence this methodology is considered an improvement over all earlier evaluation procedures of WDP that was adopted or followed by various authors and agencies in India.

Table 2. Sustainability Indicators based on *Performance* and *State* for evaluation of WDP

Unique no.	Spatial level / Sustainability issue / Sustainability indicator	Source of data	Method of analysis	Scoring technique for assessing sustainability
Household-level				
Livelihood Security aspect				
1	Size of landholding	Land records / Socio-economic survey / primary data	Land records data with GIS input	Actual value (ha)
2	Total Crop production	Socio-economic survey, RS data	Field data	Actual value (t)
3	Availability / Cultivation of fodder	Socio- eco / Field Survey, NDVI, RS data	Purchase / no livestock Crop residue Collection from CPR Growing fodder	0 - Unsustainable 1 - Low 2 - Medium 3 - High
4	Gross agricultural income	Socio-eco survey, WPI, Dist. Statistics	Field data	Actual value (agri. production) (Rs.)
5	Security of tenure	Socio-eco survey, Interviews & Village records, Panchayat Office	Leased land Own land	0 - Low 1 - High
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data	No planning Plan implementation	0 – Unsustainable 1 - Sustainable
7	Per capita land availability	Socio-economic survey, interviews, Panchayat	Size of land holding / No. of family members	Actual value (ha)
8	Nutritional security among women & children	Socio-eco survey & interview with SHG, extension agents	Prevalence Non - prevalence	0 – Unsustainable 1 – Sustainable
9	Availability of irrigation facility	Primary data, Survey, Remote sensing	**By quantity** Inadequate Scarce Adequate	0 – Unsustainable 1 – Moderate 2 – Sustainable
			By sources Rainfed Borewell Dugwell Tank	0 – Unsustainable 1 – Low 2 – Moderate 3 – High

10	Input cost	Socio-eco survey, interviews & WPI	Cost A (working capital + (1% interest on working capital * (crop duration in **months /2))** Working capital (seed cost+ labour charges+fertilizer cost+ equipment charges+land revenue+ depreciation on farm implements) (Johl & Kapur, 1992)	Actual value (Rs.)
11	Equity		Statistical techniques (Wessa, 2008) Statistics and Forecasting software Ver.1.122-r6)	Actual value
Economic viability aspect				
12	Net income	Socio-eco survey & WPI	Gross agricultural income+ livestock income + labour income - cost of cultivation (Cost A)	Actual value (Rs.)
13	Extent of migration	Socio-eco survey & interviews, MRO	No. of families forced to migrate Permanent migration Seasonal No migration	 1 – Unsustainable 2 – Moderate 3 – High
10	Input cost	Socio-eco survey, interviews & WPI	As indicated earlier	
14	Market accessibility	Socio-eco survey, GIS maps, Dist. Handbooks	No cultivation Local businessman Local market Govt. market	0 – Unsustainable 1 – Low 2 – Moderate 3 - Sustainable
15	Transport facility		No facility for sale Local Private (Lorry / Van) Govt. (Bus)	0 – Unsustainable 1 – Low 2 – Moderate 3 – Sustainable
16	Gainful employment	Socio-eco survey & Interviews, Panchayats, SHG	Migration Working as labour Cultivation in both seasons	0 – Unsustainable 1 – Moderate 2 – Sustainable
8	Nutritional security among women & children	Socio-eco survey & interview with SHG, extension agents	As indicated earlier	

Social acceptability aspect				
17	Credit facility	Socio-eco survey & interview with SHG, Co-op banks& PSU	Local Money lender/ Poor farmer	0 – Unsustainable
			Public-sector Bank Co-operative Society	1 – Low 2 – Medium
			Self -Help -Group (SHG) / Self finance	3 – High
18	Membership of Watershed Committee	Socio-eco survey & interview with Panchayat & Mandal Dev. Officer	No membership Committee membership	0 – Unsustainable 1 – Sustainable
19	Avail./consumption of fuel wood	Socio-economic survey, Panchayat, RS data	As indicated earlier	
3	Availability / Cultivation of fodder	Socio- eco / Field Survey, Panchayat & RS data		
20	Participation in Govt. sponsored programs	Govt. policy report / Socio-economic survey, SHG	No policy Some policy Program in action	0 – Unsustainable 1 – Moderate 2 – Sustainable

Field -level				
Agricultural Productivity aspect				
21	Cereal yield	RS data analysis & correlation with socio-economic survey	Field data	Actual value (t/ha)
22	Aggregate yield (Other crops excl. cereals)			
9	Availability of irrigation facility	Primary data, Survey, temporal analysis of satellite data & GIS	As indicated earlier	
2	Total Crop production	Socio-economic survey, RS data		
4	Gross agricultural income	Socio-eco survey, WPI, Dist. Statistics		
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques	Available N (kg/ha) < 240 240 to 560 > 560	1 –Low 2 – Medium 3 –High
			Available P (kg/ha) < 10 10 to 25 > 25	1- Low 2 – Medium 3 – High
			Available K (kg/ha) < 140 140 to 280 > 280	1 – Low 2 –Medium 3 – High
24	Soil OC	Soil survey & analysis, RS data	< 0.5 0.5 to 0.75 > 0.75	1 –Extreme limit. 2 - Severe limit. 3-Moderate limit.

25	Farm OM recycling	Field survey & interviews, RS data	As indicated earlier	
26	S& WC structures	Field survey & interviews, DGPS, RS & GIS	No Check dam (CD)	0 – Unsustainable 1– Low
			Stone weir & CD	2 – Fairly low
			Only mech. structures	3 – Moderate
			All cons. practices incl. biol. measures	4 – Highly sustainable
16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG	As indicated earlier	
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data		

Livelihood security aspect				
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques	As indicated earlier	
24	Soil OC			
1	Size of landholding	Land records / Socio-eco survey primary data	As indicated earlier	
27	Soil depth	Field survey, RS data	Depth (cm)	
			< 15	0 – Unsustainable
			15 to 30	1 – Low
			30 to 50	2 – Medium
			> 50	3 – High
9	Availability of irrigation facility	Primary data, Survey, temporal analysis of satellite data & GIS	As indicated earlier	
28	Slope	SOI Toposheet, DGPS, Satellite data	Slope (in per cent)	
			9 to 12	0 – Unsustainable
			6 to 8	1 - Low
			4 to 5	2 – Moderate
			0 to 3	3 - Highly sustainable
4	Gross agricultural income	Socio-eco survey, WPI, Dist. Statistics	As indicated earlier	
2	Total Crop production	Socio-economic survey, RS data		
5	Security of tenure	Socio-eco survey, Interviews & Village records, Panchayat Office		
3	Availability / Cultivation of fodder	Socio- eco / Field Survey		
29	Change in Land Cover	Field survey, RS data, GIS	>10	0 – Low
			5 to 10	1 – Steady
			< 10	2 – Rapid
30	Crop Diversity Index	Field Survey, Satellite data, GIS	No. of crop / total size of landholding	Actual value

31	Crop Cafeteria Index	Field survey, Satellite data, GIS	Cropped area/ Total culturable area	Actual value
39	Economic returns from a unit of land area	Field survey, Secondary data, WPI	Farm income/ Size of land holdings	Actual value (Rs./ha)
33	Visible soil erosion	Satellite data, field survey, GIS	Area eroded (%) > 50 25 to 50 10 to 25 < 10 0	 0 – Unsustainable 1 – Low 2 – Medium 3 – High 4 – Stable
25	Farm OM recycling	Field survey & interviews, RS data	As indicated earlier	
26	S& WC structures	Field survey & interviews, DGPS, RS & GIS	As indicated earlier	
10	Input cost	Socio-eco survey, interviews & WPI		
17	Credit facility	Socio-eco survey & interview with SHG, Co-op banks& PSU		
16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG		
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data		
34	Soil moisture conservation measures	Field survey, RS data, GIS	Not practiced Limited practice Fully practiced	0 – Unsustainable 1 – Moderate 2 – Sustainable
Environmental protection aspect				
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques	**As indicated earlier**	
30	Crop Diversity Index	Field Survey, Satellite data, GIS		
31	Crop Cafeteria Index	Field survey, Satellite data, GIS		
25	Farm OM recycling	Field survey & interviews, RS data		
35	Deforestation rate	RS (temporal data) GIS (Farm forestry data)	Deforestation = (Previous data - Current **data)/Previous data**	100 % = 0 (Unsustainable) 100 to 50 =1 50 to 0 = 2 (Moderate)
			Forestation = (Previous data - Current data)/ Current data	0 to 50 = 3 50 to 100 = 4 100 = 5 (highly sustainable)
26	S& WC structures	Field survey & interviews, DGPS, RS & GIS	As indicated earlier	
3	Availability / Cultivation of fodder	Socio- eco / Field Survey		
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data		
29	Change in Land Cover	Field survey, RS data, GIS		

28	Slope	SOI Toposheet, DGPS, Satellite data	As indicated earlier
33	Visible soil erosion	Satellite data, field survey, GIS	
24	Soil OC	Soil survey & analysis	
32	Role of extension agents	Socio-eco survey & interviews, MRO	
5	Security of tenure	Socio-eco survey, Interviews & Village records, Panchayat Office	
34	Soil moisture Conservation measures	Field survey, RS data, GIS	

Economic viability aspect				
4	Gross agricultural income	Socio-eco survey, WPI, Dist. Statistics	As indicated earlier	
10	Input cost	Socio-eco survey, interviews & WPI		
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques		
14	Market accessibility	Socio-eco survey, GIS maps, Dist. Handbooks		
15	Transport facility	Socio-eco survey & interviews		
1	Size of landholding	Land records / Socio-eco survey primary data		
9	Availability of irrigation facility	Primary data, Survey, temporal analysis of satellite data & GIS		
30	Crop Diversity Index	Field Survey, Satellite data, GIS		
24	Soil OC	Soil survey & analysis		
2	Total Crop production	Socio-economic survey		
25	Farm OM recycling	Field survey & interviews, RS data		
26	S& WC structures	Field survey & interviews, RS data		
17	Credit facility	Socio-**eco survey & interview with** SHG, Co-op banks& PSU		
5	Security of tenure	Socio-eco survey, Interviews & Village records, Panchayat Office	As indicated earlier	
36	Market price of farmland	Socio-economic survey, MRO	High competing demand for land Low demand	1 – Low 2 – High
16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG	As indicated earlier	
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data		
3	Availability / Cultivation of fodder	Socio- eco / Field Survey		
32	Role of extension agents	Socio-eco survey & interviews, MRO		
34	Soil moisture Conservation measures	Field survey, RS data, GIS		

Social acceptability aspect			
25	Farm OM recycling	Field survey & interviews, RS data	As indicated earlier
26	S& WC structures	Field survey & interviews, RS data	As indicated earlier
16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG	
17	Credit facility	Socio-eco survey & interview with SHG, Co-op banks& PSU	
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques	
24	Soil OC	Soil survey & analysis	
32	Role of extension agents	Socio-eco survey & interviews, MRO	
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data	
35	Deforestation rate	RS (temporal data) GIS (Farm forestry data)	
3	Availability / Cultivation of fodder	Socio- eco / Field Survey	
34	Soil moisture Conservation measures	Field survey, RS data, GIS	

Watershed -level				
Agricultural productivity aspect				
21	Cereal yield	RS data analysis & correlation with socio-economic survey	As indicated earlier	
22	Aggregate yield (Other crops excl. cereals)	Socio-economic survey		
9	Availability of irrigation facility	Primary data, Survey, temporal analysis of satellite data & GIS		
2	Total Crop production	Socio-economic survey		
4	Gross agricultural income	Socio-eco survey & interviews		
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques		
24	Soil OC	Soil survey & analysis		
25	Farm OM recycling	Field survey & interviews, RS data		
26	S& WC structures	Field survey & interviews, RS data		
16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG		
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data		
34	Soil moisture Conservation measures	Field survey, RS data, GIS		
37	Change in cultivated area	Satellite data, field survey, GIS	Fallow area (%) > 50 50 to 25 < 25 Seasonal	 1 – Unsustainable 2 – Moderate 3 – Sustainable 4 – High

			Land degr. / problem area (%)	
			> 75	0 – Unsustainable
			50 to 75	1 – Low
			25 to 50	2 – Moderate
			10 to 25	3 – Sustainable
			< 10	4 – High
38	Yield gap	Primary data, Survey, Satellite data, MRO	Actual yields / target **farm** yields	Actual value
Livelihood security aspect				
1	Size of landholding	Land records / Socio-eco survey primary data		As indicated earlier
9	**Availability of irrigation** facility	Primary data, Survey, temporal analysis of satellite data & GIS		
28	Slope	SOI Toposheet, DGPS, Satellite data		
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques		
24	Soil OC	Soil survey & analysis		
27	Soil depth	Field survey, RS data		
2	Total Crop production	Socio-economic survey, RS data		
4	Gross agricultural income	Socio-eco survey, WPI, Dist. Statistics		
3	**Availability / Cultivation** of fodder	Socio- eco / Field Survey		
30	Crop Diversity Index	Field Survey, Satellite data, GIS		
31	Crop Cafeteria Index	Field survey, Satellite data, GIS		
39	Economic returns from a unit of land area	Field survey, Secondary data, WPI		
5	Security of tenure	Socio-eco survey, Interviews & Village records, Panchayat Office		
25	Farm OM recycling	Field survey & interviews, RS data		
26	S& WC structures	Field survey & interviews, RS data		
16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG		
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data		
33	Visible soil erosion	Satellite data, field survey, GIS		As indicated earlier
10	Input cost	Socio-eco survey, interviews & WPI		
17	Credit facility	Socio-eco survey & interview with SHG, Co-op banks& PSU		
29	Change in land cover	Field survey, RS data, GIS		
34	Soil moisture conservation measures	Field survey, RS data, GIS		
37	Change in cultivated area	Satellite data, Primary data, Survey		
13	Extent of migration	Socio-eco survey & interviews, MRO		
11	Equity	Socio-eco survey & interview, SHG, Panchayat		
20	Participation in Govt. sponsored programs	Govt. policy report / Socio-economic survey, SHG		
7	Per capita land availability	Socio-eco survey & interviews		

Environmental protection aspect			
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques	As indicated earlier
25	Farm OM recycling	Field survey & interviews, RS data	
30	Crop Diversity Index	Field Survey, Satellite data, GIS	
31	Crop Cafeteria Index	Field survey, Satellite data, GIS	
35	Deforestation rate	RS (temporal data) GIS (Farm forestry data)	As indicated earlier
24	Soil OC	Soil survey & analysis	
26	S& WC structures	Field survey & interviews, DGPS, RS & GIS	
6	Contingency crop planning	Field survey, Govt. policy, report, RS data	
3	Availability / Cultivation of fodder	Socio- eco / Field Survey	As indicated earlier
29	Change in land cover	Field survey, RS data, GIS	
33	Visible soil erosion	Satellite data, field survey, GIS	
28	Slope	SOI Toposheet, DGPS, Satellite data	
32	Role of extension agents	Socio-eco survey & interviews, MRO	
5	Security of tenure	Socio-eco survey, Interviews & Village records, Panchayat Office	
34	Soil moisture conservation measures	Field survey, RS data, GIS	
13	Extent of migration	Socio-eco survey & interviews, MRO	
37	Change in cultivated area	Satellite data, Primary data, Survey	

Economic viability aspect			
1	Size of landholding	Land records / Socio-eco survey primary data	As indicated earlier
9	Availability of irrigation facility	Primary data, Survey, temporal analysis of satellite data & GIS	
4	Gross agricultural income	Socio-eco survey, WPI, Dist. Statistics	
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques	
30	Crop Diversity Index	Field Survey, Satellite data, GIS	
10	Input cost	Socio-eco survey, interviews & WPI	
14	Market accessibility	Socio-eco survey, GIS maps, Dist. Handbooks	
15	Transport facility	Socio-eco survey & interviews	
2	Total Crop production	Socio-economic survey, RS data	
24	Soil OC	Soil survey & analysis	As indicated earlier
25	Farm OM recycling	Field survey & interviews, RS data	
26	S& WC structures	Field survey & interviews, DGPS, RS & GIS	

16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG	As indicated earlier
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data	
3	Availability / Cultivation of fodder	Socio- eco / Field Survey	
17	Credit facility	Socio-eco survey & interview with SHG, Co-op banks& PSU	
5	Security of tenure	Socio-eco survey, Interviews & Village records, Panchayat Office	
36	Market price of farmland	Socio-economic survey, MRO	
34	Soil moisture conservation measures	Field survey, RS data, GIS	As indicated earlier
13	Extent of migration	Socio-eco survey & interviews, MRO	
7	Per capita land availability	Socio-eco survey & interviews	
11	Equity	Socio-eco survey & interview, SHG, Panchayat	

Social Acceptability aspect			
23	Soil fertility	Soil survey & analysis, Geo-statistical techniques	As indicated earlier
24	Soil OC	Soil survey & analysis	
26	S& WC structures	Field survey & interviews, DGPS, RS & GIS	
16	Gainful employment	Socio-eco survey & Interviews, Panchayat, SHG	
6	Contingency Crop Planning	Field survey, Govt. policy, report, RS data	As indicated earlier
3	Availability / Cultivation of fodder	Socio- eco / Field Survey	
32	Role of extension agents	Socio-eco survey & interviews, MRO	
17	Credit facility	Socio-eco survey & interview with SHG, Co-op banks& PSU	
35	Deforestation rate	RS (temporal data) GIS (Farm forestry data)	
34	Soil moisture conservation measures	Field survey, RS data, GIS	
11	Equity	Socio-eco survey & interview, SHG, Panchayat	
20	Participation in Govt. sponsored programs	Govt. policy report / Socio-economic survey, SHG	
38	Yield gap	Primary data, Survey, Satellite data, MRO	
13	Extent of migration	Socio-eco survey & interviews, MRO	
25	Farm OM recycling	Field survey & interviews, RS data	

Indicators relevant for use at Village - and AESR -level				
Unique no.	Spatial level / Sustainability issue / Sustainability indicator	Source of data	Method of analysis	Scoring technique for assessing sustainability
40	Crop intensity index	Field survey, RS data, GIS	% of permanent crop area/ Total cultivable land	1 - Low 2 - Medium 3 - High
41	Sediment load in surface flow	Field survey, RS data, GIS	High sediment Low sediment	0 - Unsustainable 1 - High
42	Salinity in Water (TDS) in irrigation water	Field survey, Water analysis	High TDS level TDS level in fresh water	0 - Unsustainable 1 - Sustainable
43	Societal value of land	Field survey, RS data, GIS, Socio-eco survey	Accessibility (High)	0 - Unsustainable
			Accessibility (Low)	1 - Sustainable
44	Predicted/ actual soil erosion	USLE, Monitoring, Modelling through recorded observation	Exposed roots, rills & gullies, reduced top soil depth & change in soil color indicating subsoil exposure	0 -Unsustainable
			Some S&WC measures Mechanical & live bunding, SWC	1 - Low 2 - Fairly Low
			Bunding , SWC, minimum tillage	3 - Moderate
			Minimum tillage, live bunding, SWC, Cover crop	4 - Moderately high
			Ground cover & SWC	5 - High
45	Land users awareness-participation in farmer associations	Socio-eco survey & interview	No participation Limited participation Active participation	0 - Unsustainable 1 - Moderate 2 - Sustainable
46	Sale of small & marginal holdings	Socio-eco survey, Field survey, RS data, GIS	High Many Few None	0 - Unsustainable 1 - Low 2 - Moderate 3 - Sustainable
47	Increase in number of landless people	Socio-eco survey & interviews	As % of village / watershed population > 50% 30 - 50 10 - 30 5 - 10 < 5%	0 - Unsustainable 1 - Low 2 - Moderate 3 - Moderately high 4 - Sustainable
48	Inter-sectoral linkage	Policy Review, Govt. & Business publications	No agriculture based industry Few agro-horticulture industrial units Complete agro-industry linkage	0 - Unsustainable 1 - Moderate 2 - Sustainable
49	Gender-related issues	Socio-economic survey& interviews	No. role in local politics or associations Limited role Role in politics, decision making, Chairman of Panchayat board	0 - Unsustainable 1 - Moderate 2 - High

50	Food self-sufficiency	Socio-eco survey, interviews	Low purchasing power Dependent on PDS Ability to purchase food from market	0 - Unsustainable 1 - Moderate 2 - Sustainable
51	Export/ import substitution	Govt. Policy paper	No Policy Policy provision	0 - Unsustainable 1 - Sustainable

Steps for Data Generation and Analysis:

The methodology for evaluation of WDP comprises of fieldwork for reconnaissance survey initially besides soil sampling and conducting socio-economic survey; lab work comprised of soil analysis, construction of relevant indicators, database creation, interpretation of satellite data and mapping, and finally analysis of impact of WDP.

Step 1: Undertaking field survey:

Field surveys were conducted annually during the months of Jan. – Mar., May – June, and Sept – Nov. from 2005 onwards to collect socio-economic data from farmers of each of the eight micro-watersheds selected for the study. Data from each household and each field in the selected micro-watershed was collected. Table 3 indicates the number of farmers and fields present in each watershed in all four villages while Table 4 indicates the number of farm households and fields included in the present study.

