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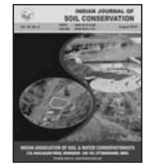
Vol. 44, No. 2, pp , 2016
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home



Measuring agricultural sustainability - spatial evaluation of development in watershed projects

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ARTICLE INFO

Article history :
Received : April, 2014
Revised : September, 2014
Accepted : October, 2014

Key words :
GIS,
Indicators,
Rainfed agriculture,
Remote sensing,
Spatial evaluation,
Sustainable development,
Watershed development projects

ABSTRACT

Watershed development project is a popular NRM and agriculture development strategy in rainfed agriculture. The program has attracted huge investments since its initiation in 1980s in the country. Till date, several phases of watershed projects have been implemented under guidelines that have been modified at regular intervals to adapt to changing situations. Monitoring and evaluation of watershed projects have always been a challenge. However, use of tools of Geo-informatics makes the task manageable and provides the facility to measure the immeasurable, namely sustainable development. This paper presents a methodology developed to measure sustainability of agriculture in rainfed regions of India. The paper discusses the methodology developed under ICAR National Fellow scheme which was used to monitor changes in identified treated watersheds in two districts in erstwhile state of Andhra Pradesh, namely Nalgonda and Rangareddy which are presently part of Telangana, a new state carved out of the former. Temporal study carried out in the selected watersheds since 2006 helped in indicating which aspects of watershed development program were critical and eventually contributed to agricultural sustainability. This information could be vital for the Project Implementing Agency (PIA) that can use the information to carry out mid-term correction or undertake an overhauling of the whole project based on actual requirements in the field. Study indicated that although full sustainability had not been achieved in the selected project sites, watershed development program was found to be useful and had actually contributed positively to development of rainfed agriculture in the region.

1. INTRODUCTION

Assessing agricultural sustainability especially through NRM interventions like implementation of watershed projects has always been difficult but the advances in the field of Geo-informatics has changed this situation. To start with, the concept of agricultural sustainability was defined in order to make it measurable and a treated watershed was selected as a natural unit to assess and measure agricultural sustainability. This exercise was facilitated by the use of GIS and remote sensing tools and techniques. Satellite data of pre-watershed implementation phase and post-watershed situation were procured, interpreted and used as input for further analysis using a number of other data in a GIS environment. Implementation of watershed projects has been a popular scheme for soil and water conservation in India since 1980s and huge public and private investments have been made in India under numerous schemes by various Ministries. However, measuring and comparing the outcome of each project or the impact of the program has remained difficult. Hence in 2005, an ICAR National Fellow Scheme was launched in CRIDA in order to develop a procedure and a tool to measure the impact of watershed projects on agricultural sustainability in rainfed regions in India which account for over 77 m ha out of a total net sown area of 142 m ha in the country.

As watershed projects are typically a multidisciplinary intervention, there was a need to measure various aspects of the program to measure its impact on agricultural sustainability for which a set of pertinent indicators consisting of fifty-one indicators derived from multiple disciplines, were constructed. A score-card was generated for these indicators and questionnaires were structured to capture this information during the first phase of National Fellow scheme. Subsequently a method was evolved to identify a set of 12 critical indicators using Principal Component Analysis (PCA) which were then used to assess agricultural sustainability at various levels. Six of these indicators signifying various interventions of watershed program were found to contribute over 68% towards agricultural sustainability in the study area *i.e.,* AESR 7.2 covering a major part of Telangana. The methodology developed for monitoring and evaluation of watershed projects based on this indicator-based system has enabled a rational, replicable and objective procedure for assessment of watershed projects which was not possible earlier. The objectives of this study were to develop suitable indicators, identify critical indicators signifying interventions essential to achieve agricultural sustainability and to develop a methodology to carry out a comprehensive spatial evaluation of watershed projects that is objective and rational (Kaushalya *et al.,* 2013).

2. MATERIALS AND METHODS

In order to evolve a procedure for measuring agricultural sustainability and assessing the impact of watershed projects, eight micro-watersheds in four villages in Rangareddy (RR) and Nalgonda districts located in the new state of Telangana-a part of erstwhile Andhra Pradesh, was started in 2005. Area under four villages encompassing over 6000 ha of agricultural land is located at $16^0$50'-$17^0$30' N and $78^0$10'-$78^0$50' E in various blocks in Nalgonda and Rangareddy districts in southern Telangana region encompassing AESR 7.2 (Table 1). Over 450 farm households located in the watershed villages with land holdings in the selected micro-watersheds were surveyed annually since 2005 using two structured questionnaire developed particularly to monitor and evaluate (M&E) the watershed projects at three spatial levels *viz.,* household, field (landholding/ survey no./parcel) and at watershed level.

Each of the four villages selected for the study in Rangareddy and Nalgonda districts in Telangana, could be divided into 7 to19 micro-watersheds, out of which one treated and one untreated micro-watershed covering an area of 100 - 150 ha each, were selected for the study. The location of watershed projects is indicated in Table 1 and all of them were implemented under DPAP and NWDPRA schemes during 1998-2004. Since April, 2008, Common Guidelines for Watershed Development Program have been implemented and new IWMP projects are being formulated and implemented according to CGWD-2008. The information generated under the present study would be invaluable to implementation of the new set of watershed projects as it demonstrates the utility of tools of Geo-informatics to carryout spatial evaluation of watershed projects. The indicators and methodology developed and the tool constructed for spatial evaluation *viz.,* Raster Tool can help in monitoring and evaluation of a seemingly immeasurable entity *viz.,* sustainable development in agriculture in a watershed framework. The procedure developed for monitoring and evaluation of watershed projects would thus facilitate undertaking of mid-term corrections by PIA as and when required in the field and for evaluation of the projects by funding agencies at the completion of watershed program.

To evaluate impact of watershed development program (WDP) and consequent changes in the watersheds, a complete methodology was evolved as indicated in Fig. 1. Assesment procedure comprised of activities in the field, *viz.,* traversing for reconnaissance survey, soil sampling and carrying out socio-economic survey, focus-group discussion, social mapping *etc.,* while lab work included creation of database, construction of relevant indicators for monitoring and evaluation of watershed projects and for assessing agricultural sustainability, interpretation of satellite data, mapping and analysis using GIS, and finally assessment of impact of watershed project and study of change in the watersheds. In this paper, a brief description of the methodology developed and the spatial tool constructed for an objective monitoring and evaluation of watershed projects has been presented (Kaushalya *et al*., 2009, 2010, 2011; Mandal *et al*., 2011; Wani *et al*., 2011).

PCA was used to identify twelve critical indicators for monitoring (Table 2) and evaluation (Table 3) of watershed projects. It was seen that the aspects of watershed project signified by the six action-oriented monitoring indicators could contribute to over 68% of agricultural sustainability. These indicators denote actions or strategies that the PIA may initiate in order to develop a watershed project for agricultural sustainability. Similarly, six status-based

Table: 1
Study area

S.No.	District	Name of Agency	Name of Watershed	Location (Toposheet no.)	Funding Agency
1	Rangareddy	DPAP, Govt. of AP	Dontanpalli, Shankarpalli Mandal	56 K / 3	MoRD
2	Rangareddy	PROGRESS	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

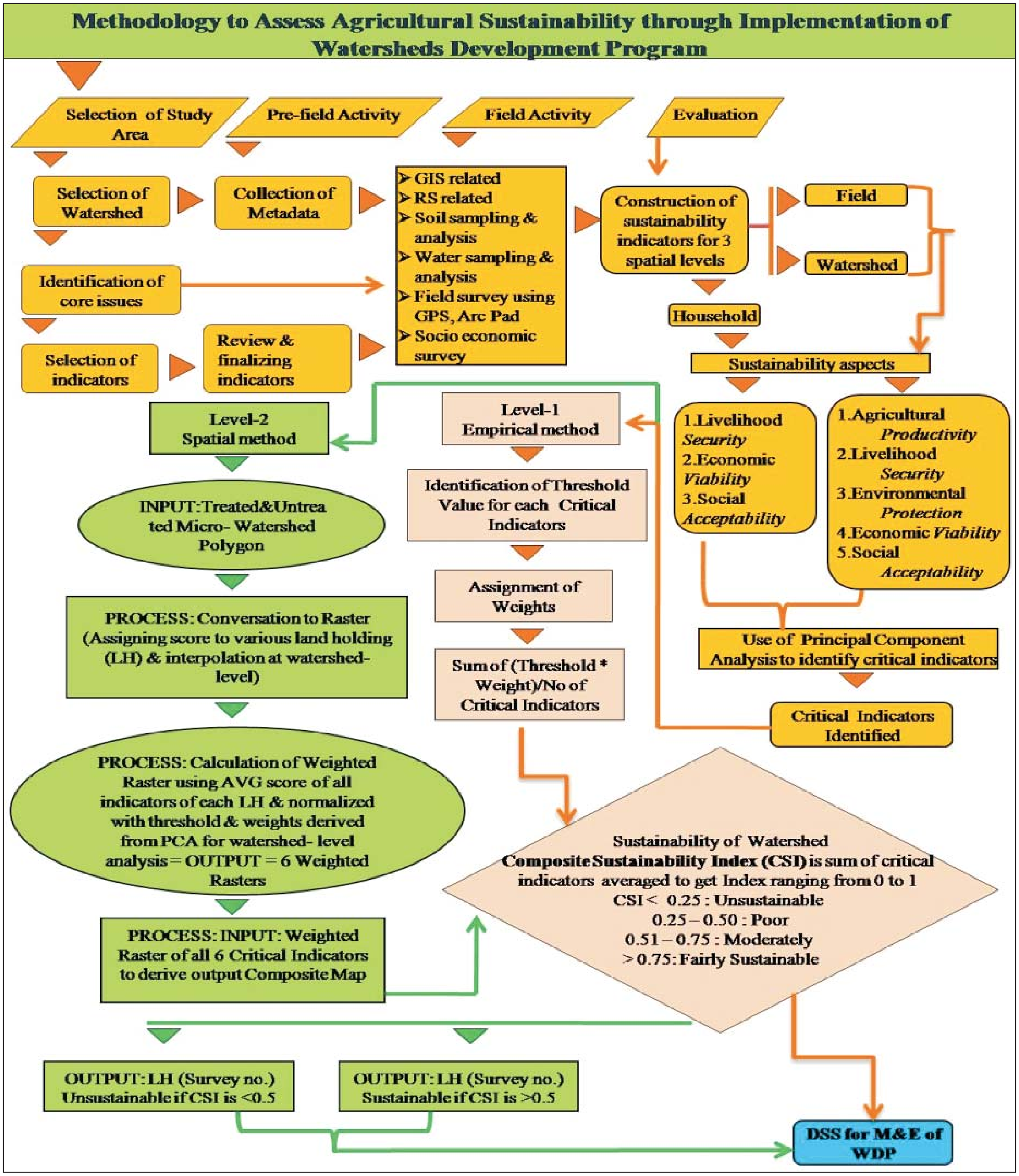


Fig. 1. Methodology for monitoring & evaluation of watershed projects

critical evaluation indicators were also identified as indicated in Table 3 that represent various aspects or status of natural/agricultural/ social resource base in the watershed village (Sharda *et al*., 2012, Sikka *et al*., 2014). Study indicated that if these aspects were adequately addressed under watershed development program, over 80% of issues related to agricultural sustainability could be addressed through implementation of the program. Evaluation indicators indicate the state of resources as a result of interventions under the program. Both sets of indicators are non-correlated and hence ideal for monitoring and evaluation of watershed projects.

Based on these indicators, a spatial assessment tool for monitoring and evaluation of watershed projects was developed using ArcGIS Spatial Analyst module. The entire procedure for monitoring and evaluation (M&E) of watershed projects was developed in the form of a two-level procedure under the National Fellow scheme and has been described in detail in the paper.