Table 3: Number of Households and farm holdings in selected watersheds

	Household (Number of farmer)		Farm -holding (Number of sub-division)	
	TMW	UTMW	TMW	UTMW
Chintapatla	82	58	181	214
Dontanpalli	47	55	74	114
Pamana	119	70	256	167
Gollapalli	62	49	129	106

Source: Village Pahani records collected form respective Mandal Office

Table 4: Number of households and farm-holdings surveyed in selected watershed

	Total Household data collected				Total Farm-holding data collected			
	2007		2008		2007		2008	
	TMW	UTMW	TMW	UTMW	TMW	UTMW	TMW	UTMW
Chintapatla	61	41	72	39	87	95	106	133
Dontanpalli	22	34	19	25	52	83	32	75
Pamana	91	48	74	49	188	112	183	99
Gollapalli	45	49	42	31	77	98	104	72

Step 2: Geo-referencing of soil sampling sites

Step 3: Geo-referencing of S&WC structures and updating field boundary.

Initiating Lab work:

Step 4: Preparation of database in ***MS-Access,*** to store data in the form of Tables. In all, fourteen tables were prepared to store information pertaining WDP, For e.g., in the database Table-II related to resource base in the watershed / village; Table- III to landholding information, table-IV for land use, table-V for household information; table-VI for recording farm assets, table-VII for cropping pattern details; table-VIII for soil information; table-IX for agricultural production, table-X for livestock data; table-XI for credit facility; table-XII for market details, XIII for enumerating role of women, table-XIV for recording farmer's perception on risks information on cottage industry in the village, and so on.

Step 5: Development of an application in ***Dot Net*** for entering data in database by using Forms and Database as *back-end* of application besides undertaking small calculations and assigning scores while entering data into the database. If indicator contained quantitative values, for e.g., size of land holding, agricultural production, etc., values were stored directly. For storing qualitative data, programming was done to get the necessary result. For indicator s*ecurity of tenure* programming was done using *if* condition; in the *Landholding Form*, an input control named **Land Ownership** was set. Using ***if*** condition, scores were assigned as follows:

For '*Leased Land'* the score assigned was '0'

For '*Own land'* the score assigned was '1'

Step 6: Conversion of *MS -Access* Database Tables into *MS-Excel* for setting indicators for initiating evaluation at three spatial levels as mentioned earlier, namely - household, farm and watershed-levels and five aspects of sustainability viz., Livelihood *Security*, Economic *Viability*, Agricultural *Productivity*, Environmental *Protection* and Social *Acceptability*.

Steps 1 to 6 are common and are a prerequisite for screening for identifying critical indicators.

Step 7: Screening for critical indicators using two statistical techniques – *Bivariate Correlation* technique and *Principal Component Analysis.* These methodologies have been explained in detail in Step 8 and 9.

Step 8: Methodology for identifying critical indicators using *Bivariate Correlation (BVC)* technique

SPSS (Ver.16.0) was used to screen for critical indicators for the study and the methodology followed was as follows. From the Main Menu of *SPSS ver.16.0 for Windows,* the following items were chosen:

Analyze

Correlate

Bivariate

To start analysis, a minimum of two variables were selected for which the following options are available:

Correlation Coefficients - For quantitative, normally distributed variables, the *Pearson's Correlation Coefficient Technique* was chosen. If data was not normally distributed or had ordered categories, then one had to choose a *Kendall's tau-b* or a *Spearman*'s *- rho*, which measured the association between the scores or the orders. While interpreting the results, care was taken not to draw any cause-and-effect conclusion owing to any significant correlation (SPSS 16.0 for Windows help).

Testing Significance - One could select a two-tailed or a one-tailed probability method. If the direction of association was known in advance, one must select a one-tailed method, otherwise a two-tailed method was found more suitable. Significant correlations were flagged with *asterisk.*

For the present study, the following algorithm was used for identifying critical indicators.

Example: Algorithm for assessing impact of WDP on Agricultural ***Productivity*** at ***field-level:***

Step a: To assess sustainability of Agricultural ***Productivity*** at ***field-level***, eleven indicators were constructed. (See Table 2).

Step b: A Bivariate Correlation analysis was performed on the eleven indicators to identify the most significantly - correlated indicators (p = 0.05) whose performance was critical for achieving sustainable Agricultural ***Productivity***.

Step c: The indicators with p= 0.05 significance were selected for further analysis.

Step 9: Methodology for screening of critical indicators using *Principal Component Analysis*

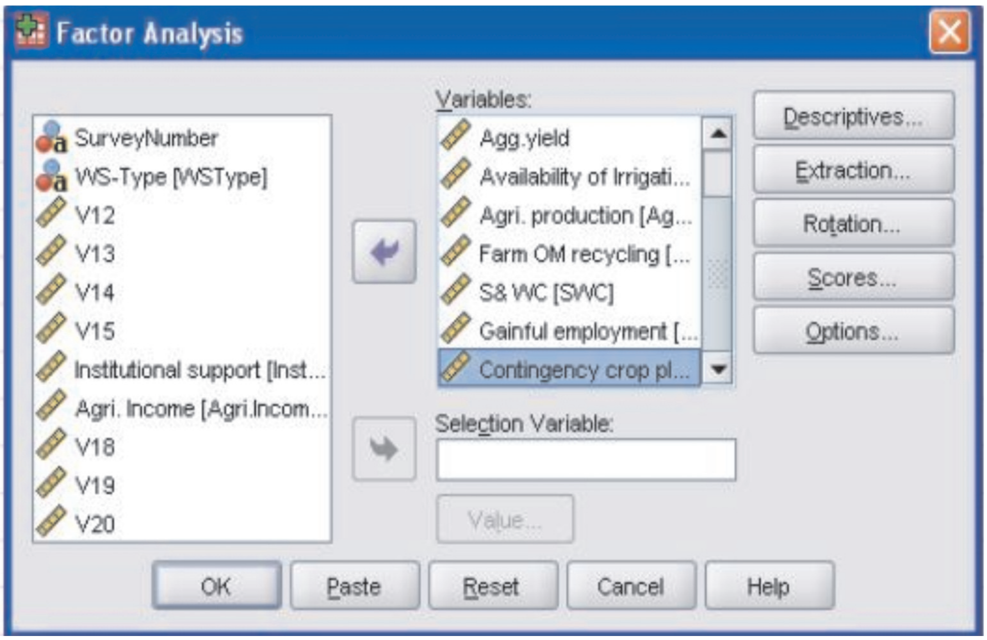
A *Principal Component Analysis* technique was also used to screen critical indicators on the same set of data as mentioned earlier and SPSS was used for this purpose. The method adopted for the analysis was as follows:

Step a: Identifying relevant variables from database and storing them in *MS- Excel sheet*.

Step b: Opening the data in **SPSS Window**.

Step c: Selecting following options from **SPSS** Main Menu

Analyze → *Data Reduction* → *Factor;* this step *is* indicated in Screenshot 1 below.



Screenshot 1

Step d: Selection of indicators into ***Variables Text Box*** followed by clicking **<OK>.** This would lead to display of **<Communities Table>, <Total Variance Explained Table>,** and **<Component Matrix Table>** as indicated in following Screenshot no. 2, 3 & 4.

Communalities

	Initial	Extraction
Agri. Income	1.000	.933
Cereal yield	1.000	.802
Agg.yield	1.000	.127
Availability of Irrigation facility	1.000	.817
Agri. production	1.000	.936
Farm OM recycling	1.000	.365
S& WC	1.000	.610
Gainful employment	1.000	.783
Contingency crop planning	1.000	.679

Extraction Method: Principal Component Analysis.

Screenshot 2

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.832	31.470	31.470	2.832	31.470	31.470
2	1.861	20.675	52.146	1.861	20.675	52.146
3	1.358	15.093	67.238	1.358	15.093	67.238
4	1.000	11.106	78.344			
5	.722	8.019	86.364			
6	.589	6.542	92.906			
7	.359	3.991	96.896			
8	.242	2.687	99.583			
9	.037	.417	100.000			

Extraction Method: Principal Component Analysis.

Screenshot 3

Component Matrix[a]

	Component		
	1	2	3
Agri. Income	.911	-.243	.209
Cereal yield	.864	-.230	-.043
Agg.yield	.039	.352	-.043
Availability of Irrigation facility	.378	.466	-.676
Agri. production	.926	-.179	.213
Farm OM recycling	.371	.449	.161
S& WC	.018	.595	.506
Gainful employment	.338	.690	-.439
Contingency crop planning	-.025	.586	.578

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Screenshot 4

Step e: From the Table depicted in Screenshot 4, three components were extracted. From the ***<Component Matrix >*** for each component, maximum value was selected from which 10% was subtracted to arrive at a figure.

Step f: This was followed by selection of all indicators that fell within the range of *[(max value) to (max value – 10% of max value)].*

Step g: From the set of indicators identified under each component, critical indicators were screened.

Step h: From this set of indicators, a correlation was established under each Principal Component.

Step i: In each component, an indicator was identified which correlated most with other indicators at 0.01 level of significance.

Step 10: This was followed by selection of common indicators identified under both techniques employed in the study i.e., BVC and PCA for each aspect of evaluation. These common indicators were considered as critical indicators and used for further study.

Step 11: For critical indicators so far identified, ***threshold values*** were estimated before commencement of analysis.

For e.g., where indicators elicited quantitative data, actual values were used in the following manner: Threshold was derived as 20% over mean based on community performance (Gomez et al., 1996).

Where qualitative data was available, scores were assigned and threshold value was assumed as maximum score.

Step 12: After generating ***Threshold Value*** as indicated in ***Step 11***, a ratio was calculated between ***Actual*** and ***Threshold Values***. An average value was again calculated on the basis of all ratios generated pertaining to each sample, viz., *Farmer Id* or *Survey no.* as the case may be. This final number was deemed to determine if a sampled farmer or field was sustainable. If this final value was found to be **< *1*** it denoted that the sample was unsustainable. On the contrary, if this value was **> 1** it denoted that the sample was sustainable.

If the *state* or *performance of an indicator* was better than the *average state* or *performance of a community*, it was considered both desirable and sustainable and a score of > 1 were concluded sustainable. Performance lower than the *Community*

Performance as indicated by *Threshold Value* was assigned a score of < 1 and termed unsustainable.

Step 13: From the critical indicators identified in Step 10, a PCA was performed to assign weightage for each indicator according to its' contribution towards achieving sustainability. For e.g., for indicator ***Farm OM recycling*** which was found to be critical under PC1 in 3 villages (Chintapatla, Dontanpalli & Pamana) and PC3 in case of Gollapalli, an average weightage was calculated. Similarly, weightage was estimated for 3 of the critical indicators identified for household level and 12 critical indicators identified for field and watershed-levels respectively. Finally, the relative contribution of each of the critical indicators were estimated as a ratio for indicating its' role or contribution towards achieving sustainable development through WDP.

The contribution of each of the critical indicators identified has been presented in Section 13.

8. Summary of Findings

Table 5 and 6 indicates the level of success achieved in collecting field -level data considering the village-level constraints. While the *Pahani* (Village) records indicated a number of land parcels (Survey number), where the records did not tally with the ground reality, as there was more sub-divisions besides some amalgamations that were not reflected in the village records. Table 6 to 9 indicated the sample size during each year i.e., 2006, 2007 and 2008 in both types of watersheds in each village. Utmost care was taken to sample and analyse a set of common farm households during each year in each of the watersheds for undertaking trends in change reported. For e.g. in case of Pamana village, 21 households were surveyed in the treated micro-watershed who collectively cultivated an area of over 30.76 ha annually (Table 7). In untreated micro-watershed in the same village, 6 farm households were evaluated who cultivated a total area of 9.96 ha. In case of Chintapatla village, 7 households were studied in the TMW who collectively cultivated 9.84 ha of land while in UTMW, 13 households who cultivated a total area of 16.48 ha, were assessed (Table 8). In Table 9 and 10 the number of households surveyed in Dontanpalli and Gollapalli have been listed.

Table 5: Household-level data sourced and evaluated

	No. of farm households according to village Pahani		Data collected (No. of Household)				Actual household assessed (%)			
	No. of farmers		2007		2008		2007		2008	
	TMW	UTMW	TMW	UTMW	TMW	UTMW	TMW	UTMW	TMW	UTMW
Chintapatla	82	58	61	41	72	39	74	70	87	67
Dontanpalli	47	55	22	34	19	25	47	62	40	45
Pamana	119	70	91	48	74	49	76	69	62	70
Gollapalli	62	49	45	49	42	31	73	100	68	63

Table 6: Field-level data collected and analysed

Village	Landholding (No. of sub-divisions) according to Pahani record		Data collected (No. of Field)				Actual field data collected (%)			
			2007		2008		2007		2008	
	TMW	UTMW	TMW	UTMW	TMW	UTMW	TMW	UTMW	TMW	UTMW
Chintapatla	181	214	87	95	106	133	48	44	59	62
Dontanpalli	74	114	52	83	32	75	70	73	43	66
Pamana	256	167	188	112	183	99	73	67	71	59
Gollapalli	129	106	77	98	104	72	60	92	81	68

Table 7. Consolidated list of households evaluated in watersheds in Pamana

Year/ Sample	Sample size (No. of Farm holdings)		Area (ha)	
2006	TMW	UTMW	TMW	U TMW
Actual (Total)	39	15	59.13	26.35
Sample (common across years)	21	6	30.76	9.96
2007				
Actual (Total)	90	50	116.67	84.66
Sample (common across years)	21	6	30.76	9.96
2008				
Actual (Total)	77	30	81.80	62.66
Sample (common across years)	21	6	30.76	9.96

Table 8. Consolidated list of households evaluated in watersheds in Chintapatla

Year/ Sample	Sample size (No. of Farm holdings)		Area (ha)	
2006	TMW	UTMW	TMW	UTMW
Actual (Total)	25	25	33.62	23.06
Sample (common across years)	7	13	9.84	16.46
2007				
Actual (Total)	62	43	65.15	58.23
Sample (common across years)	7	13	9.84	16.46
2008				
Actual (Total)	18	34	20.06	30.17
Sample (common across years)	7	13	9.84	16.46

Table 9. Consolidated list of households evaluated in watersheds in Dontanpalli

Year/ Sample	Sample size (No. of Farm holdings)		Area (ha)	
2006	TMW	UTMW	TMW	UTMW
Actual (Total)	20	40	16.73	34.47
Sample (common across years)	5	12	8.34	20.31
2007				
Actual (Total)	23	37	25.31	57.98
Sample (common across years)	5	12	8.34	20.31
2008				
Actual (Total)	21	28	20.82	44.28
Sample (common across years)	5	12	8.34	20.31

Table 10. Consolidated list of households evaluated in watersheds in Gollapalli

Year/ Sample	Sample size (No. of Farm holdings)		Area (ha)	
2006	TMW	UTMW	TMW	UTMW
Actual (Total)	14	45	62.47	84
Sample (common across years)	7	17	12.22	44.62
2007				
Actual (Total)	45	49	90.68	103.5
Sample (common across years)	7	17	12.22	44.62
2008				
Actual (Total)	40	33	61.48	44.20
Sample (common across years)	7	17	12.22	44.62

In Tables 11 – 13 details of field-level information collected across the villages during 2006, 2007 and 2008 have been indicated.

Table 11. Detail information of field-level assessment undertaken during 2006

Village	Fields according to village records (No.)		Size of landholding (ha)		Fields actually studied (No.)	Area assessed (ha)	Fields actually studied (No.)	Area assessed (ha)
	TMW	UTMW	TMW	UTMW	TMW		UTMW	
Pamana	48	34	133.5	102	33	105.85	16	61.02
Chintapatla	15	32	52.92	49.8	8	33.87	19	42.47
Dontanpalli	18	29	49.76	108	11	73.10	20	87.71
Gollapalli	27	29	91.43	88.7	21	73.43	24	77.88

Table 12. Details of field-level assessment undertaken during 2007

Village	Fields according to village records (No.)		Size of landholding (ha)		Fields actually studied (No.)	Area assessed (ha)	Fields actually studied (No.)	Area assessed (ha)
	TMW	UTMW	TMW	UTMW	TMW		UTMW	
Pamana	48	34	133.5	102	46	129.97	31	104.44
Chintapatla	15	32	52.92	49.8	15	52.92	32	49.76
Dontanpalli	18	29	49.76	108	16	99.96	28	105.40
Gollapalli	27	29	91.43	88.7	27	91.43	27	85.89

Table 13. Details of field-level assessment undertaken during 2008

Village	Fields according to village records (No.)		Size of landholding (ha)		Fields actually studied (No.)	Area assessed (ha)	Fields actually studied (No.)	Area assessed (ha)
	TMW	UTMW	TMW	UTMW	TMW		UTMW	
Pamana	48	34	133.5	102	42	123.72	30	102.93
Chintapatla	15	32	52.92	49.8	6	27.07	20	41.05
Dontanpalli	18	29	49.76	108	10	54.36	19	78.94
Gollapalli	27	29	91.43	88.7	18	66.8	28	89.59

- Based on the evaluation of eight micro-watersheds selected for the study, it was found that to evaluate sustainability at ***household-level,*** only 20 indicators were found relevant from the list of indicators developed as assessment was applicable for only three aspects of sustainability at the household–level namely, livelihood ***security,*** economic ***viability*** and social ***acceptability****.* Of these 20 indicators, only 3 indicators were found to be critical for sustainable development. They form the minimum data set for the purpose of evaluation, namely - *input cost, nutritional security among women and children,* and *local availability or cultivation of fodder* by a household.

- For analysing impact of WDP on all five aspects of sustainability at ***field –level,*** 29 indicators were found relevant. Of these some indicators seemed more crucial for sustained agricultural development than others as they could impact various aspects of sustainability simultaneously at a given point of time. From these, a minimum data set of 12 indicators was identified as critical for sustainable development at the field – level. These are - *soil moisture conservation measures, effective S & WC structures, adopting Contingency Crop Planning, farm OM recycling, availability of gainful employment options, gross agricultural income, total crop production, local availability or cultivation of fodder, availability of irrigation facility, Crop Diversity, security of tenure* and *enthusiastic extension workers.*

- For analysing impact of WDP on all five aspects of sustainability at ***watershed – level***, 35 indicators were found relevant. A minimum data set of 12 critical indicators was identified through statistical techniques. They were - efficacy of *S & WC structures, soil moisture conservation measures, farm OM recycling, gainful employment, Contingency Crop Planning, Crop Diversity, security of tenure, gross* *agricultural income, total crop production, local availability or cultivation of fodder, availability of irrigation facility* and *area under cultivation.*

- During 2008, 153 households were interviewed in the TMW across the study area and 129 in case of UTMW. During the year, 84 Survey nos. / Fields or landholdings were evaluated within the TMW and 97 in case of UTMW.

- Twelve physico-chemical and biological parameters of soils were analysed both in the TMW and UTMW. These soil-related parameters were - pH, EC, CEC, Organic Carbon (OC), major nutrients available - N, P, K, micro- nutrients available - Cu, Fe, Mn and Zn, besides microbial biomass carbon (MBC) and dehydrogenase assay (DHA). In TMW, most soils were found to be neutral with some alkalinity reported in Gollapalli while in UTMW in Dontanpalli, slightly acidic soils were found. Soil EC was <0.8 ds/m in both types of watersheds indicating their suitability for all types of crops. Soil CEC was higher in both watersheds in Pamana due to presence of *Vertisols* and associated soils while in the rest of watersheds where *Alfisols* and associated soils are found there was not much difference. Soil OC content was low across both types of watersheds except in Gollapalli and Pamana. Among major nutrients in soil, N content was low in both types of watersheds while P was high in Chintapatla TMW, low in Gollapalli and medium in Pamana. The situation was similar in UTMW that constrained agriculture. K content was medium to high in both types of watersheds and restricted agriculture as it interfered with crop maturity.

- Due to low soil fertility, it was essential to use recommended doses of fertilizers, FYM, OM recycling, vermin-compost and mulching. Among micronutrients, *Cu* content was found to be high in both types of watersheds, while *Fe* content was low in Chintapatla and Gollapalli but high in Pamana and Dontanpalli. *Mn* content was high across the watersheds while *Zn* was high in Pamana TMW but low in other three watersheds. However in case of UTMW, it was low in all watersheds including Pamana. In case of MBC, soils in Gollapalli watersheds were found to be better while DHA was >2 in both watersheds in Gollapalli and Dontanpalli.

- ***Net income*** accrued from agriculture to marginal farm households owing <1 ha of land in treated micro-watershed (TMW) in Pamana during 2008 was 18929.52 rupees (5933.77/- capita^{-1} year^{-1}) at current price (*Base year (1993-94= 100);*

WPI (2007) at 213.8; Source: CSO, Govt. of India 2008). In untreated micro-watershed (UTMW) that was taken as control in the village, average income among marginal households was 10843.50 rupees (4047.44/- capita^{-1} year^{-1}) at current price. The 74.5% increase in income among farm households in TMW in Pamana was largely from wage earnings and a 10% increase from livestock husbandry. In case of small farmers owing 1 – 2 ha of land in the TMW in the village, income was calculated at 17654.92 rupees (4751.23/- capita^{-1} year^{-1}) at current price while among semi-medium farm households with 2- 4 ha of agricultural land, income was estimated at 46895.16 rupees (14269.98/- capita^{-1} year^{-1}) at current price which was over 67.5% more than their counterparts in the UTMW in the village. Analysis of income structure indicated that over half of it came from wages and the rest from agriculture while livestock rearing contributed < 5%. In case of medium-size farmers owning 4 – 10 ha of land, income accrued was 121607.45 rupees (Rs.20665.41/- capita^{-1} year^{-1}) at current price that was 4.5 times higher than the income accrued to their counterparts in the UTMW in the village (Figure 16). Most of this income came from cultivation of vegetables - tomatoes, carrot and maize besides beetroot and cotton. Thus, it is evident that farmers owning < 4 ha land, both within treated as well as untreated micro-watersheds, depended on labour-work for their income especially under NREGS in 2008, while the medium- and large-size farmers with > 4 ha land, undertook cultivation of vegetables in the TMW which increased their income and consequently their livelihood security and economic viability of their agricultural enterprise.