Table: 2
Critical indicators to monitor impact of watershed project on agricultural sustainability

Critical Monitoring Indicators	
At Watershed-level	Weights derived by PCA considered as contribution to sustainable agriculture (%)
S&WC structures (maintenance)	17.9
Soil Moisture Conservation (adoption)	17.9
Farm OM recycling (adoption)	13.4
Total Crop Production (actual data)	7.8
Gross Agricultural Income (actual data)	7.8
Availability of Fodder (adequacy)	3.5
Total	68.3

Table: 3
Critical indicators to evaluate impact of watershed project on agricultural sustainability

Critical Evaluation Indicators	
At Watershed-level	Weights derived by PCA considered as contribution to sustainable agriculture (%)
Credit Facility (access)	15.9
Crop Diversity Index (No. of crops/ size of landholding)	13.6
Soil Organic Carbon (actual data)	13.4
Gainful Employment sources (access)	13.4
Soil Fertility status (actual data)	12.4
Availability of Fodder (adequacy)	12.2
Total	80.9

Procedure for Monitoring and Evaluation (M&E) of Watershed Projects (WDP)

A two-stage procedure for monitoring and evaluation of watershed projects was developed as indicated in Fig. 1 that comprised of Level-1 where empirical methods were employed to monitor and evaluate watershed projects and Level-2 that employed Geo-informatics tools and techniques for the purpose. The outcome from employing either of the two procedures was seen to be similar and preference to use one or the other has been left to the PIA or any agency undertaking Monitoring and Evaluation work.

M&E procedure for WDP - Level 1 (Empirical method)

Level- 1 of the M&E procedure is relatively simple and based on empirical techniques. After identification of critical indicators listed in Table 2 and Table 3, a method was evolved to make all indicators comparable. For example, some indicators yielded quantitative value, *viz.,* crop production, area under agriculture and agricultural income, while others yielded only qualitative information *viz.,* status of S&WC structures, soil organic carbon status, availability of fodder, based on adequacy *etc.* It was essential to make the quantitative and qualitative indicators comparable so that the whole procedure could be made objective, measurable and robust for which a score-card was developed (Kaushalya Ramachandran *et al.,* 2010). It was also essential to normalize the indicator, namely Gross Agricultural Income calculated as follows:

Normalized Gross Agricultural Income = (Actual Income of a farm household/Max income among land holdings of a specific watershed/village)*10

This step was essential to harmonize the data in comparison to values obtained from other indicators, because while data of agricultural income was in thousands of rupees, other values of pertinent indicators were either in ones or tens of units. This procedure helped in making the comparison of performance among watershed projects possible which was not the case earlier.

To make the monitoring and evaluation procedure measurable, a concept of Threshold Value (TV) was devised. It was assumed that the state of natural resources and agriculture in a treated watershed would be better than that of fields in the neighbouring untreated watersheds. Hence TV of pertinent indicators in fields/landholdings in treated watersheds could be higher compared to that in an untreated watershed. Threshold value was derived as 20% above mean with respect to an indicator, based on the community performance for a specific indicator as suggested by Gomez *et al.* (1996).

In case of qualitative data considered for analysis, the maximum score of concerned indicator was assigned to TV of that indicator. Ratio for each indicator was calculated by dividing actual value for an indicator by corresponding TV. Weights of indicators were derived from PCA based on Eigen value for each indicator which was multiplied with ratio estimated for a specific indicator (actual value/TV). The sum of contribution to agricultural sustainability estimated for six monitoring and six evaluation indicators was normalized to 100% irrespective of weights arrived at by PCA. While six monitoring indicators contributed to 68.3% and six evaluation indicators contributed to 80.9% of agricultural sustainability in watersheds, both were normalized to 100% for ease in calculation. For assessing agricultural sustainability, the value against each of the six monitoring and evaluation indicators was averaged and a Composite Sustainability Index (CSI) ranging from 0 to 1 was determined for each household/field (land-holding/Survey no)/ watershed. Depending on the CSI value, agricultural sustainability at each field/ watershed-level was determined in the following manner: CSI < 0.25 (Unsustainable); 0.25-0.5 (Poor); 0.5-0.75 (Moderately sustainable) and > 0.75 (Fairly sustainable).

The procedure for monitoring and evaluation has been described step-wise using actual field data pertaining to each of the six monitoring and six evaluation indicators indicated earlier. Table 4 indicates the actual data.

Step 1: TV for each indicator was arrived at in the following manner: For indicators with quantitative[1] (actual data), TV = Average + 20%; for qualitative indicators, TV was Max score for respective indicators. In Table 4, the TV of both sets of indicators has been indicated in the last row.

Step 2: Actual data (value obtained from field study) indicated in Table 4, is divided by corresponding TV. This is indicated as values in Table 5a in Column 3-8 in case of monitoring process, and in Table 5b (Column 3-8) for evaluation procedure.

Step 3: Ratio derived as indicated in Step 2 is then multiplied by respective indicator weight as derived by PCA and indicated in Table 2 and Table 3 earlier. Values indicated in Column 9-14 in Table 5a and Table 5b denote this.

Step 4: Sum of Col. 9 to 14 is then divided by total weight derived from PCA for Monitoring and Evaluation Indicators respectively. The value is then multiplied by 100 to arrive at percent of agricultural sustainability and divided by 100 to arrive at Composite Sustainability Index (CSI) which is assigned a range of 0 to 1. Depending on the CSI value, impact of watershed development project on agricultural sustainability at field and/or watershed-levels were determined as follows:

CSI < 0.25 (Unsustainable); 0.25-0.5 (Poor); 0.5-0.75 (Moderately sustainable) and > 0.75 (Fairly sustainable).

The micro-watersheds in Pamana village were evaluated for their impact on agricultural sustainability using critical evaluation indicators identified and listed (Table 3) earlier. The methodology for evaluation was similar to monitoring except that a different set of critical indicators found relevant for the purpose except the indicator Availability of fodder which was critical for both monitoring and evaluation processes had a higher weight as evaluation indicator *i.e.,* 12.2 than as a monitoring indicator where it had a weight of 3.5. Table 5(b) illustrates the evaluation procedure for assessing watershed projects.

Spatial Analysis for M&E at Watershed-level (Level 2)

Spatial analysis enables one to assess the impact of watershed project on various bio-physical matrixes of agricultural systems at watershed-level. While statistical technique like PCA helped in empirical analysis of impact of watershed projects at all three levels, *i.e.,* household-, field- and watershed-levels, the GIS facility enabled overlaying of various thematic maps to understand the impact of watershed program at the watershed-level while considering it as a distinct hydrological unit, that was not possible earlier. Thematic maps pertaining to various M&E indicators as described earlier were drawn. Raster Calculator Tool (Fig. 1) in Spatial Analyst Module of ArcGIS software, helped in overlaying the thematic maps both vector and raster images in addition to, assigning scores as per estimated TVs derived as described earlier. Based on the nature of indicators, some values could be derived directly, *viz.,* agricultural production or income while others were derived by interpolating on a spatial basis in GIS as in case of Soil OC and slope, that were derived through kriging and used for thematic mapping and evaluation. The spatial tool treats a watershed as a unit area and not as an aggregate of various fields/land holdings or survey nos.