- Comparison of ***net income*** accrued to farm households of various categories across the villages, indicated that income among marginal farm households in TMW was higher when compared to UTMW. This increase ranged from 12.7% in Chintapatla TMW to 74.5% in case of Pamana TMW and a major reason for this increase was the availability of wage-earning labour within the TMW apart from the Govt. sponsored NREGS. Income from labour accounted for > 52.7% in TMW among all categories of farmers compared to 33.2% in case of UTMW. In case of medium category farmers, those in TMW in Pamana and Gollapalli fared better. In Pamana agriculture, especially cultivation of cash crops gave higher returns (46.7%) when compared to those in UTMW; in Gollapalli TMW, livestock rearing provided 32% of income.

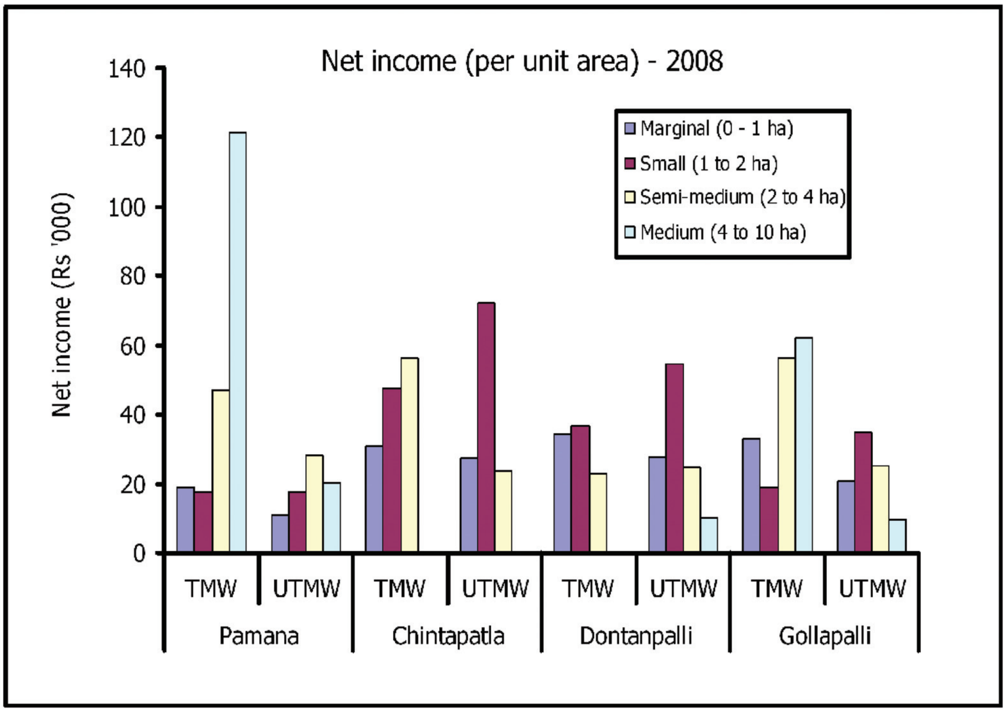


Figure 16: Average net income of farmers in 2008 in selected watersheds

- ***Operating-ratio*** or ratio of operating expenses to gross income was calculated to assess the cost of cultivation. In Chintapatla TMW in 2006, *Operating - ratio* was higher among marginal and semi-medium farmers, but in 2008 it fell to <0.25. In UTMW, *operating - ratio* in small and semi-medium farmers was comparatively lower and fell to 0.27 in 2008 (Figure 17a & b). In Dontanpalli, *operating - ratio* was higher among marginal, small and semi-medium farmers in UTMW when compared with those in TMW; it fell in 2008 compared to previous years. *Operating-ratio* in Gollapalli TMW was slightly higher among semi-medium farmers and remained consistent across the years. *Operating- ratio* was consistently high among all categories of farmers in TMW when compared with those in UTMW.

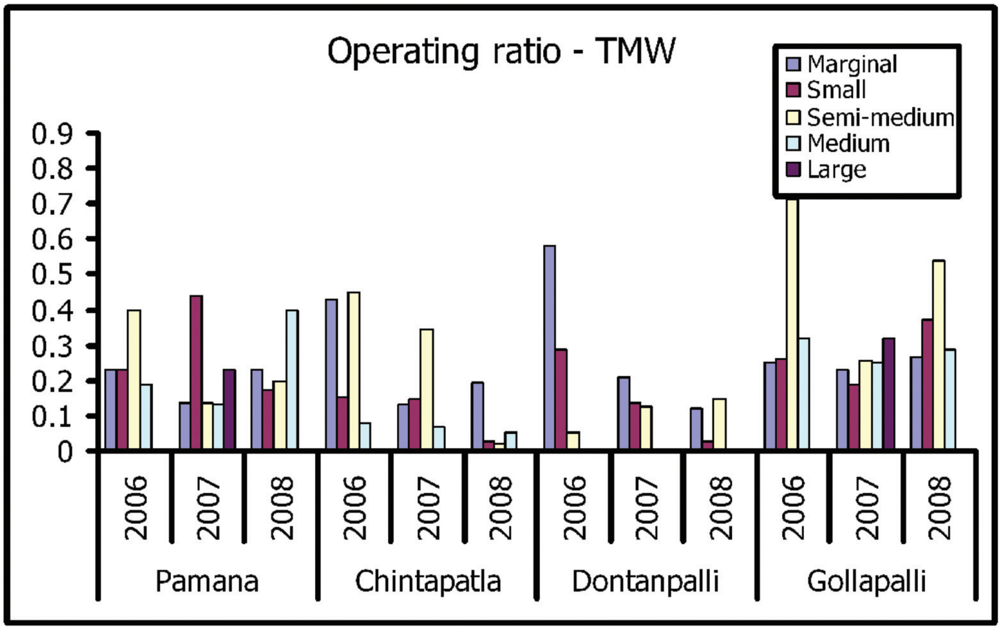


Figure 17a: Trend in ***operating -ratio*** among farmer categories in treated watersheds

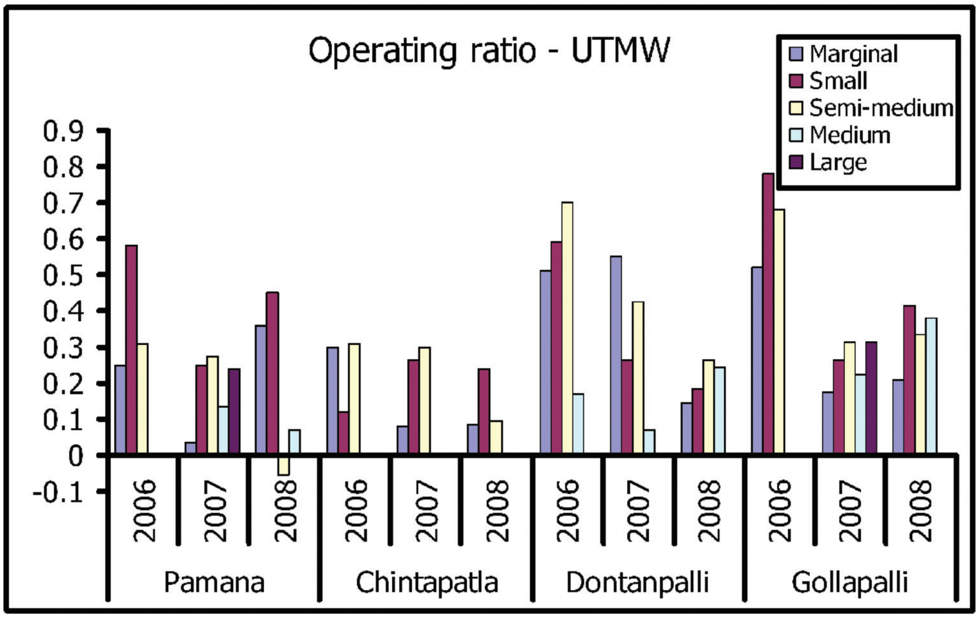


Figure 17b: Trend in ***operating –ratio*** among farmer categories in untreated watersheds

- ***Gross -ratio*** is calculated as a ratio of total costs (cost of equipment, labour, seed, fertilizer, depreciation on farm equipments, land revenue, interest on borrowed capital etc.) from gross income. This ratio indicates input use-efficiency while ensuring higher productivity or higher returns per unit of input utilized. It is calculated as Cost A / Gross Income as indicated by Johl & Kapur (1992). In case of Chintapatla TMW, *gross-ratio* among marginal and semi-medium farmers was high and it was found to be higher in 2006 compared to 2008. The trend was similar in UTMW although at a lower - level. In case of Dontanpalli, it was seen to be higher among marginal farmers in TMW and semi-medium farmers in UTMW; it fell in 2008 when compared to previous years. *Gross-ratio* was higher in TMW in Gollapalli; it was found to be higher among semi-medium farmers. Comparison across the villages indicated that It was higher among all categories of farmers in TMW as indicated in Figure 18a & b.

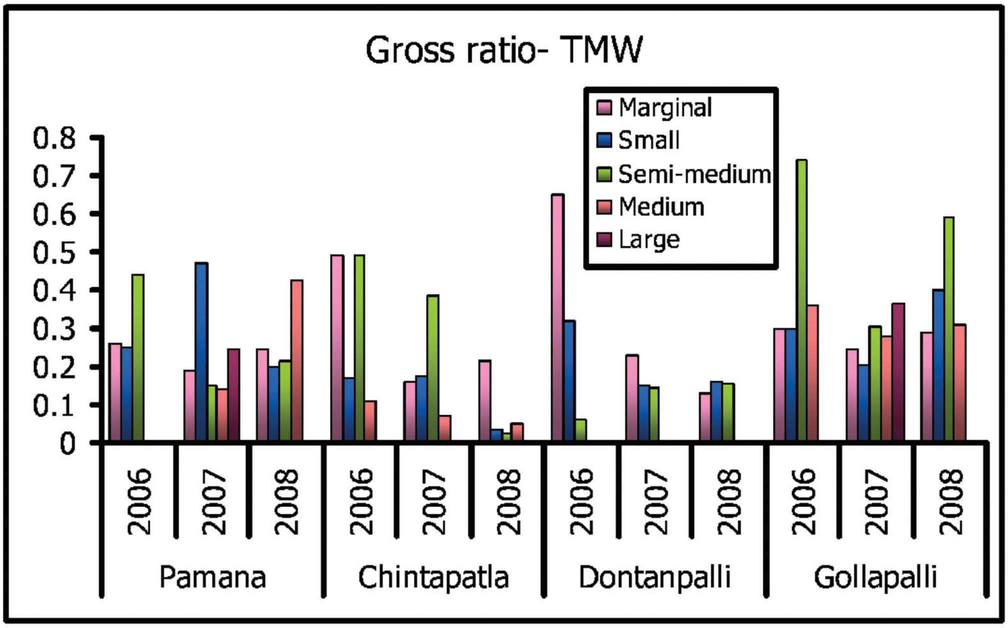


Figure 18a: Trends in ***gross -ratio*** among farmer categories in treated watersheds

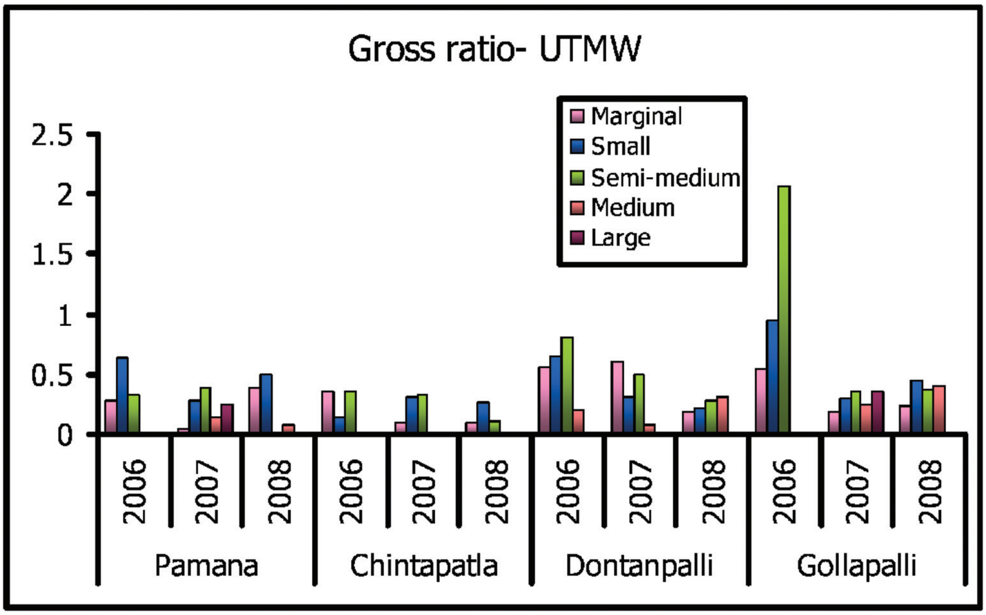


Figure 18b: Trends in ***gross -ratio*** among farmer categories in untreated watersheds

- ***Rate of turn - over from agriculture:*** For the present study *rate of turn-over from agriculture* for a household was defined as the *ratio of income from agriculture to value of agricultural assets with the farmer like bullock, tractor, farm implements, etc.* In 2008 in Chintapatla, the *rate of turn - over from agriculture* in TMW was twice that of UTMW and marginal farmers faired better compared to all others. In UTMW marginal, small and semi-medium farmers fared similarly although not as good as their counterparts in the TMW. In Dontanpalli, the *rate of turn - over from agriculture* was high among marginal farmers in 2008 in both types of watersheds. It was high among marginal, small and semi-medium farmers in TMW in 2007 and 2008 when compared to UTMW. *Rate of turn - over* among all categories of farmers in Gollapalli TMW was higher in 2007 and 2008 when compared to all watersheds in other three villages. Thus, it is evident that the *rate of turn - over from agriculture* was higher in case of TMW and that the impact of WDP was positive on livelihood security among farmers (Figure 19a & b).

- ***Rate of turn - over from livestock rearing*** was defined as the *ratio of income from livestock to total value of livestock asset with the farmer, viz., size of livestock* *holding*. During the study in 2008 it was seen that the rate of *turn - over* was higher in case of TMW in Pamana and Chintapatla villages although the contribution of income from livestock was lesser than that from agriculture. The ratio was poor in TMW in Chintapatla in 2006 and 2007 except excluding the case of marginal and medium farmers. On the other hand in UTMW the *rate of turn - over* from livestock rearing was comparatively better. In Dontanpalli, small farmers faired better in UTMW in 2008 although in TMW, marginal and semi-medium farmers stood to gain more. The *rate of turn - over* was high among semi-medium farmers in both types of watersheds in 2008 and higher in UTMW across all categories of farmers in 2008. Evidently, positive impact of WDP on livestock rearing as a source of assured income in the study area, has been limited (Figure 20a & b).

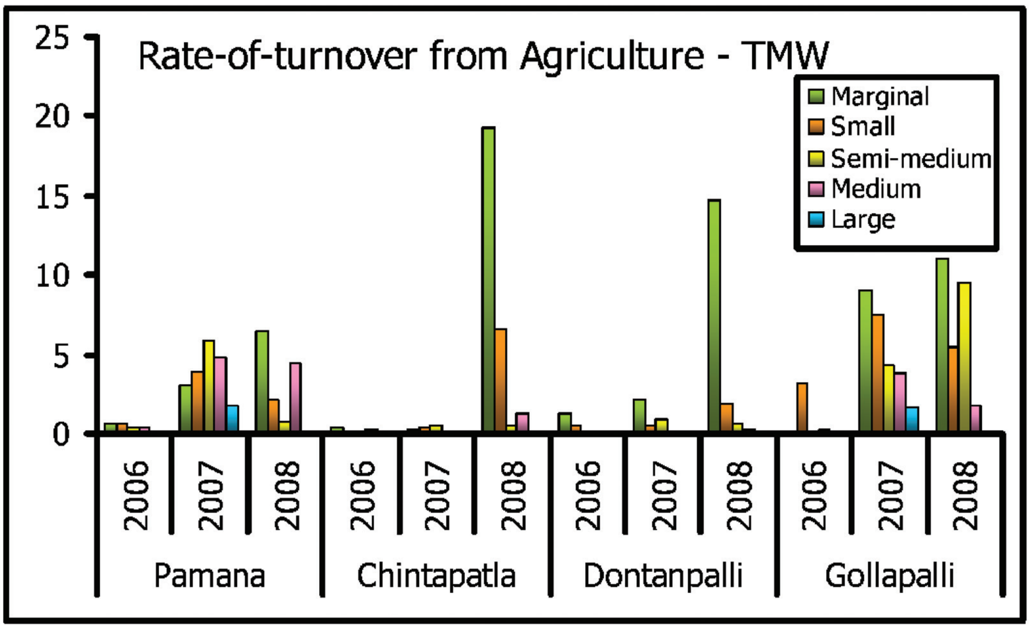


Figure 19a: *Rate - of -turnover* from agriculture among farmer categories in treated watersheds

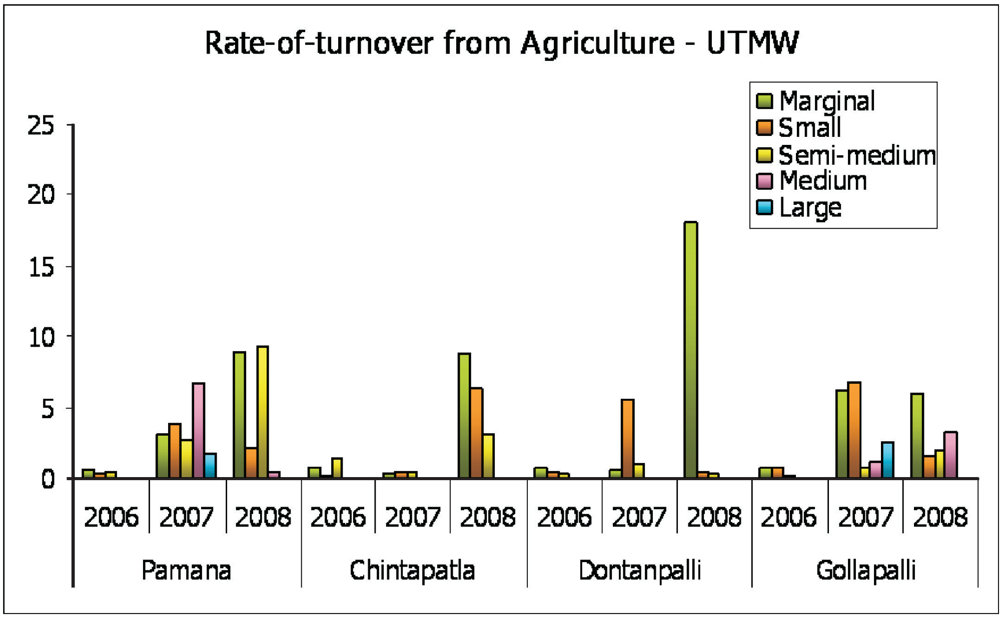


Figure 19b: *Rate - of -turnover* from agriculture among farmer categories in untreated watersheds

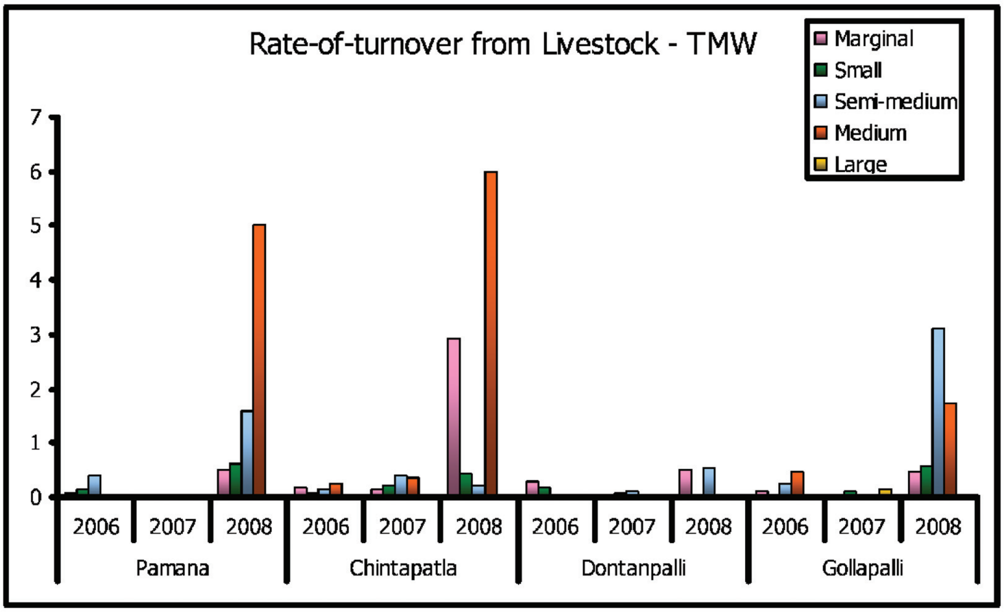


Figure 20a: Trend in r*ate – of - turnover* from livestock rearing among farmer categories in treated watersheds

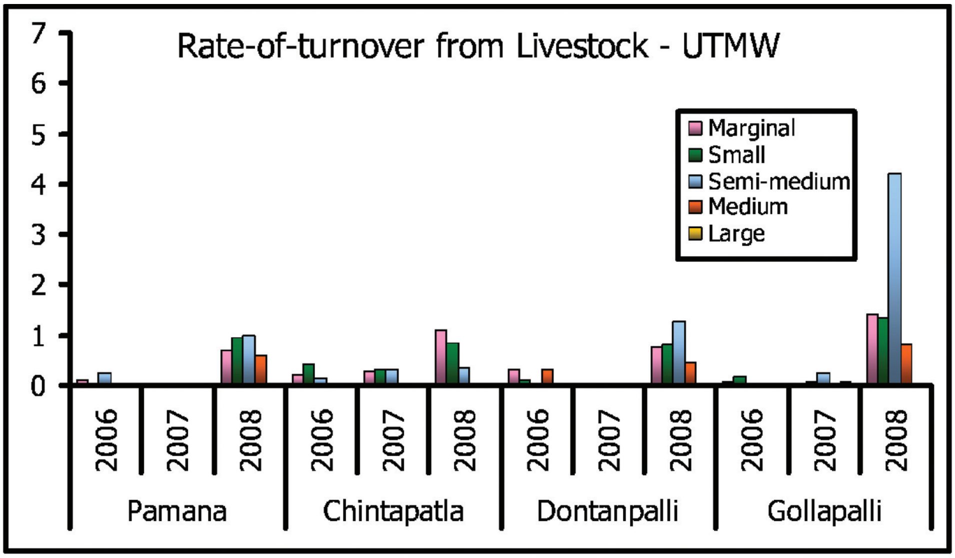


Figure 20b: Trend in r*ate – of - turnover* from livestock rearing among farmer categories in untreated watersheds

- ***B: C ratio*** was found to be favourable amongst semi-medium and medium categories of farmers owning 2 - 4 and 4 -10 ha of land respectively, in TMW across the study area. The ratio ranged from 4.5 to 4.64. However, in case of farmers from UTMW, the B: C ratio was found to be lower and generally same among all categories of farmers (Figure 21a & b).