For raster based monitoring or evaluation process, each Survey No./landholding was considered to be a polygon and scores derived for an indicator either for monitoring or

Table: 4
Actual field data from Pamana watershed (2013) with Threshold Value for each indicator

Survey No.	Treated (TMW)/ Untreated (UTMW) Micro-watershed	Crop diversity Index[1]	Total Prod. (t ha^{-1})	Agri. Income[1] (normalized)	Availability of fodder	Gainful Employment	S&WC Structures	Farm OM recyling	Soil Moisture Conservation	Soil OC[1]	Soil Fertility[1]	Credit Facility
1	2	3	4	5	6	7	8	9	10	11	12	13
258	TMW	2.5	4.9	3.9	0.0	2.0	2.0	3.0	2.0	0.0	0.0	1.0
256	"	0.0	2.3	2.9	1.0	1.0	4.0	3.0	2.0	2.0	6.0	3.0
296	"	2.5	4.8	4.2	1.0	2.0	2.0	3.0	2.0	2.0	6.0	1.0
273	UTMW	1.3	5.0	8.8	1.0	2.0	0.0	3.0	2.0	0.0	0.0	1.0
248	TMW	0.6	6.0	7.5	2.0	2.0	3.0	3.0	1.0	3.0	6.0	3.0
279	UTMW	2.4	5.4	6.7	3.0	2.0	2.0	3.0	2.0	3.0	4.0	1.0
244	TMW	0.9	15.2	3.8	2.0	2.0	3.0	3.0	1.0	2.0	6.0	3.0
254	"	1.2	5.3	10.0	0.0	2.0	3.0	3.0	2.0	2.0	7.0	1.0
40	"	0.9	20.0	7.0	3.0	2.0	2.0	3.0	2.0	2.0	6.0	1.0
220	UTMW	1.5	20.0	7.3	0.0	2.0	4.0	3.0	2.0	2.0	6.0	3.0
Thres-hold value		1.6	10.68	7.4	3.0	2.0	4.0	3.0	2.0	3.0	7.0	3.0

*For indicators with quantitative[1] (actual data), Threshold Value (TV) = Average + 20%; for qualitative indicators Threshold Value (TV) was Max score

Table: 5(a)
Monitoring of Pamana micro-watersheds using critical indicators (2013)

Survey No.	Treated (TMW)/ Untreated (UTMW) Micro-watershed	Total Prod. (t ha^{-1})[2]	Agri. Income[1] (normalized)[2]	Availability of fodder[2]	S&WC Structures[2]	Farm OM recyling[2]	Soil Moisture Conservation[2]	Total Prod* weight[3]	Agri. Income* weight[3]	Fodder avail* weight[3]	State of S&WC weight[3]	Farm OM* weight[3]	SMC* weight[3]	CSI (Sum Col. 9 to 14/ Total Weight*100)/100[4]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
258	TMW	0.5	0.5	0.0	0.5	1	1	3.9	3.9	0	8.9	13.4	17.9	0.70
256	"	0.2	0.4	0.3	1	1	1	1.5	3.1	1.1	17.9	13.4	17.9	0.81
296	"	0.4	0.6	0.3	0.5	1	1	3.1	4.6	1.1	8.9	13.4	17.9	0.72
273	UTMW	0.5	1.2	0.3	0	1	1	3.9	9.3	1.1	0	13.4	17.9	0.67
248	TMW	0.6	1	0.7	0.8	1	1	4.6	7.8	2.3	14.3	13.4	17.9	0.88
279	UTMW	0.5	0.9	1.0	0.5	1	1	3.9	7.0	3.5	8.9	13.4	17.9	0.80
244	TMW	1.4	0.5	0.7	0.8	1	1	10.9	3.9	2.3	14.3	13.4	17.9	0.92
254	"	0.5	1.3	0.0	0.8	1	1	3.9	10.1	0	14.3	13.4	17.9	0.87
40	"	1.9	0.9	1.0	0.5	1	1	14.8	7.0	3.5	8.9	13.4	17.9	0.96
220	UTMW	1.9	1	0.0	1	1	1	14.8	7.8	0	17.9	13.4	17.9	1.05

[2]Column 3-8: Actual data indicated in Table 4, is divided by corresponding TV; [3]Column 9-14: Value in[2] *Weight of CMI; [4]Column 15 [Sum (Actual data÷corresponding TV) *Weight)/Total Weight*100]/100

Table: 5(b)
Evaluation of Pamana micro-watersheds (2013) using critical indicators

Survey No.	Treated (TMW)/ Untreated (UTMW) Micro-watershed	Crop diversity index[5]	Credit facility[5] (t ha^{-1})[2]	Gainful employment[5]	Soil org. Carbon[5]	Soil fertility[5]	Avail. of fodder	CDI weight[6]	Credit facility* weight[6]	Gainful employment* weight[6]	Soil OC* weight[6]	Soil fertility* weight[6]	Availability of fodder* weight[6]	CSI (Sum Col. 9 to 14/ Total weight*100)/100[7]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
258	TMW	1.6	0.3	1	0	0	0.0	21.8	4.8	13.4	0.0	0.0	0.0	0.49
256	"	0	1	1	0.7	0.9	0.3	0.0	15.9	13.4	9.4	11.2	4.1	0.67
296	"	1.6	0.3	1	0.7	0.9	0.3	21.8	4.8	13.4	9.4	11.2	4.1	0.80
273	UTMW	0.8	0.3	1	0	0	0.3	10.9	4.8	13.4	0.0	0.0	4.1	0.41
248	TMW	0.4	1	1	1	0.9	0.7	5.4	15.9	13.4	13.4	11.2	8.1	0.83
279	UTMW	1.5	0.3	1	1	0.6	1.0	20.4	4.8	13.4	13.4	7.4	12.2	0.89
244	TMW	0.6	1	1	0.7	0.9	0.7	8.2	15.9	13.4	9.4	11.2	8.1	0.82
254	"	0.8	0.3	1	0.7	1	0.0	10.9	4.8	13.4	9.4	12.4	0.0	0.63
40	"	0.6	0.3	1	0.7	0.9	1.0	8.2	4.8	13.4	9.4	11.2	12.2	0.73
220	UTMW	0.9	1	1	0.7	0.9	0.0	12.2	15.9	13.4	9.4	11.2	0.0	0.77