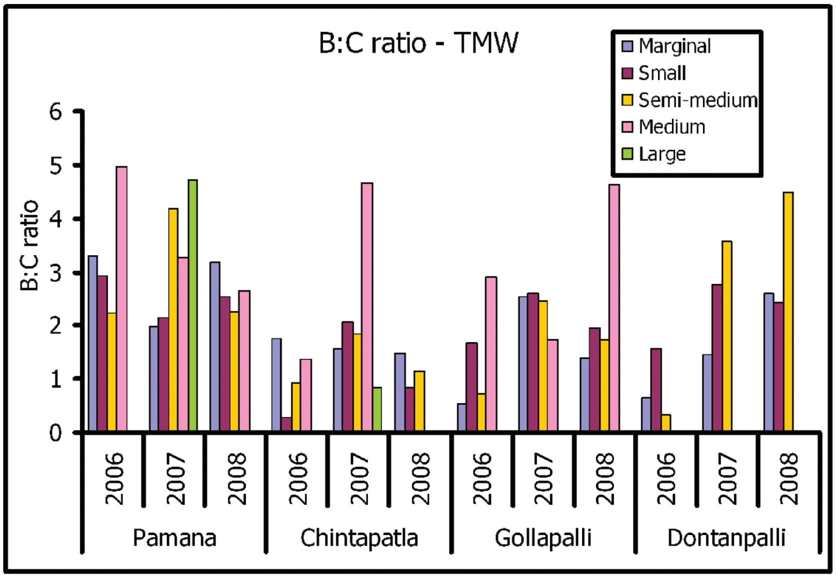


Figure 21a: B: C ratio among farmer categories in treated watersheds

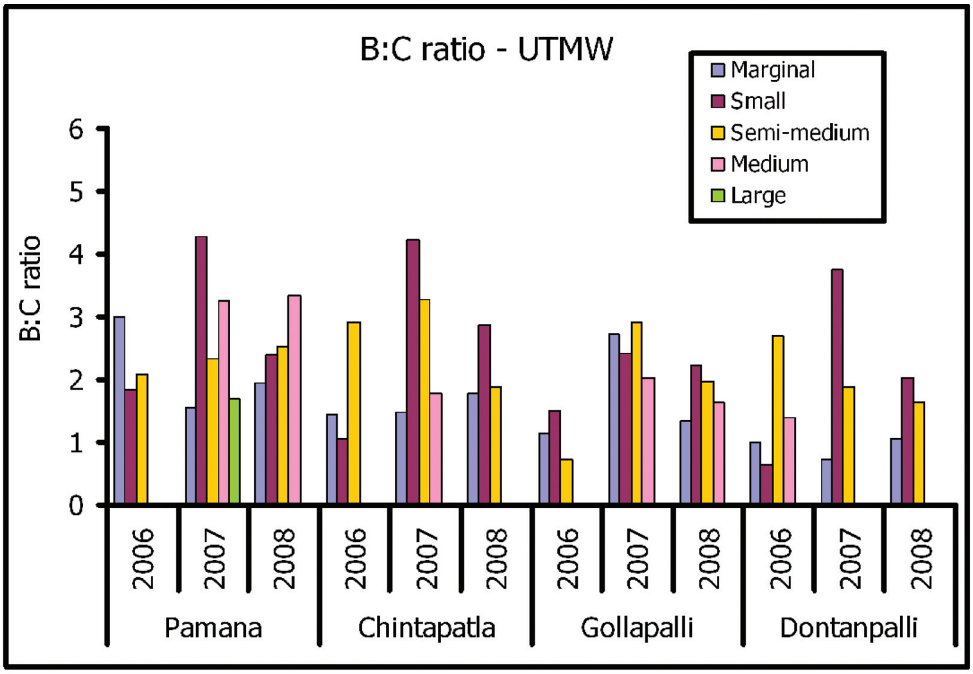


Figure 21b: B: C ratio among farmer categories in untreated watersheds

- ***Gini - coefficient*** is a measure of statistical dispersion and is commonly used as a measure of inequality of income or wealth. The Gini coefficient ranges from a minimum value of ZERO, when all individuals are considered equal, to a theoretical maximum of ONE in an infinite population in which every individual except one has a size of zero (Wessa, 2008). Lorenz curve was developed by Max O. Lorenz in 1905 for representing income distribution. In economics, the Lorenz curve is a graphical representation of the cumulative distribution function of a probability distribution. It is a graph showing the proportion of the distribution assumed by the bottom y% of the values. It is used to represent income distribution of bottom (x%) of households and what percentage (y%) of the total income is accrued to them so that they accumulate wealth or assets. Most economists now consider it to be a measure of social inequality (Lorenz, 1905).

The distribution of net income among farm households in TMW and UTMW were analysed using *Lorenz Curves* (Figure 22 a). A total of 310 farm households in TMW and 232 farm households in UTMW were studied across the four villages (Table 3) out of which 207 were selected for study in TMW and 144 from UTMW in 2008 (Table 4). *Gini-coefficient* analysis indicated that a better and equitable distribution of income was seen in case of farmers in Chintapatla TMW (*Gini-coefficient = 0.41*) and a poor distribution was seen among farmers in Dontanpalli TMW (*Gini-coefficient = 0.67*). However, as indicated earlier in case of Chintapatla, crop yield and productivity *per - unit - land* was low, and hence, although the distribution of income may be better in Chintapatla, the households were poor when compared to their counterparts in Dontanpalli where some farmers gained higher income through higher yield from cash crops and vegetables. On the other hand, in case of UTMW, the income distribution was poor (Figure 22 b). Thus, it may be said that in case of Chintaptla, it was more a case of distribution of '*poverty*' rather than a distribution of '*wealth or assets*'.

In case of Pamana ***Gini-coefficient*** was seen to be low both in TMW and UTMW, although the condition in TMW was better. However, the situation is far from satisfactory as noted in a meta - analysis of a number of watershed projects in the country (Joshi et al., 2005) (Figure 22a & b).

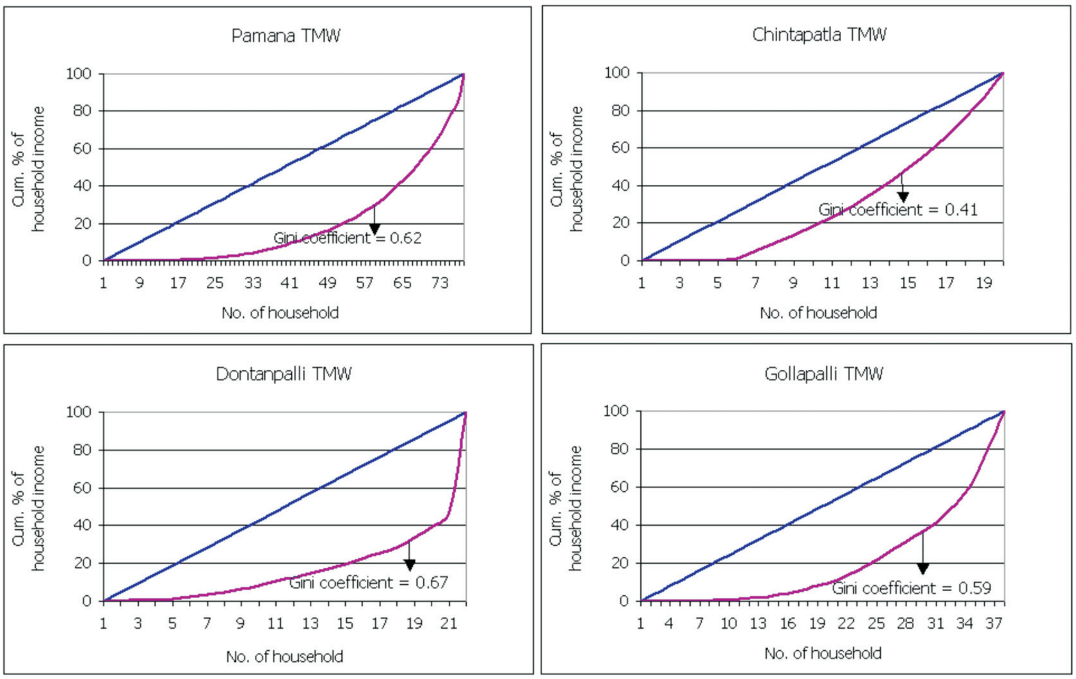


Figure 22a: *Gini-coefficient* among farm households in TMW in study area

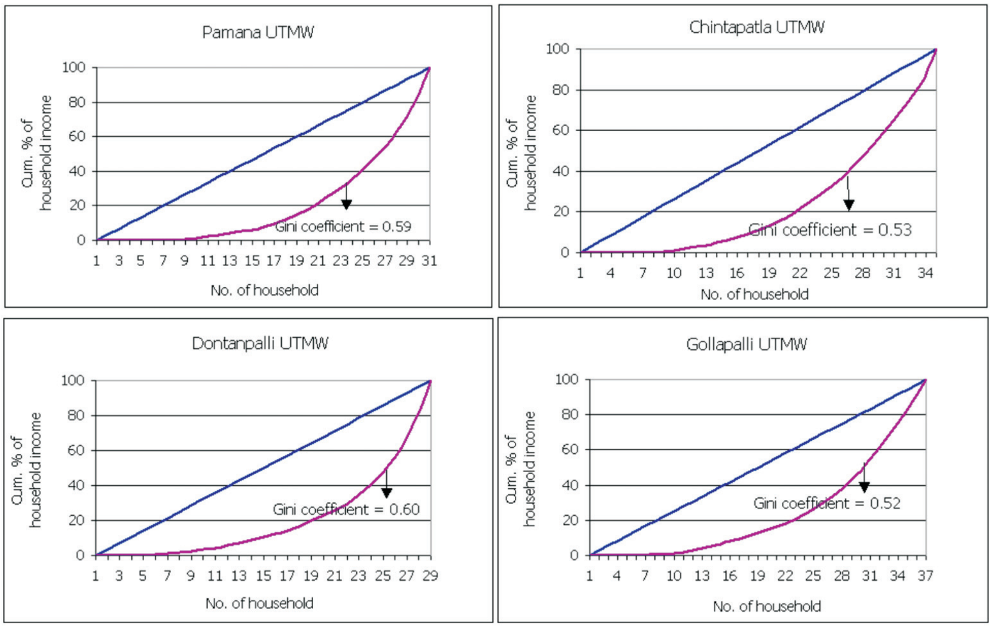


Figure 22b: Gini-coefficient among farm households in UTMW in study area

- ***Crop - wise yield*** was analysed in both types of watersheds during the study. Paddy yield in TMW registered an increase between 2006 and 2007, although it was similar in UTMW also. Paddy yield ranged from 3.47 t ha^{-1} in Gollapalli to 4.96 t ha^{-1} in case of Chintapatla in 2008 (Figure 23a & b). Traditional rainfed crops like castor and sorghum seemed to have lost their pre-eminence as is evident from their lower spatial extent and poor yield levels. Other cash crops like cotton and maize besides vegetables namely, tomato and carrots were increasingly preferred by the farmers in TMW as their yield and returns were better, thus ensuring higher agricultural productivity and economic viability. This change has evidently been due to implementation of WDP in this area.

- ***Input Cost / Unit of land (ha)***: A measure of sustainable economic viability of agricultural enterprise under WDP was taken as the *Input Cost / Unit of Agricultural Land* (ha). During the study it was seen that input cost from one hectare of agricultural land in TMW rose from 2006 to 2008 and it was higher in 2007. For instance in 2008 in TMW in Pamana, average input cost was Rs. 4009.21 ha^{-1} at constant price (*WPI with Baseline year 1993-94*) while in UTMW it was Rs. 3126.38 ha^{-1} (Figure 24a & b). This does not augur well for sustainable economic viability of agriculture under WDP.

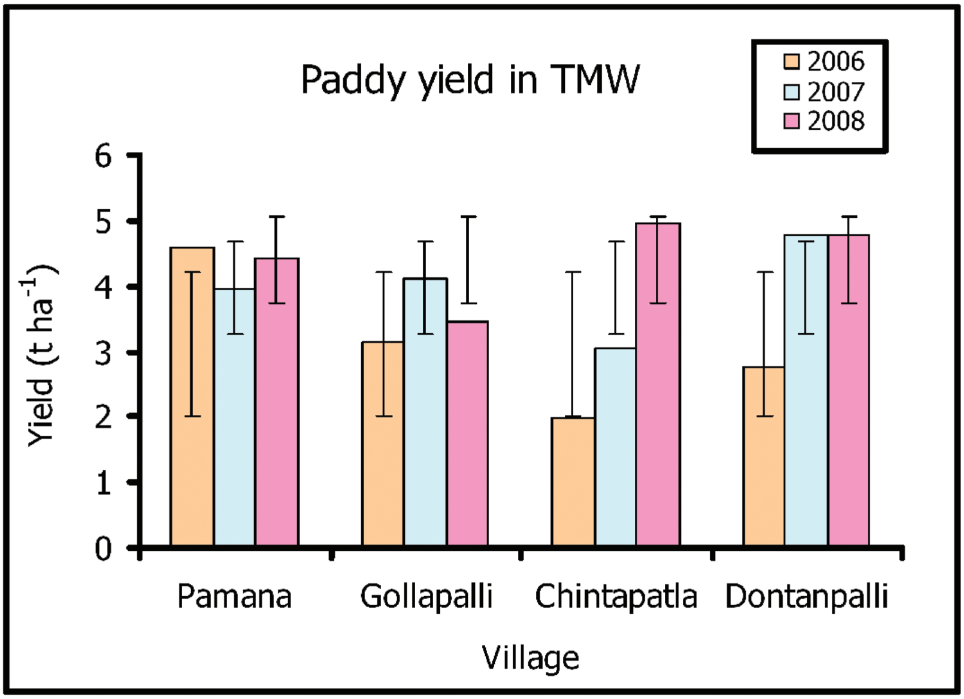


Figure 23a: Yield of paddy crop in treated watershed

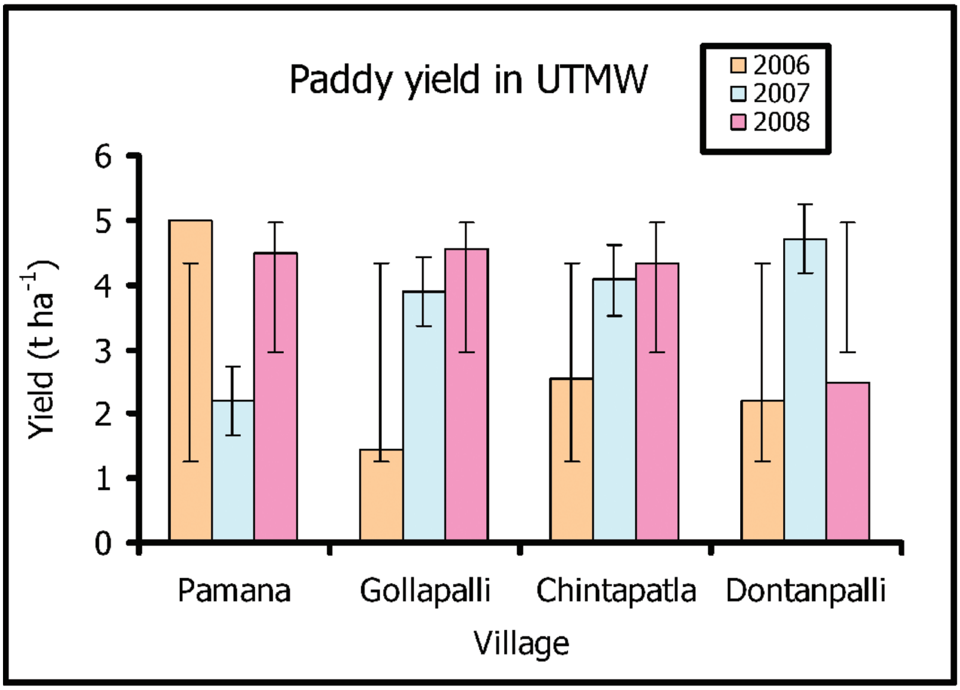


Figure 23b: Yield of paddy crop in untreated watershed

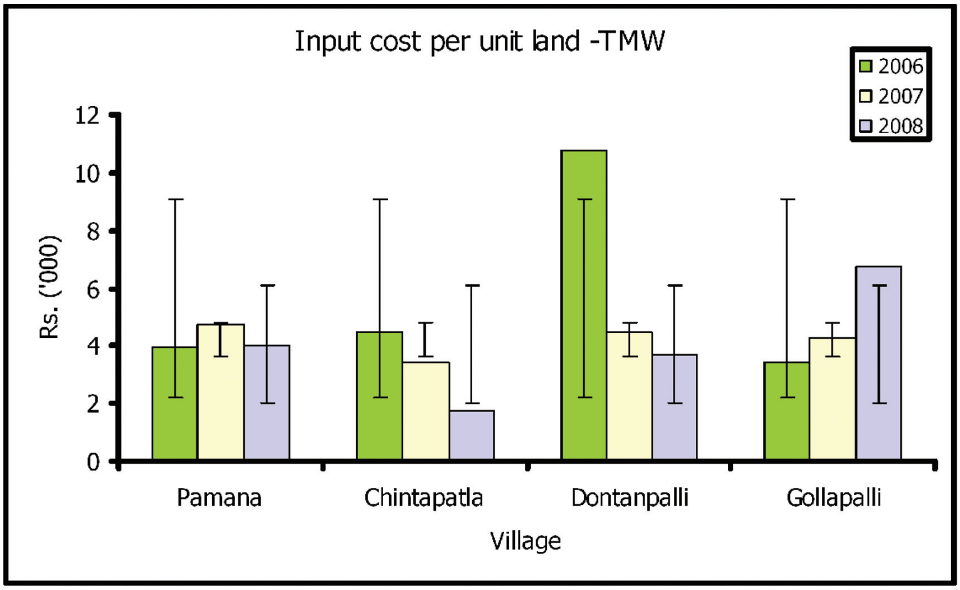


Figure 24a: *Input cost* / Unit Land (Rs. ha^{-1}) in TMW

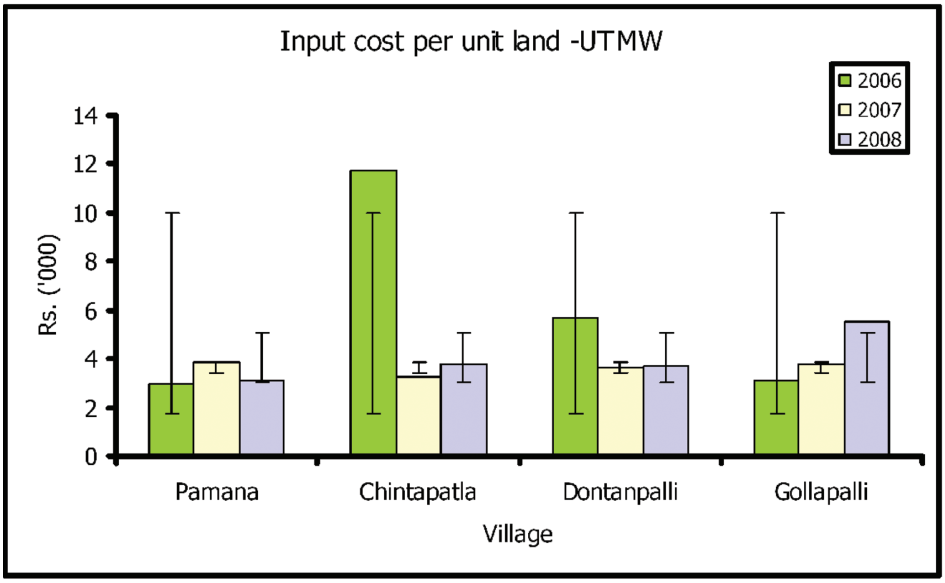


Figure 24b: *Input cost* / Unit Land (Rs. ha^{-1}) in UTMW

- ***Rice Equivalent Yield*** (t ha^{-1}): As a measure to compare yield of various crops during various years (2006-2008) at several locations within the study area, *Rice Equivalent Yield* was calculated. Figure 25 indicates that yield level was marginally better in case of TMW when compared to those in UTMW. For instance, in Pamana TMW agricultural yield was better when compared to yield levels achieved in the

UTMW even in 2008 when the onset of southwest monsoon was delayed and *Kharif* crop was adversely affected. In case of Chintapatla TMW, a slight yield improvement was seen. In case of Dontanpalli, yield levels were higher in TMW. However, in case of Gollapalli, yield levels were seen to be similar in both types of watersheds. In case of Dontanpalli in 2008, paddy yield in TMW was good despite a delay in onset of SOUTHWEST Monsoon. In UTMW, yield of paddy + sorghum was better than the previous years.

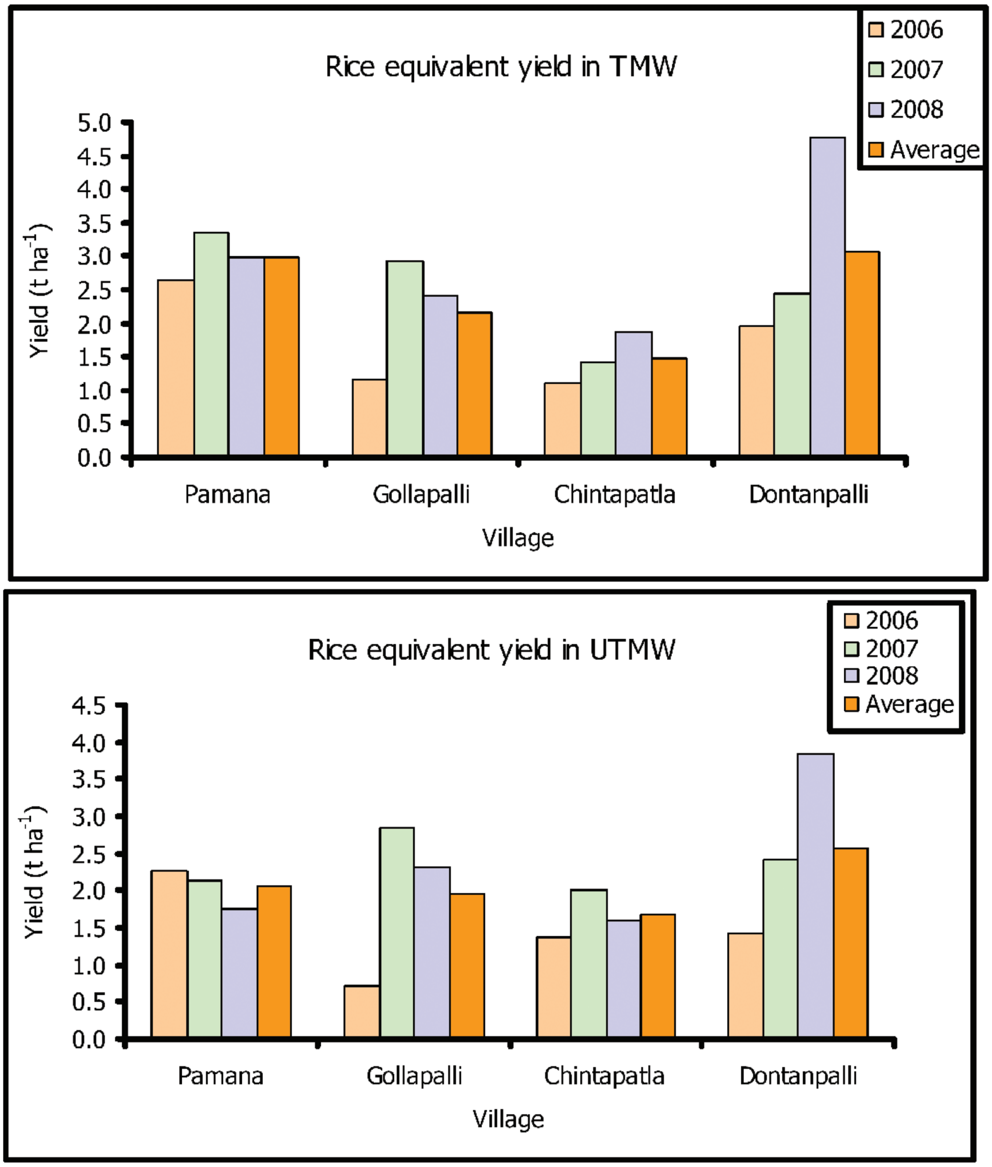


Figure 25: Rice equivalent yield (t ha^{-1}) in TMW and UTMW (2006-2008)

- ***Economic returns per unit of land:*** Economic returns accruing to a farmer is an important indicator of livelihood security and economic viability. It was measured as *economic returns / hectare of agricultural land* owned by him in rupee ha^{-1}. During the study it was seen that in TMW it was higher albeit only marginally. In case of Dontanpalli TMW, it was estimated at Rs. 26400 ha^{-1} at current price (2008) while in Pamana TMW it was calculated at Rs. 23778.99 ha^{-1}. Economic returns were seen to be least in case of Chintapatla TMW (Rs. 9872 ha^{-1}). In comparison, in the four UTMW, economic returns ranged from Rs. 6505.76 ha^{-1} in Gollapalli to a maximum of Rs. 21785 ha^{-1} in case of Chintapatla, where WDP seemed to have fared poorly.

- **Economic returns at current price** were also analysed for various category of farmers (Figure 26a & b). In Pamana, Dontanpalli and Gollapalli all categories of farmers in TMW fared better than those in UTMW in the village. However in case of Chintapatla all categories of farmers in UTMW fared better than their counterparts in TMW. Analysis across all TMW indicated that marginal and medium category of farmers in Pamana earned higher returns due to cultivation of vegetable crops. On an average small and medium category farmers earned 23,800 rupees from one ha of land in TMW. In Gollapalli TMW the economic returns from land was similar across all categories of farmers.

- Analysis of **trend of economic returns** indicated an increase in TMW between 2006 and 2008, although the returns were higher in 2007. Highest intra-annual increase during 2007 and 2008 in a TMW was noted in case of Dontanpalli (26%) and least in case of Chintapatla (-59%). In UTMW, highest increase in economic returns during 2008 was noted in Chintapatla (11%) and least in case of Pamana, i.e., -23.7% (Figure 27a & b).

- **Analysis of income** among farmer category in 2008 indicated that NREGS had a positive impact on WDP in Pamana, Gollapalli and Dontanpalli except Chintapatla. Study indicated that 69% of all marginal, small and semi-medium farmers owing < 4 ha of dryland were participating in NREGS scheme and earned 70% of their livelihood from it.

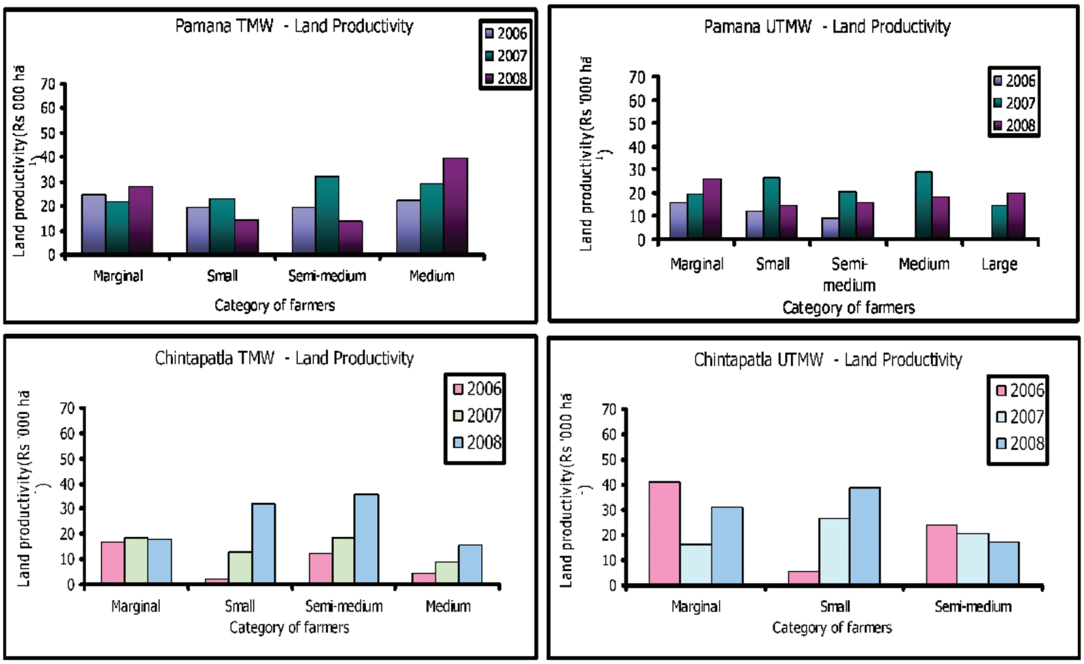


Figure 26 a: Economic returns among farmer categories from one ha of land in Pamana and Chintapatla

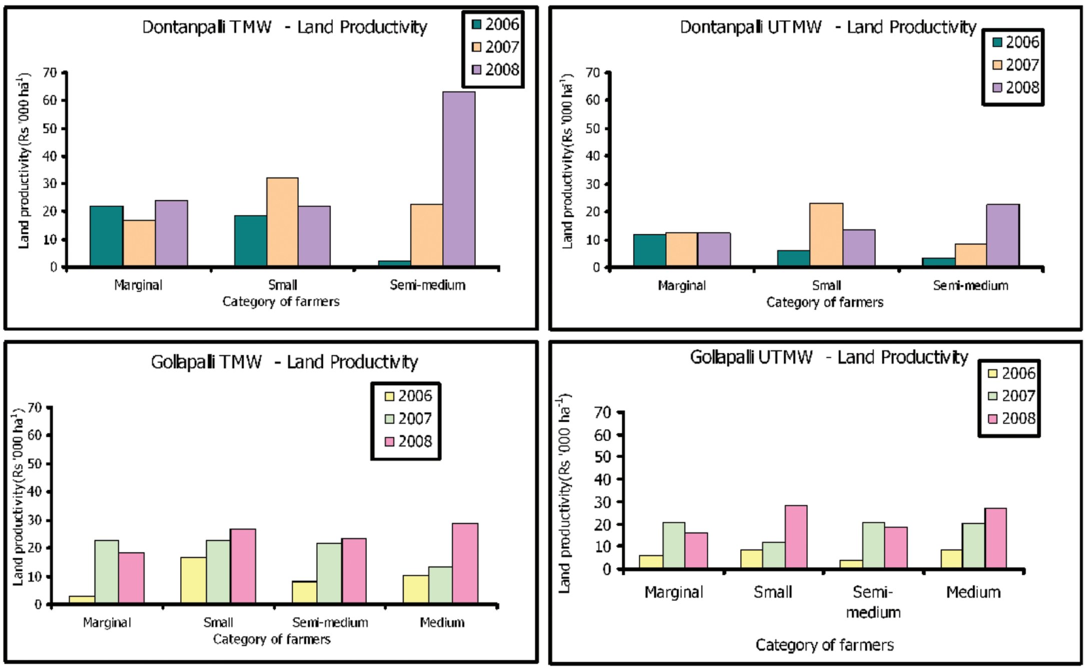


Figure 26 b: Economic returns among farmer categories from one ha of land in Dontanpalli and Gollapalli.

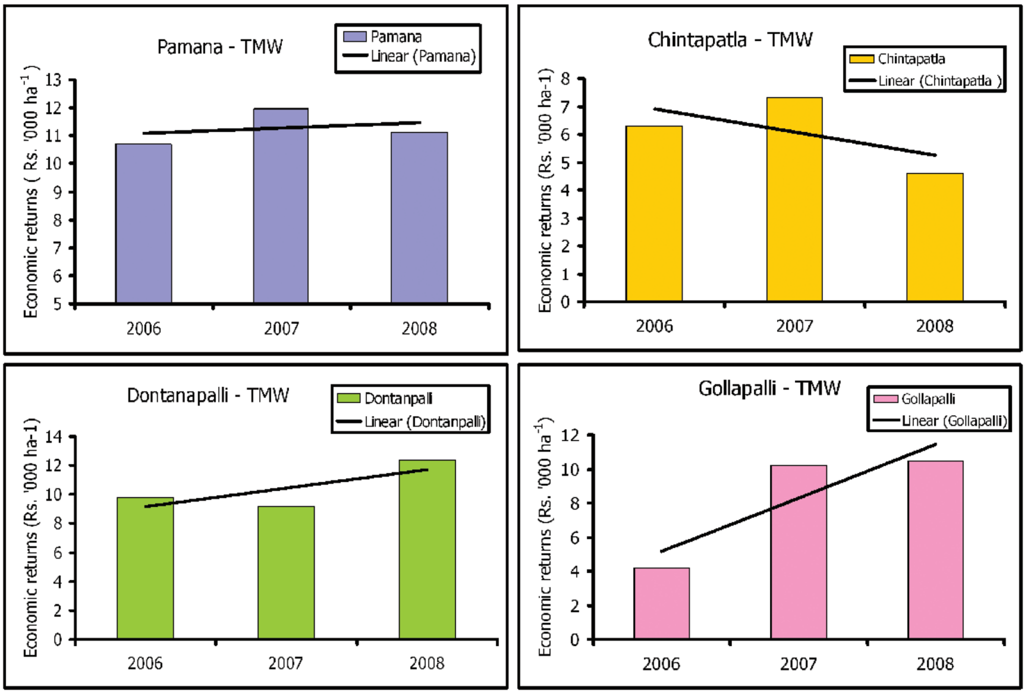


Figure 27 (a): Economic returns per unit land in TMW (2006 – 2008)

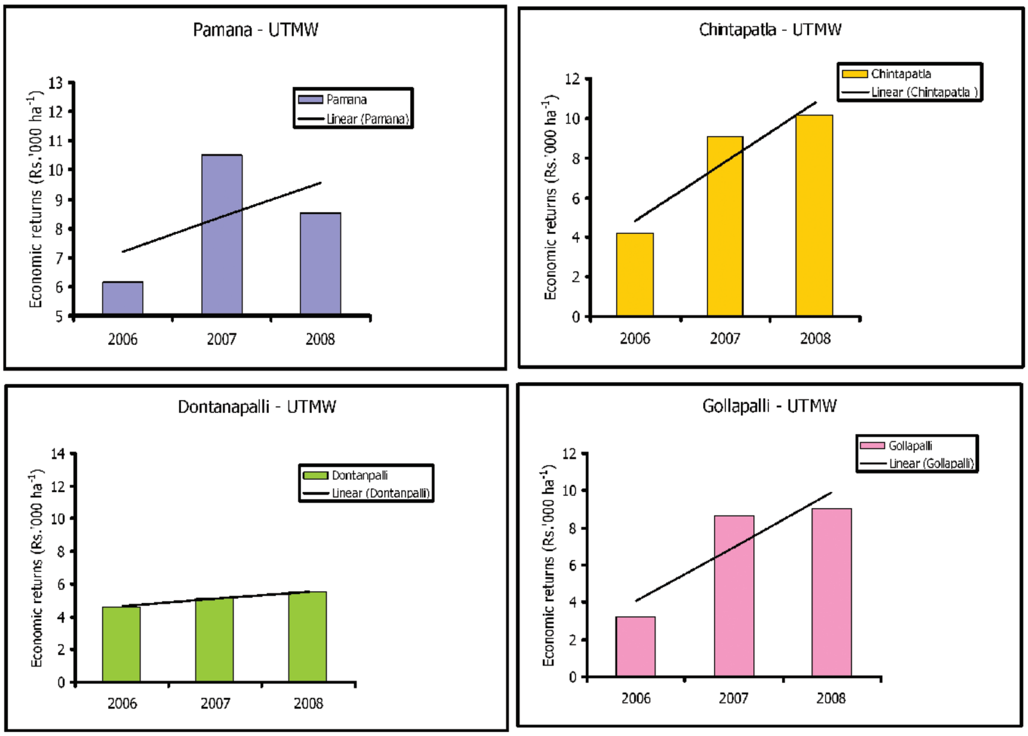


Figure 27(b): Economic returns per unit land in UTMW (2006 – 2008)

9. Analysis of Performance Indicators

Analysis at ***household-level*** indicated that from each TMW only one family was able to achieve sustainable development as a result of WDP in 2008, thus indicating only a marginal impact on ensuring household sustainability in the study area. In Pamana TMW one out of 77 households was found to be sustainable in all three aspects of sustainability viz., *livelihood security, economic viability and social acceptability*. In case of Dontanpalli TMW, no household was found to be sustainable and in Gollapalli, one household was sustainable while fourteen others had achieved sustainability in only two out of the three aspects that are essential for overall sustainable development at the household -level.

Evaluation of sustainability at ***field-level*** and ***watershed-level*** indicated that except for TMW in Dontanpalli and Gollapalli, none of the field or watershed either of the two villages – Pamana and Chintapatla, had achieved sustainability in all five aspects – *productivity, viability, security, protection* and *acceptability*. In case of Pamana, only two land holdings (Survey nos.) accounting for 3.42 ha out of 133.52 ha in the TMW or 3% of the watershed area, was found to be sustainable in four aspects of sustainability except economic viability; this is indicative of an unsustainable development in the TMW despite investments under WDP. In case of Chintapatla, one landholding of 3.5 ha accounting for 7% of area under TMW was found to be sustainable in four of the five aspects of sustainability i.e., except Social Acceptability. This would eventually make the watershed unsustainable, as Social Acceptability is essential for the success of WDP. In Dontanpalli, 4 farm holdings were found to be sustainable in all aspects of sustainability; they accounted for 19.34 ha or 18% of the area of TMW in the village. In case of Gollapalli, three farm holdings accounting for 10.75 ha or 11.7% of the TMW was found sustainable in all five aspects of sustainability.

10. Weakness of WDP implemented in study area

The study helped in identifying the limitations of WDP in the selected watersheds. *Cob -web* diagrams were used to identify which aspects of the WDP were strong and which were the weak - links in the program that could hurt the prospect of achieving sustainable development. For e.g., in Pamana TMW in household - level (HHL),

Livelihood Security was not achieved, as impact of WDP was marginal on account of three critical indicators namely, *size of land holding*, *gross agricultural income* and *input cost* (Figure 28). In case of ***Economic Viability*****,** gains were low due to *lack of gainful employment options* in villages leading to migration to urban centres, high *input cost*, poor *market acceptability* and cost of *transport* to market. ***Social acceptability*** was evidently not achieved in the TMW as farmers reported lack of *credit facility* that resulted in a lack of enthusiasm among them for WDP and its' tenets like increasing *fodder production* for self-reliance in livestock rearing and for maintaining ground vegetative cover.