[5]Column 3-8: Actual data indicated in Table 4, is divided by corresponding TV; [6]Column 9-14: Value in[5] *Weight of CEI; [7]Column 15 [Sum (Actual data ÷ corresponding TV) * Weight)/ Total Weight*100]/100

evaluation, was assigned as one value for each polygon in each thematic layer pertaining to that indicator. For each indicator, a raster layer was created from the vector polygon layer with corresponding attribute values by using conversion option in ArcGIS. Indicators were weighted using *Raster Calculator* in Geospatial Analyst Tool in ArcGIS. As mentioned earlier, weights for indicator was estimated statistically through PCA (Table 2 and Table 3) and were assigned to each critical indicator. To assess agricultural sustainability achieved in individual farm holdings/Survey No. within a watershed, the weighted thematic layers were summed and normalized with aggregate weight.

3. RESULTS AND DISCUSSION

Change in Agriculture in Treated Micro-Watersheds

To analyze change in landuse-landcover (LULC) in treated micro-watershed (TMW), field surveys were conducted and corresponding satellite data were analyzed (Table 6). To assess impact of watershed projects on agricultural sustainability, various aspects and relevant indicators were analysed. To assess the impact of watershed projects on Environmental Protection, three indicators were analysed status of Soil & Water Conservation measures (SWC), adoption of Soil Moisture Conservation measures (SMC) and Farm Organic Matter (OM) recycling. It was seen that while SWC was improving in Chintapatla and Dontanpalli watersheds, adoption of SMC was seen in all watersheds except in case of Gollapalli. Farm OM recycling was evident in all watersheds except in Dontanpalli (Table 6). In case of Dontanpalli village, the watershed project had lost its relevance by 2009-2010 due to massive change in LULC due to rapid pace of urbanization around Hyderabad urban agglomeration. In case of another aspect of sustainability *viz.,* Economic Viability*,* four indicators were assessed namely, increase in agricultural income, availability of fodder, Crop Diversity Index (CDI) and access to credit facility. Analysis indicated that positive gain was achieved in case of CDI and accessibility to credit facility in all watershed villages while fodder availability improved in Chintapatla and agricultural income increased in Gollapalli due to higher contribution from animal husbandry. The aspect of Agricultural Productivity was positive in all watersheds except in case of Dontanpalli where agricultural land use diminished due to large-scale land conversion to built-up area. In case of Livelihood Security, only one indicator *i.e.,* increased access to gainful employment - was found critical and study indicated that all treated micro-watersheds (TMW) had gained positively as a result of watershed program when compared to situation in untreated micro-watershed (UTMW). In case of Social Acceptability*,* it was seen that S&WC structures were maintained in TMW, although not satisfactorily as stakeholders failed to identify and accept ownership for them.

Assessment of Watershed Projects using Empirical Method (Level-1)

Monitoring & Evaluation (M&E) of sampled watersheds in Rangareddy and Nalgonda districts was carried out during 2012-2013 as in previous years. Household, field survey and focus group discussions (FGD) were held in Pamana village during post-*Kharif* season in November, 2012 and in February 2013 which coincides with the end of *rabi* season in study area. Thirty-five households in TMW in Pamana who operated 65 landholdings were surveyed and their fields and agricultural activities were evaluated. In untreated micro-watershed (UTMW) taken as control for study in the same village, 17 households with 22 landholdings were evaluated. Six critical monitoring indicators and 6 critical evaluation indicators as indicated earlier (Table 2 and Table 3) were

Table: 6
Monitoring & Evaluation (M & E) of watershed projects in study area

Sustainability Aspects	M&E Indicators	Types of Watersheds							
		Chintapatla		Gollapalli		Pamana		Dontanpalli	
		TMW	UTMW	TMW	UTMW	TMW	UTMW	TMW	UTMW
Environmental Protection	State of S& WC measures	1	0	0	0	0	1	1	1
	Adoption of Soil Moisture Conservation measures	1	0	0	0	1	1	1	1
	Farm OM recycling	1	1	1	1	1	1	0	0
Economic Viability	Increase in Agri. income	0	0	1	1	0	0	0	0
	Improvement in availability of fodder	1	1	0	0	0	0	0	0
	Access to Credit facility	1	1	1	1	1	1	1	1
	Crop Diversity Index	1	1	1	1	1	1	1	1
Agri. Productivity	Increase in Agri. production	1	0	1	1	1	1	0	0
Livelihood Security	Access to Gainful employment	1	1	1	1	1	1	1	1
Social Acceptability	Maintenance of S& WC measures	1	0	0	0	0	1	1	1
Total		9	5	6	6	6	8	6	6

Note: Scores: 1= Increasing trend; 0 = Decreasing trend.

used to monitor and evaluate both types of watersheds. Actual field-level data collected with respect to relevant indicators is indicated in Table 4 as mentioned earlier. Table 5(a) indicates the procedure used to monitor the impact of watershed project while 5(b) indicates evaluation of WDP in treated micro-watershed. Corresponding Threshold Values, weights of indicators and the Composite Sustainability Index (CSI) derived from the mean value of 6 critial indicators in each case for each sample farm/land-holding have also been indicated. It was seen that landholding, namely Survey No. 244 in TMW was assessed as fairly sustainable although Survey No.220 in UTMW was also sustainable. Cob-web diagrams were used to indicate the comparative performance of various indicators in both types of watersheds. Three indicators that imparted a fair amount of sustainability to agriculture in the treated micro-watershed were improvement in agricultural production, increase in income from agriculture and increase in Crop Diversity Index (No. of crops/unit area). Situation was fairly similar in UTMW in the village (Fig. 2).

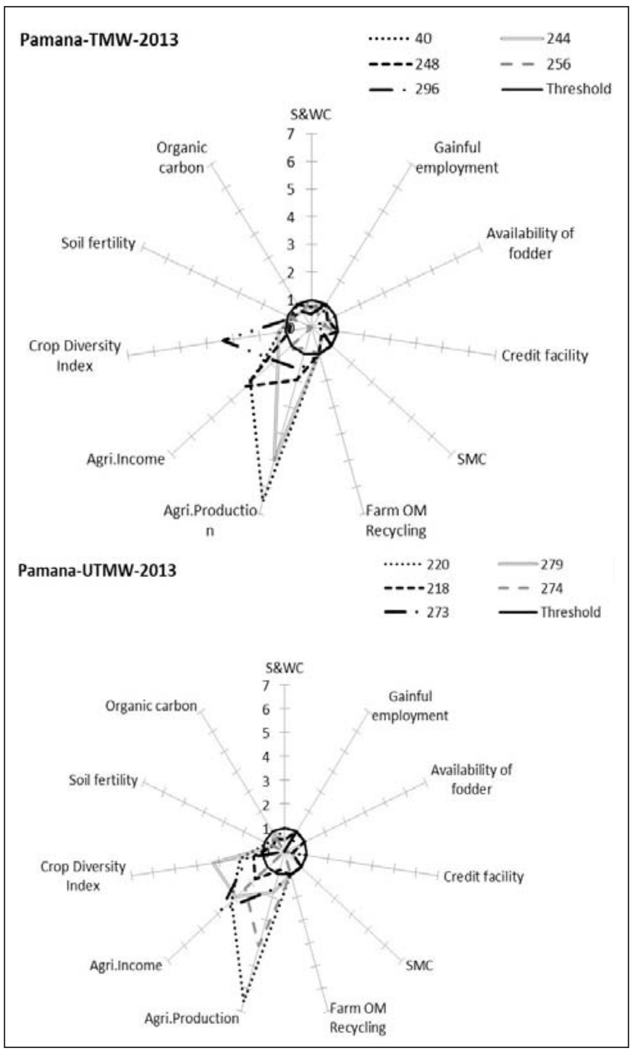


Fig. 2. Cob-web diagrams indicate relative gain in agricultural sustainability in treated and untreated micro-watersheds

Evaluation of watershed program in Pamana indicates that no farm household or field achieved agricultural sustainability. Cob-web diagram (Fig. 2) shows the comparative situation in both types of micro-watersheds. The axis emanating from the central hub denotes the various critical indicators used for evaluation. The thick grid line denotes the TV while the other lines indicate the gains made by selected farm-households/landholdings in respective watersheds. Correlation among critical indicators was analyzed and it was seen that it was poor among monitoring indicators. In case of evaluation indicators, soil fertility and soil organic carbon status were highly correlated (0.81) while soil organic carbon status was fairly related to availability of fodder (0.52). Crop Diversity Index was related to increased accessibility to Gainful employment denoting that staggered cropping pattern lead to employment generation among farm labour besides small and marginal farmers who often opt to work as labour for wages in Telangana region.

Similar analysis was carried out in case of other watersheds. In Chintapatla watersheds, survey of 30 households operating 65 landholdings in TMW and 23 households with 16 landholdings in UTMW micro-watershed were carried out. Two landholdings in UTMW were found to be sustainable while one Survey No. in TMW was found to be fairly sustainable.

Like in Pamana, watershed program in Chintapatla has contributed to agricultural sustainability through gains in Agriculture production, Agriculture income and Crop Diversity Index (CDI). In case of Gollapalli watersheds, study of 28 households cultivating 38 land holdings in TMW and 29 households farming 38 landholdings in UTMW, was carried out. Two holdings in each watershed-TMW and UTMW, were found to be fairly sustainable, although situation in UTMW was found to be better denoting a limited impact of watershed project in the village.

Trend in Agricultural Sustainability through Watershed Projects

In Pamana TMW, Survey No. 244 was found to be sustainable. In UTMW, Survey No. 220 was assessed to be fairly sustainable. A brief description of farming activities carried out by the farm households is presented here as illustration. One farmer named Davalgari Narayana Reddy owning 4.04 ha of land cultivated Bt. cotton during *kharif* season and produced 20 q from which he earned ₹ 82,000/- in 2013. Additionally he earned ₹ 3,200/- from livestock and ₹ 19,800/- as wages accrued to his family members. Study indicated that he practiced compartmental and contour bunding and incorporated FYM in soils and followed fertilizer recommendations issued from time to time. He owned a bore well and adopted S&WC measures, practiced soil moisture conservation techniques besides undertaking soil amendments like application of farmyard manure (FYM) and vermi-compost and undertook summer ploughing. Cob-web diagrams indicated in Fig. 3 show the trend in impact of watershed program in Pamana. In Survey No. 220, a farmer named Kavali Narshimulu had 0.76 ha of land and cultivated 30 q of maize and earned ₹ 36,000/- from agriculture alone. His wife Yadamma earned an income of ₹ 18,000/- as agriculture labour.