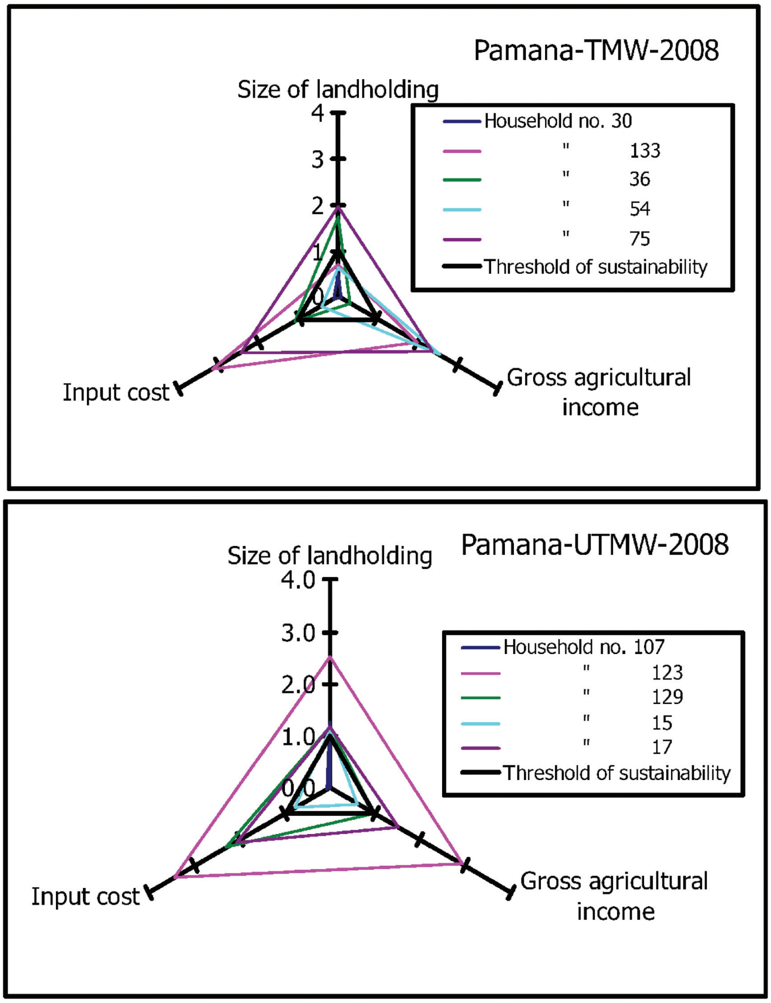


Figure 28: Evaluation of sustainability of ***livelihood security*** at household-level in Pamana - 2008

Impact of WDP at ***field - level*** was limited due to several reasons. In case of ***Agricultural Productivity,*** *small size of land holdings, lack of adequate irrigation facility, low yield, lower income resource leading to resource constraint, failure to recycle farm organic matter, poor maintenance of S&WC structures* and *lack of gainful employment leading to resource constraint to buy adequate inputs, etc.* were a constraint to achieving sustainable development through WDP. ***Livelihood Security*** could not be adequately ensured due to lack of adequate *irrigation facility* that would enable the farmer to cultivate more land and grow high value crops that could increase his income; failure to *recycling farm OM* and development and maintain *S&WC structures*, lack of institutional *credit facility* and *gainful employment* within the village and failure to follow *soil moisture conservation measures*. For ***Environmental Protection***, farm OM recycling, S&WC measures and soil conservation measures were found to be critical; however, limited progress was seen in these areas. For improving ***Economic Viability***, better implementation and maintenance of *S&WC structure* to ensure *irrigation* through water harvesting, practicing *soil conservation measures*, developing easy *credit facility*, *soil moisture conservation measures*, *farm OM recycling*, *cultivation of fodder for livestock* and availability of *gainful employment* within the village were found to be critical but lacking which affected the outcome of WDP. To evaluate ***Social Acceptability*** of WDP, the indicators found useful were farm OM recycling by farmers, maintenance of S&WC structures, fodder cultivation, adoption of soil moisture conservation measures etc., that could be ensured through opening *gainful employment opportunities* and making *credit available* within the village. As the WDP projects failed to ensure these two critical issues at the village-level, social acceptability for the program was found to be poor. Figure 29 indicates which indicators were critical for sustainable agricultural productivity at field level and how few farmers had achieved sustainable development in these areas.

In case of watershed-level, it was seen that apart from the issues highlighted at field-level, factors like *role of extension agents*, improved *transport and market facility*, adoption of *Crop Contingency Plans*, *participation in Govt. sponsored programs* and *demand for agricultural land* for alternate uses leading to a *decrease in cultivated land,* could impact sustainable development. In order to make WDP sustainable, the PIA may have to emphasize on external linkages like institutional support, infrastructure development, political goodwill and social awareness creation. Figure 30 indicates which indicators were critical for ***Environmental Protection*** on a sustainable basis at watershed-level and how some farmers had fared in this area in the Pamana village.

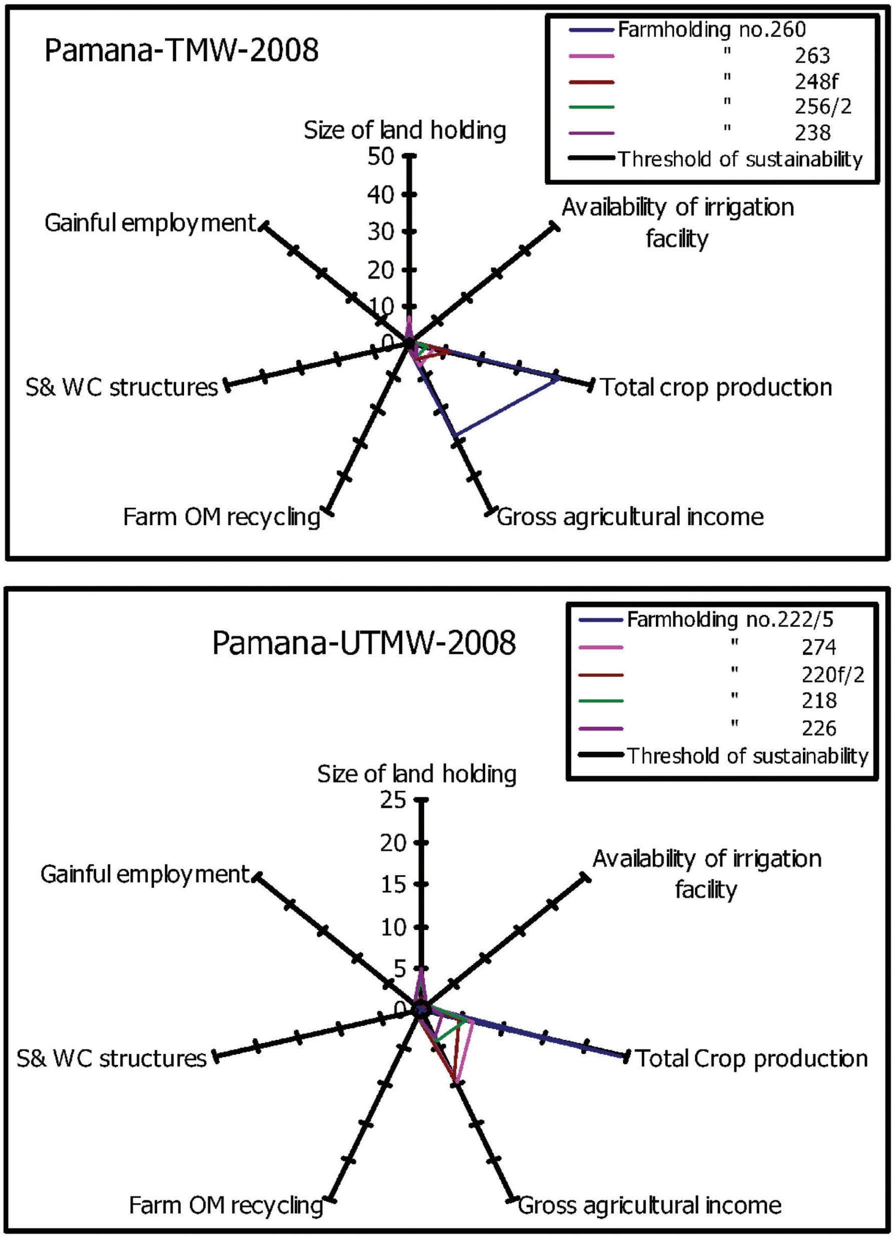


Figure 29: Evaluation of sustainability of ***Agriculture Productivity*** at field-level

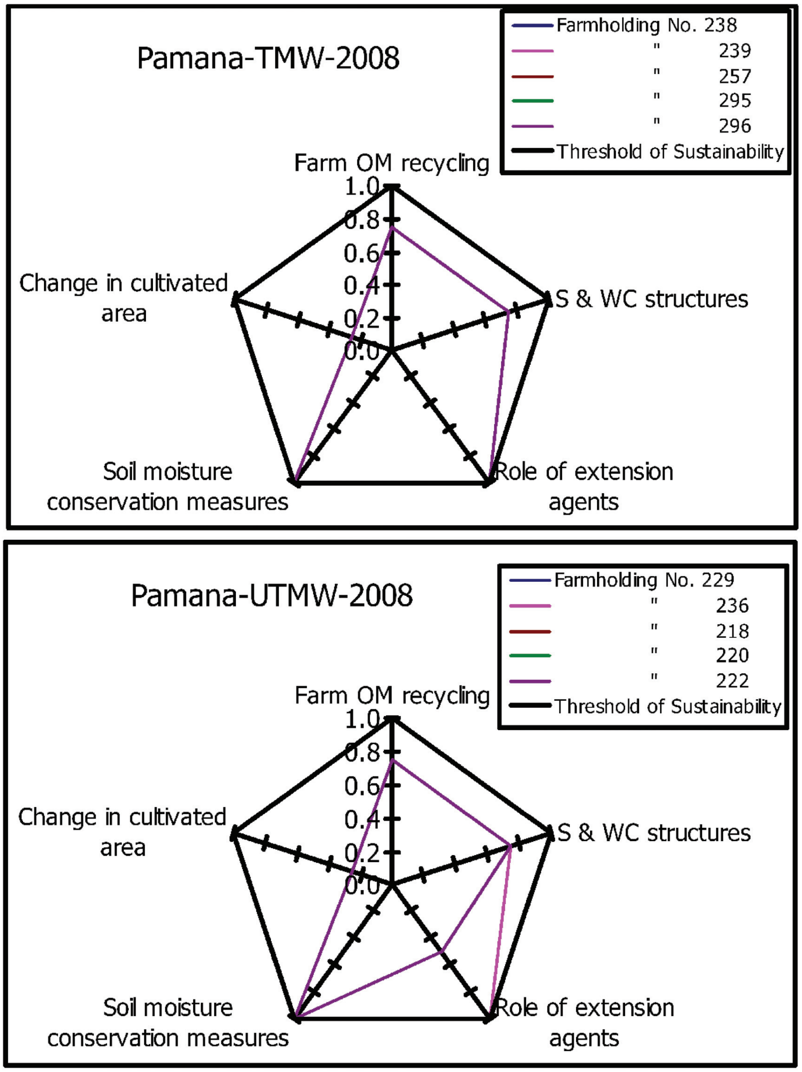


Figure 30: Evaluation of sustainability of ***Environmental Protection*** at watershed-level

11. Identification of critical indicators for sustainable development at various spatial levels

Critical indicators at household-level (HH)

For assessing sustainability of **Livelihood Security** at household-level, the critical indicators identified were *gross agricultural income* and *total crop production*. For evaluation of **Economic Viability**, *market accessibility* and *transport facility* were seen to be critical, while for **Social Acceptability**, *participation in government funded poverty reduction program* and *cultivation of fodder* were found to be critical (Figure 31).

Critical indicators at field-level (FL)

For evaluating sustainability of **Agricultural Productivity**, critical indicators identified were *agriculture production*, *agricultural income* and *availability of gainful employment options*. For evaluating **Livelihood Security**, *Total Crop Production* and *gross agriculture income, S&WC structures* and *Crop Cafeteria Index* (defined as ratio of landholding under effective cultivation) were found to be critical. For evaluating **Environmental Protection**, *S&WC structures* and *farm organic matter recycling* were found to be critical. For evaluation of **Economic Viability**, *market accessibility* was found to be the single most critical indicator. For **Social Acceptability**, *maintaining S&WC structures* and *practicing soil moisture conservation* were found to be two critical indicators. Figure 32 indicates the critical indicators identified for evaluating agricultural sustainability at field-level.

Critical indicators identified for Household-level evaluation

	Livelihood security	Economic viability	Social acceptability
Availability / Consumption of fuel wood			P,G,D,C
Credit facility			P,G,D,C
Membership of watershed committee			P,G,D,C
Participation in Govt. sponsored program			P,G,D,C
Gross Agricultural income	P,G,D,C		
Total Crop production	P,G,D,C		
Availability of irrigation facility	P,D,C		
Crop Contingency Planning	P,G,D,C		
Decision to migrate		P,G,D,C	
Equity	P,G,C		
Gainful employment		P,G,D,C	
Market accessibility		P,G,D,C	
Net income		P,G,D,C	
Per capita land availability	P,G,D,C		
Security of tenure	P,D,C		
Size of landholding	P,G,D,C		
Transport facility		P,G,D,C	
Availability/cultivation of fodder	P,G,D,C		P,G,D,C
Input cost	P,G,D,C	P,G,D,C	
Nutritional security among women and children	P,G,D,C	P,G,D,C	

ritical to sustainable development

- Low (Selected in Social acceptability aspect only)
- Medium (Selected either in security aspect or in viability aspect)
- High (Selected in two aspects)

P- Pamana
G-Gollapalli
D-Dontanpalli
C-Chintapatla

Figure 31: Critical indicators identified for sustainable development through study at household –level. *Minimum data set indicated in bold font essential for ensuring sustainable development at household- level*

Critical indicators identified for field-level evaluation

Indicators	Economic viability	Agricultural Productivity	Livelihood security	Environmental protection	Social acceptability
Aggregate yield (other crops)		P,G,D,C			
Cereal yield		P,G,D,C			
Change in land cover				P	
Deforestation rate				P	
Economic returns from per unit of land area			P,G,D,C		
Market accessibility	P,G,D,C				
Market price of farmland	P,G,D,C				
Transport facility	P,G,D,C				
Crop Cafeteria Index (% cultivated area)			P,G,D,C	P,G,D,C	
Input cost	P,G,D,C		P,G,D,C		
Credit facility	P,G,D,C		P,G,D,C		P,G,D,C
Size of landholding	P	P	P,G,D,C		
Slope			C	C	C
Soil OC	P			P	P
Soil fertility	P	P		P	P
Role of extension agents	P,G,D,C			P,G,D,C	P,G,D,C
Security of tenure	P,G,D,C		P,G,D,C	P,G,D,C	
Crop Diversity Index (No.of crops/ Cultivated area)	P,G,D,C		P,G,D,C	P,G,D,C	
Availability of irrigation facility	P,G,D,C	P,G,D,C	P,G,D,C		
Availability/cultivation of fodder	P,D,C		P,D,C	P,G,D,C	P,G,D,C
Total Crop production	P,G,D,C	P,G,D,C	P,G,D,C		
Gross agricultural income	P,G,D,C	P,G,D,C	P,G,D,C		
Farm OM recycling	G,D,C	P,D,C	P,G,D,C	P,G,D,C	P,G,D,C
Gainful employment	P,D,C	P,G,D,C	P,G,D,C		P,G,D,C
Contingency Crop Planning	P,G,D,C	P,G,D,C	P,D,C	P,G,D,C	P,D,C
S & WC structures	P,G,D,C	P,G,C	P,G,D,C	P,G,D,C	P,G,D,C
Soil moisture conservation measures	P,G,D,C	P	P,G,D,C	P,G,D,C	P,G,D,C

Critical to sustainable development

- Low (Selected in only one aspect)
- Medium (Selected in two or three aspects only or in less no. of watersheds)
- High (Selected in all aspects or in important aspects)

Figure 32: Critical indicators identified through study for field-level evaluation. *Minimum data set for undertaking sustainable development at field –level has been indicated in bold font.*

Critical indicators identified for Watershed-level evaluation

Indicators	Economic Viability	Environmental protection	Livelihood Security	Social Acceptability	Agricultural Productivity
Aggregate yield (other crops)					P,G,D,C
Cereal yield					P,D,C
Deforestation rate		P,G,D,C			
Economic returns from per unit of land area			P,D,C		
Market accessibility	P,G,D,C				
Market price of farmland	P,G,D,C				
Transport facility	P,G,D,C				
Yield gap				P,G,C	P,G,D,C
Crop Cafeteria Index (% cultivated area)		P,G,D,C	P,G,D,C		
Equity	P,G,D,C		P,G,C	P,G,D,C	
Input cost	P,G,D,C		P,G,D,C		
Participation in Govt. sponsored program			P,G,D,C	P,G,D,C	
Per capita land availability	P,G,D,C		P,G,D,C		
Role of extension agents	P,D,C	P,G,D,C		P,G,D,C	
Size of landholding	P,G,D,C		P,G,D,C		
Slope		P,C	P,C		
Soil fertility	P,D,C			P,G,D,C	P,G,D,C
Soil OC	P,G,D,C	P,G,D		P,G,C	P,G,D
Credit facility	P,G,D,C		P,G,D,C	P,G,D,C	
Extent of migration	P,C	P,G,C	G,C	P,G,C	P,G
Total Crop production	P,G,D,C		P,G,D,C		P,G,D,C
Gross agricultural income	P,G,D,C		P,G,D,C		P,G,D,C
Availability of irrigation facility	P,G,D,C		P,G,D,C		P,G,D,C
Availability/cultivation of fodder	P,G,D,C	P,D,C	P,G,D,C	P,G,D,C	
Change in cultivated area		P,G,D,C	P,G,D,C		P,G,D,C
Crop Diversity Index (No. of crops/Cultivated area)	P,G,D,C	P,G,D,C	P,G,D,C		
Security of tenure	G,D,C	G,D,C	G,D,C		
Crop Contingency Planning	P,G,D,C	P,G,D,C	P,D,C	P,G,D,C	P,G,D,C
Gainful employment	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C
Farm OM recycling	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C
Soil moisture conservation measures	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C
S & WC structures	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C	P,G,D,C

Critical to sustainable development:
- Low (Selected in only one aspect)
- Medium (Selected in two or three aspects only or in less no. of watersheds)
- High (Selected in all aspects or in important aspects)

Figure 33: Indicators identified as critical for sustainable development at watershed –level. *The minimum data required for implementing a sustainable WDP has been indicated in bold font*

Critical indicators at watershed-level (WL)

For evaluating sustainability of **Agricultural Productivity**, the critical indicators identified were *Total Crop Production* and *cereal yield*. For evaluation of **Livelihood Security**, *availability of gainful employment options, efficacy of S&WC structures* and *Crop Cafeteria Index* were found to be critical. For evaluating **Environmental Protection**, *S&WC structures* and *farm organic matter recycling* were found to be critical. For evaluation of **Economic Viability,** *S&WC structures, market accessibility* and *transport facility* were found to be critical indicators. For evaluating **Social Acceptability**, *maintaining S&WC structures* and undertaking *soil moisture conservation measures* were found to be critical indicators. Figure 33 indicates the critical indicators identified for evaluating impact of WDP. It is obvious that indicators found critical in case of farm-level studies were also found to be vital for sustainable development at watershed-level.

12. Strengths and limitations of evaluation methodology

Undoubtedly, use of sustainability indicators to evaluate a rural development program like the WDP, where multi-disciplinary evaluation procedures are required to be carried out for an accurate assessment, this methodology holds great promise due to its obvious strengths. The following are some of its strengths that would help in undertaking corrective measures in the implemented projects while the findings of this study can help in better implementation of future projects.

Use of Geo-informatics

As described in the publication, the methodology uses the tools of Geo-informatics in tandem with conventional methods of study like soil analysis, socio-economic survey and PRA. Use of GIS and Remote Sensing helped in delineation of watershed hierarchy and nesting of catchments besides quantification of several indicators for the study. Use of DGPS helped in geo-referencing sampling sites and greatly facilitated the study.

Use of Sustainability Indicators

The indicators constructed for evaluation process can be monitored at any point of time, i.e., during the project phase or the post-project period as the case may be. The indicators are quantifiable, comparable and mappable which makes the evaluation procedure relatively easy, objective and useful.

Evaluation provided specific information for undertaking corrective measures

The results of the evaluation process are specific and easily comprehendible and useful for undertaking corrective measures as and when required. For instance, to evaluate sustainability of agricultural productivity at field - level, the relevant indicators constructed were – *cereal yield, aggregate yield*, *availability of irrigation facility, Total Crop Production, gross agriculture income, farm OM recycling, S&WC structure, soil moisture conservation measures, gainful employment, Contingency Crop Planning* out of which 8 indicators namely *Contingency Crop Planning, S&WC structure, gainful employment, farm OM recycling, gross agriculture income, Total Crop Production, availability of irrigation facility, soil moisture conservation measures,* were found to be critical indicators.

Use of multi-disciplinary input for evaluation

To evaluate the impact of soil health on agricultural productivity, the indicators used were soil moisture conservation measures implemented, soil fertility status, soil OC content and farm OM recycling practice. To measure efficacy of S&WC structures developed under the WDP, rate of land degradation and deforestation expressed as change in NDVI, was measured, as S&WC structures constructed under WDP were meant for checking soil erosion in the first place. Wherever direct indicators were unavailable for measuring such parameters, surrogate indicators were identified and constructed for evaluation purpose.

Calibration of qualitative information for quantitative evaluation

Indicators that produced qualitative information only were numerically calibrated for easy comprehension, comparison and removal of any ambiguity. For instance, to study *intensity and diversity of land use* and *impact of livestock management on land, availability of fodder* was taken as a criteria and an indicator was developed. As the source of data for fodder availability was based on socio-economic survey through which only qualitative data was generated, the data was converted into meaningful score for undertaking analysis and integrating them with other sustainability indicators that were measured quantitatively. A final scorecard was thus generated to evaluate the impact of WDP on agricultural sustainability in the watershed.

Limitations of Evaluation Procedure

The study was carried out in understanding the impact of WDP in rainfed AESR 7.2 and provides a framework for quantifying the impact of such multidisciplinary development projects. The limitations of evaluation procedure are as follows.