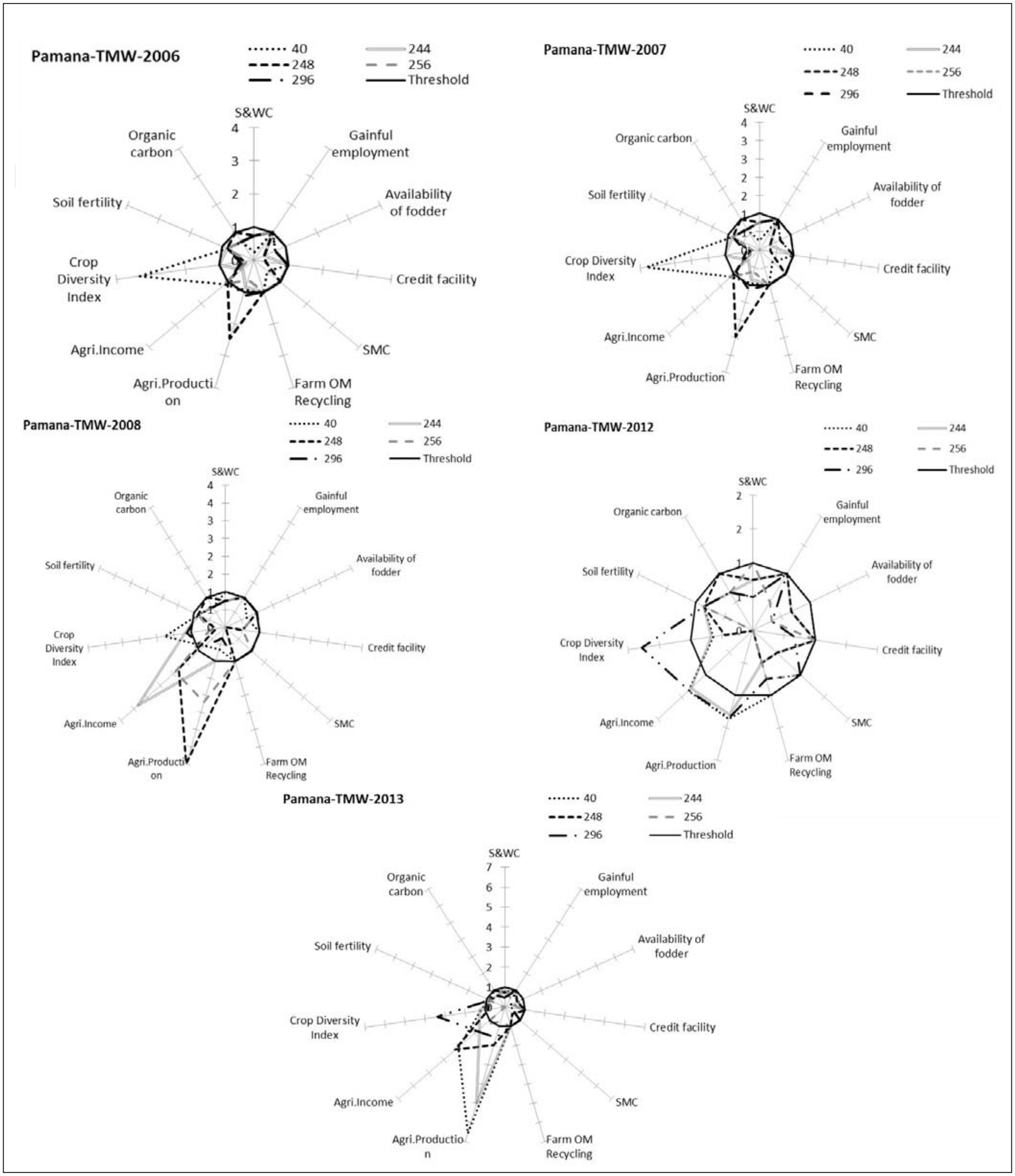


Fig. 3. Temporal change due to watershed program in Pamana villlge

Monitoring Impact of Watershed Project using Spatial Tool (Level-2)

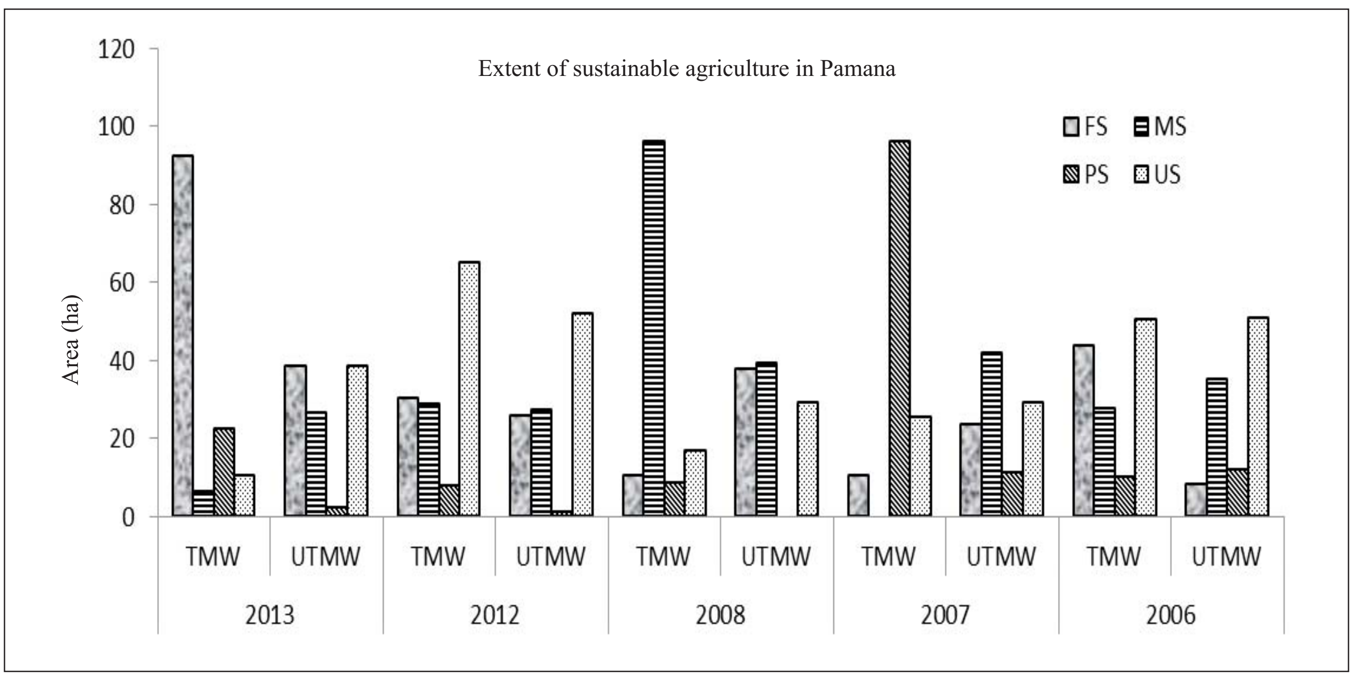
Monitoring of micro-watersheds in Pamana in 2013 indicated that several landholdings were managed sustainabily. Landholdings/Survey No. with sustainable agriculture is indicated in Fig. 4. According to CSI scale, Survey Nos. 244, 40, 254, 256 in TMW and Survey Nos. 220, 279, 256 in UTMW were assessed as fairly sustainable. From temporal analysis of landholdings, it was observed that out of ten land holdings, Survey No. 244, 296 and 254 had been managed sustainably during 2006-2013.