Problems associated with collection data in the field

At grass-root level, collection of primary data at household, field, watershed and village-level posed its own problems. Even if process of delineation of micro-watersheds using Survey of India topographical sheets and satellite data and subsequently up-linking it to the National Hierarchy of Watersheds was a tedious but a manageable task, use of village records for cadastral - level mapping and identifying the survey numbers of land holdings and their respective owners was an intractable problem that consumed a lot of project time. Most Survey Nos. or Land holdings had been sub-divided beyond recognition and the village records called the *Pahani* are obsolete. Also Govt. land has been redistributed among the landless, making the entire exercise of identifying households and stakeholders extremely difficult. Hence several assumptions had to be made before undertaking this study.

Necessity to generate baseline data

Lack of baseline data for post – WDP phase, was a daunting problem, as the PIA of these projects had not used the GIS or GPS tools. To overcome this problem, satellite data of previous years were procured from NRSC (ISRO) to generate baseline data. For production, productivity and income – related data in the final year of project implementation phase taken as base year for *Post-facto* evaluation, several assumptions had to be made. For e.g., it was assumed that there would have been at least a minimum of 20 % positive impact on the various parameters mentioned earlier, over the average community performance during the final year of WDP. This was used as the *threshold level* for comparing impact of WDP on various aspects during the study period.

General nature of core-issues

Core issues indicated in the study, are actually the general problems facing rainfed agriculture. However, the importance of these issues differs at different locations necessitating the construction of different sets of relevant indicators for each location.

Large suite of Sustainability indicators

Large number of *Sustainability Indicators* was required to be sifted, which was possible only through application of Bivariate Correlation technique and through PCA as it enabled identification of the most significant and correlated indicators for evaluation of WDP at various levels. Evaluation of sustainability of WDP was conducted separately at various spatial levels – household, field and watershed - as each level presents a different set of situation and requires a different set of activities or programs to make it sustainable.

Despite the severe limitations faced at the time of investigation, that required several assumptions to be made, the outcome of the study has not been compromised and the results hold good. As mentioned earlier, a good geo-referenced database has been established under this study, which could be used in future to revisit these watersheds and undertake fresh evaluation without any loss of time. In fact the database could be readily be used by other agencies aiming to initiate some work in this region.

13. Strategy for achieving sustainable development through WDP

The study indicated that in order to achieve sustainable development through WDP, the following strategies are required to be emphasised upon by the PIA. As mentioned earlier in the methodology developed for undertaking assessment and evaluation of WDP, a PCA analysis was performed on the critical indicators and their respective contribution for achieving sustainable development was estimated. Weightage were assigned to each of the indicators as indicated in Figure 34. For instance, at *household - level*, it was found that there is a necessity to emphasise upon *improving availability of fodder through cultivation of fodder crop* in order to ensure fodder availability for livestock and the weightage for this indicator was estimated to be 50%. The second critical strategy is the *reduction of input cost* that would ensure higher gross income on one hand and a better B: C ratio that would improve the economic viability of the agricultural production system followed by the farming household. A third critical strategy would be *improving the nutritional security in the household especially among women and children* that would ensure familial satisfaction and check out-migration from the rural areas (Figure 34).

At *field - level* there is a necessity to lay emphasise on ensuring the *adoption of Contingency Crop Planning* in the event of drought*; improving farm OM recycling; encouraging farmers to maintain the S&WC structures* constructed during the WDP implementation phase besides propagating *large-scale use of improved soil moisture conservation measures* (Figures 32 & 33). In addition *cultivation of fodder; improving Crop Diversity; improving waters availability for irrigation; securing tenure; increasing crop production* and consequently *improving gross income from agriculture* are critical. As rainfed agriculture keeps a farmer engaged only for a period of 4 to 6 months annually, there is a need to develop *other gainful employment opportunities* within the village or watershed itself like horticulture, silviculture and agro-forestry *(Venkateshwarlu, J., in Technical Manual on Watershed Management – I to V,1999)* including cultivation of medicinal and dye-yielding plants besides training the farm households on backyard farming, post-processing techniques and other artisan skills. Of these critical indicators *maintaining S&WC measures* and *large-scale adoption of soil moisture conservation measures* contributed 35.2 % to sustainable development at field level and 35.8 % at watershed level (Figure 34).

All the strategies identified as critical at *field – level* were also found to be critical for the sustainable development at *watershed – level,* except for *improving the extent of cultivated area* in case of watershed; at field-level, the *active role of extension agents* for providing guidance to farmers, was found to be critical (Figure 34).

Thus, it is evident that WDP must be treated as one of the strategy for sustainable development in rainfed agriculture as there is a great necessity to dovetail other activities of agriculture and rural development like - KVK activities; banking and infrastructure development and increasing the role of extension agents from the line departments like agriculture and rural development. Some of these strategies may at present, seem beyond the purview of the PIA, nonetheless they are critical for sustainable development of rainfed agriculture through WDP.

Critical Indicators & Strategy for Sustainable Watershed Development

Household-level	Field-level	Watershed-level	Contribution of indicators *(weight in %)*		
			Household- level	Field-level	Watershed -level
Improving availability and encouraging cultivation of fodder			50	1.6	3.5
Improving nutritional security	Increasing total crop production		25	14.1	7.8
Reducing input cost	Increasing gross agricultural income		25	9.9	7.8
	Maintaining S & WC structures			19.7	17.9
	Large scale adoption of soil moisture conservation measures			15.5	17.9
	Encouraging farm OM recycling			5.5	13.4
	Improving gainful employment options			9.9	3.5
	Practicing Crop Contingency Planning			4.5	8.6
	Improving security of tenure			1.6	7.8
	Increasing Crop Diversity (No.of crops/Cultivated area)			5.3	3.5
	Improving availability of water for irrigation			3.2	3.5
	Increased role of extension agents	Increase in cultivated area		9.4	4.9

Figure 34: Critical indicators and strategy for sustainable development through WDP at various levels

14. Lessons learnt

Based on the work undertaken so far and the feedback obtained for this study, the shortcomings of WDP implemented under earlier guidelines (MORD 2001, 2003; MOA 2001) have been recognized and the critical indicators for achieving sustainable development in rainfed agriculture identified. The apprehensions of being able to undertake an objective evaluation of rural development project like WDP in India have been laid to rest by the application of tools of Geo-informatics. The construction of a suite of sustainability indicators to evaluate performance and state of WDP and its impact on rainfed agriculture, is probably one of the most important contribution of this study, to the body of literature on rainfed agriculture in India. The adaptation of the concept of ***Five Pillars of Sustainable Development*** proposed by Smyth & Dumanski (1993, 1995) FAO (1993, 1998), Gomez et al., (1996) and Swete Kelley & Gomez (1998), to Indian context is a major step forward that would help in integrating Indian studies on Best Practices for Land Management and Stakeholders Participation for Combating Land Degradation and Desertification to the body of world literature on Sustainable Land Management (WOCAT 2007a, 2007b; UNCCD 2008, 2009; CSFD 2009; FAO 2007).

One of the issue often raised in connection with the evaluation methodology, was the multiplicity of sustainability indicators, not withstanding their requirement. In order to overcome this handicap, two statistical techniques, Bivariate Correlation Technique and PCA were used to identify critical indicators that were used to evaluate watershed projects.

Another major advantage of the evaluation procedure was the use of *Cob - web* diagrams to indicate the *performance* or *state* of an indicator at a certain spatial level in a watershed. This helped in comparing the performance of WDP across various locations besides helping in identification of weak -links in the program at various sites. The study helped in highlighting the use of tools of Geo-informatics for implementation and evaluation of WDP in addition to planning of the projects, as in vogue.

The study brought out the lacunae in the existing system of land records, village-level information and cadastral maps because of which much time and effort had to be invested in the field to undertake corrective measures like use of DGPS to map land parcels and conduct door-to-door survey to correct the existing village records.

The study helped in developing two questionnaires required for collecting relevant information at watershed- and household – level after several attritions to satisfy data requirements both in field and at the lab. These have been included in the appendices. As the evaluation procedure required a large volume of geo-referenced data, it was deemed fit to develop a Watershed Database adhering to the framework of NRDMS, making it compatible to the national database. This is a significant contribution of this study, as the geo-referenced database is readily available to other agencies; academics and researchers who wish to undertake long-term sustainability studies in future.

15. Conclusions

Although at present, WDP has been successful only to a limited extent in the study area, its' role in securing sustainable development in rainfed region is beyond doubt. If improvements were to be made in the program as indicated in this study, sustainable development could be possible at household-, field- and at watershed-level in the rainfed regions. The critical issues as identified by the indicators at each spatial level need to be strengthened first and foremost, so as to enable sustainable development of rainfed agriculture. The new Common Guidelines of WDP - 2008 have taken cognisance of several of the issues indicated in this study and hence the outcome of the newer watershed projects may be better than those implemented earlier. The evaluation methodology described in this publication could be readily used by the PIA for development of a good plan for implementation and for undertaking corrective measures to remove lacunae if any, besides funding and evaluating agencies, to undertake an objective evaluation of on-going and concluded projects.

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(Annexure –1)

Assessment of Watershed Development

Household Survey Schedule

Date: __________________Name of investigator**:** ________________________________Village: ________________

1. Survey No. ____________________ 2. Name of Respondent/:
2. Male: ___________________ s/o_____________________ Age: _____ Edu: ______________
3. Female: ________________w/o_____________________ Age: _____ Edu: ______________
3. (a) Category of Household: Marginal / Small / Semi-medium / Medium / Large

(< 0.5 ha) (0.5-1.0 ha) (1-2 ha) (2-4 ha) (> 4 ha)

(b). Social affiliation: ____

(Member of Panchayat/ NGO/ Co-op. Society/Youth Club/ Mahila Mandal)/ Watershed Committee, Dwacra)

Active Participation in Watershed program:

(c) Are you covered under any Govt. scheme:

(like IRDP, DWACRA, DPAP, JRY, TRYSEM, Food for Work, Crop insurance, Rajiv Palle Bata, Oldage pension Scheme etc…)

Member of Watershed Committee:

(d) Below poverty line/above poverty line (access to PDS card): _________________

(e) Caste / Religion: ____

4. Family information:

S.No.	Name of family member	Relationship with Head of family (Age)	Education	Occupation	Income
1.					
2.					

Benefit from Watershed Yes/No

Migration No. Of Members: Permanent:

Seasonal:

Occasionally:

Last year cultivated Land (information of 3 years):

Sale of land ___________

5. Land Value:

d) Land Value ____

Agricultural (ha) / Non agricultural use (ha): _________________

6. Land holding information (in ha):

Class	Owned cultivated	Leased in Period:		Share cropped in	Leased out Period:		Share cropped out	Fallow		Total Cultivation
		Area	Rent		Area	Rent		Current	Permanent	
Irrigated										
Garden										
Dryland										
Total Land										

7. Farm Assets:

Item	Type	Owned/ Hired	No.	Value/ Cost
Dug well / Tube well				
Pump (Diesel/ Electric)				
Tractor/ Power tiller				

Available – Water resource:

By Sources– Tank / Dug well / Bore well

By Quantity– Adequate / Scarce / Inadequate

8. Total Production and quantity sold or purchased:

Season	Survey No.	Crop	Area	Type (Dry / Irr)	Production	Sold	Value / Unit	Equipment	Seed		Labour				Fertilizer	
									Qty	Cost	Fertilizer	Interculture	Plant protec	Harvest	Qty	Value

Inter Sector linkage: (They now about the chain of process):
Any crop exported:
Contingency crop planning (Incase of drought / flood govt. Programme / (crop change)

Change in Status of Water availability:

Water quality:

9. Animal resources and rearing method

Name of animal	Type Improved/ Local	No. Of animal			Method of Feeding			Annual Income	Cost of maintenance of live stock
		Total	Milch	Non-milch	Rainy	Winter	Summer		
Cow									
Bullock									
Buffalo									
Goat									
Sheep									
Poultry									
Others									

Available Fodder resources – Growing/Local from CPR/ Crop residue/ Purchase

10. Market Information: (Market prices of important crop and livestock product should be collected)

a)	Type of market (Local / Co-operative / Govt)	
b)	Distance to market (Km)	
c)	Mode of transport	
d)	Process of selling (Direct selling) through middle man/ sell to co-operating or Govt. agencies)	
e)	If sold through middle man and percentage share of middle men	
f)	Market charges if sold in the market	

11. Credit facility and amount of credit (Rs.)

Type Of Loan	Year	Source	Year	Period	Amount	Subsidy	Interest rate	Outstanding balance	Remarks (easily available & repayment etc.)
	Short(6mon)								
	Medium(1 year)								
	Long(2-10year)								

12. Employment for self-family &others (man days / season or man days / year)

Activity	Employment generation Man days / year						Competing activities for labour demand for non-agriculture (Industry, Urbanization, Social labour)
	Low < 30% of total family labour		Medium 30-60% of total family labour		High > 60% of total family labour		
	Self	Family	Self	Family	Self	Family	
1.Farming (crop)							
2.Mixedfarming							
3.Agril.Labour							
4. Livestock							
5. Horticulture/ Agro forestry							

13. Role of Women in different activities

Activities	Participation in decision making (Yes/No)	Participation in farm operation (Yes/No)
A. Agriculture		
Land use planning		
Ploughing and planking		
Breaking of clods		
Sowing / Thinning / Gap filling		
Transplanting		
FYM Transportation and application		
Weeding / Intercultural		
Fertilizer application		
Harvesting, Threshing and winnowing		
Sale and purchase of agricultural produce		
B. Horticulture		
Land use planning		
Land preparation		
Purchase of plant material		
Manuring		
Weeding		
Tree training, pruning		
Harvesting		
Grading		

Marketing		
C. Livestock		
Fodder collection		
Animal care		
Milking etc.		
D. Cottage Industry		
Procurement of raw material		
Processing of raw material		
Actual operation		
Marketing		
E. Household activities		
Collection of fuel wood		
Cooking		
Washing of clothes		
Preparation of dung cake		
Child care		
Education		
Marriage / Ceremonies/ others		
F. Social organizations		
Member		
Office bearer		
Actual role played		

Food self-sufficiency: sufficient / insufficient.

Available Fuel Wood - Yes / No
If Yes - Social Forestry / CPR / Field Boundary
If No - LPG / Purchase (Kerosene)

Malnutrition among Women and Children:

(any diseases prevalent in the village)

14. Factors influencing the changes in cropping / land use pattern

Physical / Biological factors a. Problem soils b. Poor quality (stony / shallow) c. Subsoil hard pan d. Water scarcity e. Labour scarcity Others	**Government policy (mention the concerned crops/ enterprises)** a. Subsidies b. Incentives c. Procurement by Govt. agencies d. Influence of Agri. Departmental workers towards particular crop in fulfilling Govt. objectives. e. Minimum support price/ price policies of the Govt. f. Crop insurance scheme g. Others, if any
Economic factors a. Lower initial fixed cost b. Lower cost of production / High c. Cheaper inputs d. High price for Agri. Produce / Low price for Agri. Produce e. Higher net income f. Lower maintenance cost (incase of livestock) g. Marketing problem h. Credit facilities i. Less labour requirement Others if any	**Institutional factors (Mention concerned crop/ enterprise)** a. Easy accessibility to credit from PACS / DOA/ NGO's / Pvt seed companies / others b. Guidance / help from Dept of Agri. / Pvt. Seed companies / others c. Source of availability of quality inputs – PACS / DOA / Land dev. Bank / NGO's / Pvt seed companies/ Local/ others Availability of assured markets / processing units / regulated markets / middlemen / local markets / others if any
Technology factors a. Introduction of new technology resulting in higher yield / net returns (Specify crop & technology) b. Expected utility of introduced technology c. Expected profit	**Social factors (Extension Agents)** a. Influence of opinion leaders / Innovative farmers / Community / Nearby farmers b. Customs and tradition c. If any, other causes.

15. Problem soils and it's effect on Land use pattern –

1. Soil erosion (% area)

2. (Seviarity – low / med / high)

3. (% of problem soil)

I. Are problem soils found in your area Yes/ No

If yes, give the causes for problem soils

a. Lack of drainage facilities
b. Lack of adequate irrigation facilities / Water logged condition
c. Irrigating the crops with poor quality water
d. Formation of subsoil hardpan over long periods due to non-availability of suitable implements.
e. Excess application of chemical fertilizers due to inadequate availability of organic manures.
f. Monocroping practices
g. Other causes

Land soil type: Stony / Sandy / Hardpan / Slopy / Water-Logged

II Visual descriptors of soil in farm holding

(1) Soil depth
(2) Soil structure (arable, stony, hardpan, clods cracking)
(3) Soil texture
(4) Soil colour
(5) Roots (presence)
(6) Earth warm activity

III Soil moisture conservation practice followed

a. Compartmental bunding (self / wsc)
b. Contour bunding (self / wsc)
c. Vegetative barrier
d. Local practices (specify)
e. CD
f. Stony weir

IV. Land management practices

a. Mulching (Ploughing)
b. OM incorporation
c. Vermi Compost
d. FYM
e. Agro forestry
f. Based Fertilizer
g. Broad bed and furrow
h. Alley cropping
i. Summer Ploughing

V. Suggestions for reducing the Fallows and Wastelands present in the village / watershed.

16. I. Opinion of the farmers about changes in the land use pattern in their respective Farms / village in the last 15 years and the reasons for it.

a. Introduction of agro forestry (Casuarinas, Neem, Acacia etc.)
b. Cultivable waste area put under cultivation (Mention the crop)
c. Changes in the area under miscellaneous tree crops
d. Changes from food crops to commercial crops and vice-versa (mention the crops)
e. Increase / decrease in the area under fruit crops
f. Increase / decrease in the area under vegetable crops
g. Introduction of lower crops
h. Increase/ decrease in the area under fodder crops
i. Cultivation of export oriented crops (senns, Gherkin, Glariosa etc.)
j. Cultivation of medicinal plants (Specify the crops)
k. Increase / decrease in the area under pulses/ oil seeds
l. Increase / decrease in the cultivated area others changes (specify)

(Annexure – 2)

General Information of the Village / Watershed Physical, Socio-economic survey proforma

1. Name of village :
Block / Tahsil :
District :
State :
Area of the village (ha) :
Catchment of (Name the river/ distributory/ stream/nalla):

2. Date of Visit:

3. Name of the investigator:

4. Name of the farmers (group) interviewed & educational status:

5. Major Occupation of the Villagers:

a) Cultivator: Big (>4 ha): Medium (2-4 ha): Small (1-2 ha): Marginal (<ha):
b) Non-agriculture: Artisan: Trader: Worker: Landless labour:
c) Others (Specify)

6. Population in the Village: Total: Male: Female:

7. Cast-wise distribution of households

	<u>**Caste**</u>	<u>**No.of households**</u>	<u>**No.of persons**</u>
a)	OC		
b)	BC		
c)	SC		
d)	ST		

8. Migrants from Village (No.)
a) Regular basis
b) Seasonal basis

9. Infrastructure
a) Accessibility (distance from nearest public road)
b) Road type (kacha/ pucca)
c) Transport facility : Buses/ Trucks /Tempos/ Cart
d) Electricity : No.of houses with electrical connection:
e) Post office :
f) Credit Resources :

g)

S.No.	Sources of finance	Purpose(Seed/Fertiliser/Chemical/Implement/Livestock/others)
1	Cooperative societies	
2.	Banks	
3.	RRBs	
4.	Local meney lenders	
5.	Self help groups (SHG)	
6.	Others	

h) Source of draft Power:
No. of Electrical motors
No. of Diesel Motors
No. of Tractors
No. of Bullock pairs
Others (Specify)

i) Supply of inputs:

Inputs	Source of supply (Own/Private/University/ Inst./Department/Others)
Seeds	
Fertiliser	
Pesticides	
Fungicides	
Herbicides	
Tractor	
Machinery	
Implements	
Tools	
Diesel	
Petrol	

Other farm needs	

10. Access to Common Pool Resources (CPR)

a) Grazing land: Yes/No

b)Farm machinery: Tractor/ Thresher/ Harvester

c) Processing facilities: Common threshing yard/ others

d) Storage facilities : Godowns / Any other(Specify)

11. Market support

a) Agriculture Market Committee (AMC) exists in the village: Yes/ No

b) Distance of Regulated Market Yard (km):

c) Product sold through AMC: Yes/No

e) Any co-operatives in the village for marketing output:

f) Transport to market: Available/ Not available

g) Produce sold through Commission Agent: Yes/ No

12. Agriculture: Climate & temperature (Mean values)

a) Average annual rainfall (mm) :

b) Number of rainy days:

c) Temperature: Maximum: Minimum:

d) Relative humidity: Maximum: Minimum:

13. Natural calamities experienced in the past 15 years:

Calamities	Frequency (No. of occasions)
Drought	
Cyclones	
Floods	
Cloud burst	
Epidemics	
Others	

14. Total land (ha): Rainfed: Irrigated: Fallow:

15. Soil Particulars

Soil type	Local name	Percentage	Quality(low/ Medium/ high)	Texture	Depth	Slope (%)	Nutrient status	Value (Rs./ha) Rainfed/ Irrigated

16 . Crops grown

	Traditional practice	Present practice
a) *Kharif*		
b) *Rabi*		
c) Summer		

17. Cropping Area (ha)

a) Kharif

b) Rabi

c) *Summer*

18. Crop Yields (kg/ha)

Crop	1	2	3	4	5	6
a) *Kharif*						
b) *Rabi*						
c) Summer						

19. Source of irrigation:

Source of irrigation	Area(ha)
Canal	
Tank	
Dug Well	
Borewell	
Rainfed	
Others	

20. Change in irrigation scenario (last 10 years)

a) Ground water depletion(m) :

b) Salinization(ha) :

c) Siltation (m^3/ha-m) :
d) Others (specify) :

21. Wages prevailing:

Hiring charges	Tractor	Bullock pair	Man	Women	Child
a) Wages/day(Rs.)					
b) During season *Kharif*					
c) During season *Rabi*					
d) During off-season					

22. Other enterprises

Enterprises	Area(ha)	Investment	Annual income/ receipts	Employment (man days)
a) Horticulture (citrus, grapes, pomogranate, ber, papaya, banana, guava, mango, amla, others)				
b) Sericulture				
c) Apiculture				
d) Agro-silviculture				
e) Dairy				
f) Poultry				
g) Pasture				
h) Aquaculture				
i) Others(specify)				

23. Technology adopted

a) Crop related (seed/fertilizer/pesticide/others):
b) Soils (Conservation measure/ water harvesting/ INM/others):
c) Livestock (Improved breed/ Improved fodder/ others):

24. Farmers perceptions and decisions

Land resources managements (Farmers perception)

1.Do you consider soil and water conservation as a major problem of land resource management? Rank the solutions based on farmer's experience

a) Contour farming ( )
b) Bunding ( )
c) Broadbed furrow systems ( )
d) Summer ploughing ( )
e) Wider row spcing with deep inter-cultivation ( )
f) Compartmental bunding ( )
g) Ridges and furrows ( )
h) Cultivation across the slope ( )
i) Retention of crop residues ( )
j) Growing of green manuring crop in *Kharif* ( )
k) Vegetative measures of conservation ( )
l) Ridges and furrows ( )
m) Others (specify) ( )

2. Awareness about the Govt. and NGO programme on soil & water conservation? Yes/No
a) Participating in the programme: Yes/No
b) Weakness in the programme (if any):
c)Drawbacks if not participated in the programme:

3. Important remedies for soil & water conservation

4. Do you participate in the maintenance and management of created water resources, soil and water conservation measures etc
Yes/No (If no give reason)

5. Steps to be emphasized : Maintenance of structure/ Distribution of water / Collection of water charges / Participatory management.

6. Sowing
a) Do you adopt line sowing Yes/ No
If Yes, do you also adopt depth of sowing recommended?
If No, reasons: lack of labour/ want of proper implements / High labour class/ Other

7. Fertilisers
a) Do you use fertilizers

If Yes, what are the levels, time and method of application for each crop? (Hg/ha) area

	Crop(s)	Fertiliser(Kg/acre/ha)	Nature of application
1.			
2.			
3.			
4.			

If No, reasons: High risk/ Not remunerative / Not convinced/ Organic manure preferred/ High fertility soil/ costly/ non availability/ side effects

b) Awareness of use of bio-fertilisers Yes/No

What are the traditional methods of manuring (specify):

8. Irrigation

a) Water supply adequate: Yes/ No

If No, how do you manage irrigation? Own wells/ Buying water/ Both

b) Adopt *in situ* water conservation Yes/ No

If No, what are the constraints?

c)How do you manage drought?

(i) Water harvesting and recycling
(ii) Contingency crop planning
(iii) Removing selective crop rows
(iv) Removal of older leaves
(v) Closing of crevices on soil surface by deep intercultivation
(vi) Spraying of 2% urea after receipt of rain
(vii) Other occupation(specify)

d) Methods of irrigation: Sprinkled / Drip/ Others / None

If No, give reasons : Not aware of/ Heavy investment/ Difficult to get subsidy / Costly though subsidized/ Not convinced/ Maintenance difficult/ Require skilled labour/ Any other

If yes, state benefits : Extended irrigated area(in ha)/ saving of inputs (fertilizers) under drip system/ crop saved from drought/ Introduced fruit frees/ Invested Rs, ……………. Which is remunerative / Equipment lasts for 10 / 15 years.

9. Harvesting

Method of harvesting
Implements and tools
Human labour
Possibility of mechanized harvest

10. Farmer's perception

Opinion on new technologies recommended: Happy / Satisfied / Not satisfied
List technologies that are useful to you
1.
2.
3.
4.

if not satisfied, reasons: Location not specific/ Not relevant/ More costly / Not practicable / Risky / Relatively less remunerative / Less durable

Rural women participation in dry land agriculture
Source of drinking water for cattle………………, Human……………………
Is it sufficient ? Yes/ No
If No, what should be done?

Source of drinking water	Cattle	Human	Distance (km)

Farm Inventory

Land particulars

Land particulars	Total Area(acres/ha)					
	Own	Leased in	Leased out	Operational holding	Estimated value/acre/ha (Rs)	Source of irrigation Dug well(1) Borewell(2)Purchase of water (3) Sharing water (4) Tank/ Kunta (5)
Cultivated Rainfed Irrigated						
Uncultivated Permanent fallow Short run fallow						
Orchards						

Sole Mixed Waste land Total						

Farm implements/ machinery

S.No.	Type of Implement	Local / Improved	Own/ Hired	Number
1.	Plough			
2.	Blade harrow			
3.	Seed drill			
4.	Sprayer			
5.	Duster			
6.	Tractor			
7.	Chaff cutter			
8.	Bullock cart			
9.	Pump set			
10.	Power tiller			
11.	Any other			

Labour availability for soil and water conservation(S&WC) measures

Type of human labour	No. of days employed in		Wage/day (Rs)	Total cost(Rs)
	Farm	Livestock		
1.Farm labour a. Male b. Female c. Children				
2. Casual hired Labour a. Male b. Female c. Children				
3. Permanent hired labour a. Male b. Female c. Children				

4.Livestock particulars (for using the output of vegetative components of SWC measures)

Category of Animals	No. of animals/birds	Type/ Breed (Indigenous/ exotic)	Expense (Rs.)				
			Fodder / Straw	Top feed	Grazing	Total	Income
Milch animals							
Dry animals							
Bullocks							
He-buffaloes							
Others							
Total							

4. Income from livestock (Rs.):

Product marketed	Quantity (kg or No.)	Price (Rs/ kg of No.)	Gross income (Rs.)
Cow dung/ FYM			
Milk			
Wool			
Others			

Land Resource System Management

Land Management:
Are you aware of the rainfall amount in your village?
How do you estimate rainfall in a year (Good, Average, Poor)
Is quantification required using rain guage?
Do you observe any rainwater loss by run-off?
If yes, is it 75% / 50%, 25%/ Nil
Is it affecting your land?
If yes, how are you controlling:
Strengthening of bunds across the slope
Loose boulder waster weir
Draining of run off
Providing separate water channel
Others

Is crop failure taking place due to moisture-stress?
How can you overcome the problem?
Do you think moisture conservation practices can solve the problem? Yes/ No
If yes, what practices?

Do you like to have a quantification of loss of water, soil & nutrient from your land ?
Do you want any land treatment like bunding?
Is mechanical bunding useful?
If mechanical, what type is preferred?
Stone
Earth
Combination of Stone and Earth
Do you know live bunding?
Is live bunding (vegetative barriers) useful?
How? Do you think that best combination of mechanical and vegetative measures?
Will be effective for control of erosion?
Are you collecting runoff water and using it?
Are you using waterways to divert water?
Are gullies present in the waste land
If yes, do you need any control measures 1.
2.
Existing and desired soil & water conservation measures:

Soil & Water Conservation measures	Existing	Desired	Effect of measures on soil & water
Summer ploughing			
Strenghing of bunds			
Grassing of waterways			
Tree/grass/rice+ grass growing on bunds			
Drafting gullies/waterways between fields			
Farm ponds			
Checkdam			
Percolation tank			
Vegetative barrier			
Mixed mechanical and vegetative measures			
Any other			

Do you think growing trees and crops together will control erosion?
Improve soil quality Yes/No
Improve income Yes/No
Generate employment Yes/No
Will soil and moisture conservation practices useful for generally
Extra income-
Soil improvement-
Water quality improvement-
Water quality improvement-
Increase vegetation-
Higher fertilizer use efficiency-
For SWC measured do you know any external supplier from Govt.? Yes/No
If Yes, for which types of measures or practices?
If No, for which measures can you do on your own?

Who takes the decision for SWC measures Men/ Women/both
Are you willing to contribute a part of the cost of soil & water conservation measures? Yes/No
If Yes, how much? 10%, 20%, 50%, more
In what mode, labour/cast?
Do you think that the degradation can be checked by intensive soil & water conservation measures(both vegetative and mechanical)? Yes/No
Is the land production going up or down Up/ Down
If up, why?
If down, why? And how to check it?
Is there any Common Pool Resources (CPR) in the village : Yes/No
If Yes:

Types of Resources	Area (ha)	Use & status	Ownership*	Benefits & distribution*	Impact of policy on use	% Population dependent on
Forest		Major forest produce: Timber, pulpwood, bamboo Minor forest produce: Fuel wood, fruit, honey, gum, lac, fodder, bark, beedi leaves, thatching, medicinal plants, wild life etc.				
Grassland		Condition- Productive/degraded/moderately degraded. Use- Grazing, cut & carry, lopping of trees.				
Wasteland		Salt affected land, rock out crop, gravel pediment, water logged, ravine, gullies, mine spoils, waste dumping yard				
Rivers, streams, waterways		Fishing, irrigation, drinking, bathing, washing(human & animal, sand mining.				
Community Well/ Over-head tank		Drinking, bathing				
Community Tank/ pond percolation pond		Irrigation, washing, fishing, recreation, reeds, drinking water for livestock, ground water recharge etc.,				
Palm / Mahua tree/ Neem fruits		Beverages, Bio-pesticides, oil, etc.,				
Community land		Brick making, silt harvesting, stone quarrying, grazing etc.				
Crop cultivation		River bed, Tankd bed				
Village commons		Threshing yard, market, roads, schools, panchayats buildings, graveyard, temple lands, sacred grooves, hills and hillocks.				

* individual/ community/ sub-community/ government/ panchayat

Crop management

Details of the crops and yields obtained in each season.

Crop	Kharif				Expenditure /acre/ha	Rabi				Expenditure /acre/ha
	Variety	Area (acre/ha)	Yield (q/acre/ha)	Price (Rs)		Variety	Area (acre/ha)	Yield (q/acre/ha)	Price (Rs)	

Use of by-product

What is the source of seed? Local: Improved:

If improved, what is the source of purchase? Self/ Neighbour/ Govt. /Shop / Any other

Are you applying manure and fertilizers? Yes/No

If yes, to which crops and quantity of manure and fertilizer used

Crop	Name of the fertilizer	Quantity (kg /(acre/ha)	Type of manure *	Quantity (kg/acre/h

* FYM, Green manuring, Compost, Penning, Ploughing of legume residues in a sequence, crop rotation

What is the soil depth?

Are you recycling tank silt Yes/No

If yes, into which crop/ tree

Is application of manure & fertilizer improving the soil health? Yes/No

Are you weeding crop?

If yes : Cultural: Mechanical: Chemical: (Weedicide/ Herbicide etc)

Are you adopting plant protection measures? Yes/No

Do you want to have trainings? Yes/No

If yes, why and on which aspect ? Crop oriented/ Land oriented/ Component oriented

Did you hear about watershed development? Yes/No

If yes, what are your expectations? Are how is it beneficial to you?

Improves land quality Enhances ground water

Provides more employment Gives more yield

Diversification in production system Any other

Livestock management:

How are you managing feed and fodder for livestock?

Farm produce/ Purchase/ Open grazing

What improvement you want for higher output from your animals/ poultry?

Better health/ Better breeds/ Better nutrition

Availability of fodder:

a) Pre-monsoon (Summer March – May) Adequate/Not adequate

b) Monsoon (June- September) Adequate /Not adequate

c) Post-monsoon (October- November) Adequate Not adequate
d) Winter (December – February) Adequate Not adequate
Vegetative management:
a) Do you need income generation through fodder raising and horticulture? Yes/No

a) Do you like to have intercrop with trees/bushes? Yes/No

Option	Existing	Desired	Remarks
In the field			
On field boundary			
On field bunds			
In waterways			
In gullies			
Any other			

a) Availability of fuel wood Adequate / Not adequate

Fallow and wasteland management (for village):
Do you have fallow and wasteland? Yes/No
Reasons:
Lack of resources
For creation of irrigation source/ water harvesting
Salinity / acidity/alkalinity problem
Livestock grazing (pastures)
Recovering soil fertility for next crop
Lack of rains
Lack of soil & moisture conservation activities
If yes, are you planning to make use of fallow and wasteland available with you? Yes/No
If yes, how?
Agriculture-food crops
Agriculture-commercial crops
Horticulture-fruit trees
Forestry-multiplication trees
Pasture-grass/legumes
Medicinal and aromatic plants
Any other
If not, why?
Lack of resources
Non-availability of planting material
Inadequate market facility
Non-availability of labour
Any other (specify)
How are you going to protect & maintain the conservation measures Yes/No
If yes, how?

Water resources management
Well
Type of well (1) No. of dug well (2) No. of bore well (3) No. of dug cum bore well
At what depth water is available (m/ft) during
(1) Rainy season……… (2) Winter………… (3)Summer season…………
How many times the well dried up during the last 5 years : During which month:
Under what circumstances the wells dry up:
i) Water quality for agricultureGood/ Satisfactory/ Poor
ii) Water quality for drinking Good/ Satisfactory/ Poor
iii) Constraints in water utilization/ use
iv) Health hazards
mode of lifting water pumps/ others
if pump, what H.P……………
time taken for employing the well (hrs)
time taken for recuperating to the original level (hrs)

Type of crops grown and area irrigated

S.No.	Crop	Area(acres)	Irrigation time(hrs)

Percolation tank/ pond
No. of percolation tank
Average dimensions of percolation tank Area (in acres/ ha) ………. Average depth (in m.)……………
a) Depth of water retained
b) No. of days water is retained
c) No. of times it gets filled in a season
d) Is it getting silter up?
e) Is it improving the ground water level?
f) Does it dry fact after the filling by runoff?
Dries in how many days:
Are you using runoff water of percolation tank?
Type of lifting/ irrigation:
Type of crop grown:

Do you have water user association?
If yes, provide details:

d) How to improve the water use?

Views and observation of the investigator and additional important information:

About the authors

Dr. Kaushalya Ramachandran is a Principal Scientist & an ICAR National Fellow (Geography) since 2005. She is a DAAD Fellow, a DAAD Visiting Scientist and holds a doctorate from the University of Saarland, Saarbruecken, Germany. She was conferred the *Punjabrao Deshmukh Women Agriculture Scientist Award* in 2006 for her significant contribution in the field of natural resource management. The Global Land Project – IGBP - IHDP has issued a letter of endorsement for her research scheme *Sustainability of rainfed agriculture in India: Evaluation of watershed development projects in rainfed agro-ecological regions in peninsular India* in 2008.

Dr. K. L. Sharma is a Principal Scientist & an ICAR National Fellow in Soil Science since 2005 at Central Research Institute for Dryland Agriculture, Hyderabad. He holds a doctorate in Soil Science and Agricultural Chemistry from IARI, New Delhi. He has made significant contribution in the field of soil fertility and plant nutrition in rainfed agriculture in general and soil quality improvement and assessment in particular. He was awarded the Fellow of Indian Society of Soil Science, New Delhi in 2009 for his significant contribution in the field of soil science. He has numerous publications in national and international journals.

Dr. Uttam Kumar Mandal is a Senior Scientist in Soil Physics at Central Research Institute for Dryland Agriculture, Hyderabad. He holds a doctorate in Agricultural Physics from IARI, New Delhi. He was awarded PDF at ARO Israel during 2005-06. He was conferred Lal Bahadur Shastri Young Scientist Award in the field of NRM in 2005. In 2009 he received the Golden Jubilee Young Scientist Award from ISSS. His research interests are soil water balance, sustainable land management in watershed, soil quality assessment, and soil & water conservation. He has several publications in national and international journals.

Dr. B. Venkateswarlu is Director of Central Research Institute for Dryland Agriculture, Hyderabad. He led the NATP program for rainfed agro-ecosystem as Principal Production System Scientist from 2001 – 2006. He served as Head, Division of Crop Sciences at CRIDA during 2006 – 2008. He was recently awarded Fellow of the National Academy of Agricultural Sciences- 2010 for his outstanding contribution in the area of NRM in dryland agriculture and specific contributions in microbial ecology, biological nitrogen fixation, the molecular basis of stress tolerance in micro-organisms and adaptation of crops to climate change. He is a life member of several academic and professional societies in India and has published over 100 research papers, 10 books and holds one patent.

Global Land Project (GLP) - Letter of Endorsement

On behalf of the Scientific Steering Committee (SSC) and in my function as Chair of the Global Land Project, I hereby grant endorsement status to the following project:

Sustainability of Rainfed Agriculture in India: Evaluation of Watershed Development Projects in Rainfed Agro-ecological regions in Peninsular India

Kaushalya Ramachandran, Principal Scientist and ICAR National Fellow (Geography), Central Research Institute for Dryland Agriculture (CRIDA – ICAR), Santoshnagar, Hyderabad – 500059, AP, India

This agreement on "endorsement" status between GLP and the above mentioned project formalises the mutual recognition of the importance of the scientific work of the other program/network/project and the potential for cooperation that is beneficial for both partners. The Global Land Project recognises that the project is contributing to parts of the GLP research effort as defined in the GLP Science Plan (IGBP Report no.53/IHDP Report no.19). Elements of the endorsed project are central to the goals of the GLP, and vice versa.

- Endorsement status means that the webpage of the endorsed project can be linked from the GLP webpage.
- Endorsed partners will become part of the GLP network and will inform each other (on a regular basis, preferably through their project offices) about upcoming meetings, conferences and workshops, as well as about relevant publication opportunities and possible cooperation.
- Endorsement obliges the applicant to mention GLP in publications and presentations of research that is a product of cooperation between GLP and the endorsed project, and to inform the IPO of the GLP on such activities and publications (report on a yearly basis about written output for the GLP publication list and provide a hardcopy print of all publications for the GLP archive).
- There is also the possibility of sharing data among the members of the GLP network facilitated by the International Project Office (IPO).
- The endorsed project might be requested to provide a short annual performance report for review by the IPO and SSC (Scientific Steering Committee) of the GLP.

Prof. Anette Reenberg (Chair GLP), Copenhagen 29th September 2008

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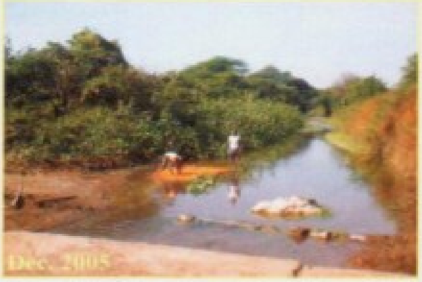
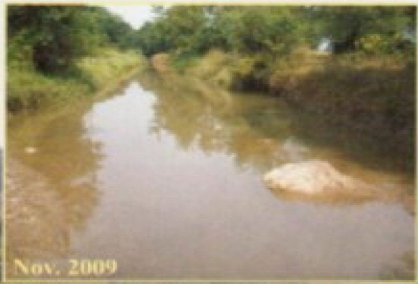
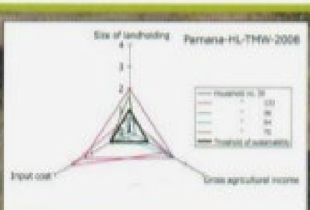
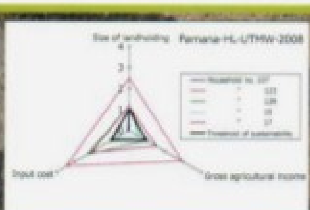
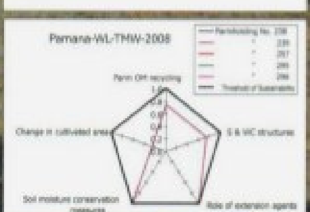
Tel. +45 35 32 25 08, Fax +45 35 32 25 01
GLP – A Joint Research Agenda of IGBP and IHDP, www.globallandproject.org

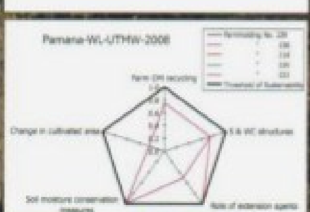












Critical Indicators & Strategy for Sustainable Watershed Development

Household-level	Field-level	Watershed-level	Contribution of indicators (weight in %)		
			Household level	Field-level	Watershed level
Improving availability and encouraging cultivation of fodder			50	1.6	3.5
Improving nutritional security	Increasing total crop production		25	14.1	7.8
Reducing input cost	Increasing gross agricultural income		25	9.9	7.8
	Maintaining S & WC structures			15.7	17.9
	Large scale adoption of soil moisture conservation measures			15.5	17.9
	Encouraging farm OM recycling			5.5	13.4
	Improving gainful employment options			9.9	3.5
	Practicing Crop Contingency Planning			4.5	8.6
	Improving security of tenure			1.6	7.8
	Increasing Crop Diversity (No.of crops/Cultivated area)			5.3	3.5
	Improving availability of water for irrigation			3.2	3.5
	Increased role of extension agents	Increase in cultivated area		5.4	4.9

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