Temporal study of Pamana watershed revealed that in 2013, area under Fair to Moderately Sustainable agriculture (CSI- >0.75 and CSI- 0.50-0.75) was 99 ha which accounted for 75% of area in the TMW. Over 39 ha or 37% of area in UTMW was found to be under Fairly Sustainable agriculture system and 27 ha or 25% of UTMW were also found to be Moderately Sustainable (CSI= 0.50-0.75). In 2006, in the same TMW, about 44 ha or 33% of the watershed was under Fairly Sustainable agriculture while in UTMW only 8 ha or 7% area was found to be under sustainable agriculture. There was an increase in area under sustainable agriculture although the pace was not steady as indicated in Fig. 5.

Evaluation of Watershed Project using Spatial Tool (Level-2)

Evaluation of impact of watershed project using spatial tools (Level -2) indicates how various landholdings were being managed in Pamana village since 2006. Study indicated a positive impact of WDP in TMW as area under Moderately Sustainable category of Composite Sustainability Index had increased. Area under Moderately Sustainable category in TMW was 12 ha (9%) in 2006 , 76 ha (58%) in 2007, 58 ha (44%) in 2008, 18 ha (14%) in 2012 and 28 ha (21%) in 2013. In 2013, due to impact of good rainfall 20 ha or 15% in TMW was evaluated as Moderately Sustainable. During the same year, over 13 ha or 12% of area in UTMW was found to be Fairly Sustainable denoting that good rainfall was essential for positive impact of watershed program in post program scenario; thus, underlining the fact that watershed program may be implemented for drought proofing rather than developing it as a substitute for provisioning water resource during a good rainfall year.

Fig. 6 and Fig. 7 indicate the outcome of spatial evaluation where weighted thematic layers were summed and normalized with aggregate weight according to procedure described earlier. The result of monitoring and evaluation (M&E) using both empirical and spatial tool were found to be comparable. While Level-1 M&E method is suitable when there is no ready access to GIS facility, Level-2 method provides a powerful tool to monitor and evaluate watershed projects and their impact on agricultural sustainability. Study has indicated that tools of geo-informatics facilities in implementation and evaluation of watershed projects in India in an objective manner.



Note: Degree of sustainability FS: Fairly, MS: Moderately, PS: Poorly, US: Unsustainable

Fig. 5. Extent of sustainable agriculture in Pamana treated (TMW) & untreated (UTMW) micro-watersheds

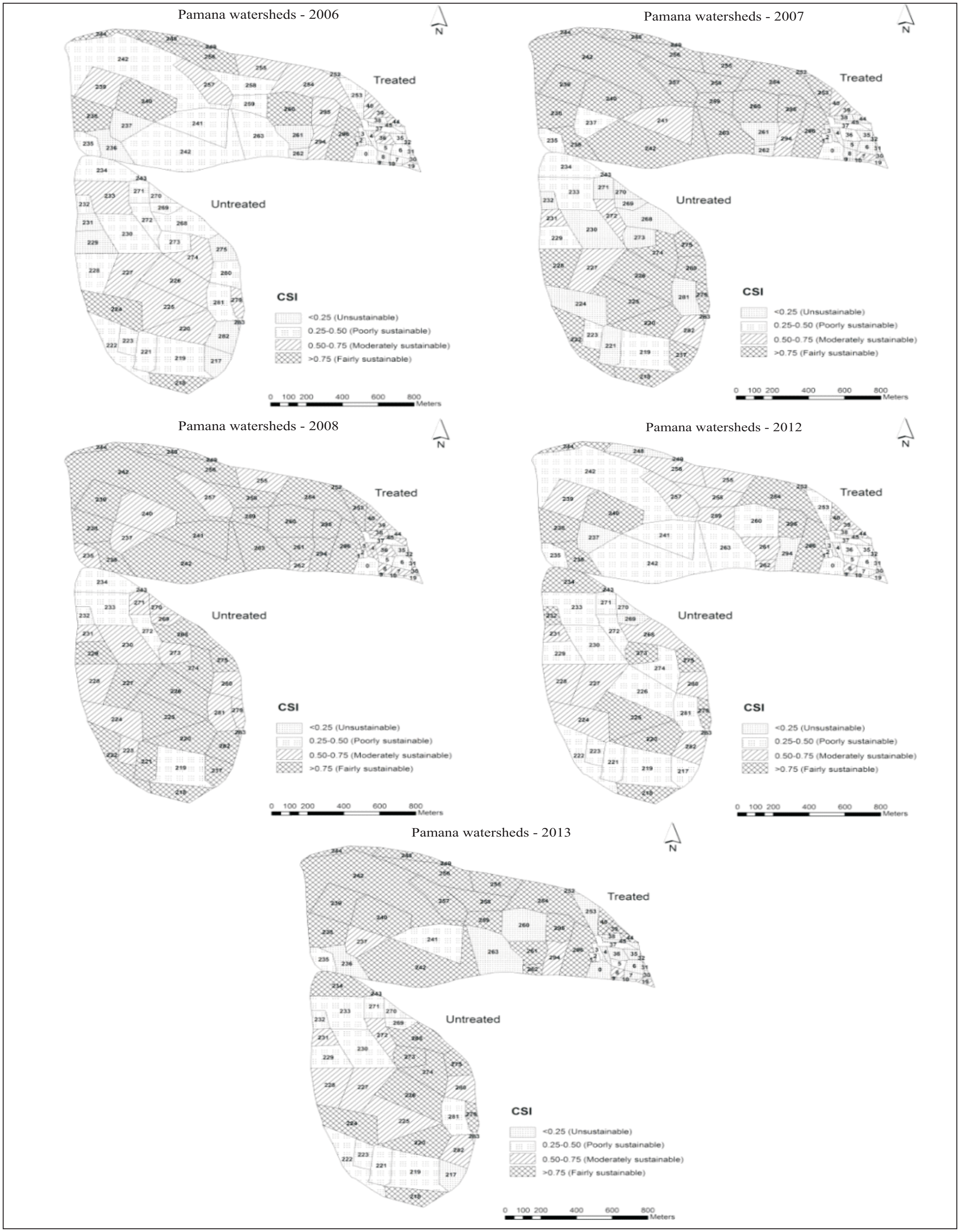


Fig. 4. Monitoring impact of watershed project in Pamana on temporal basis

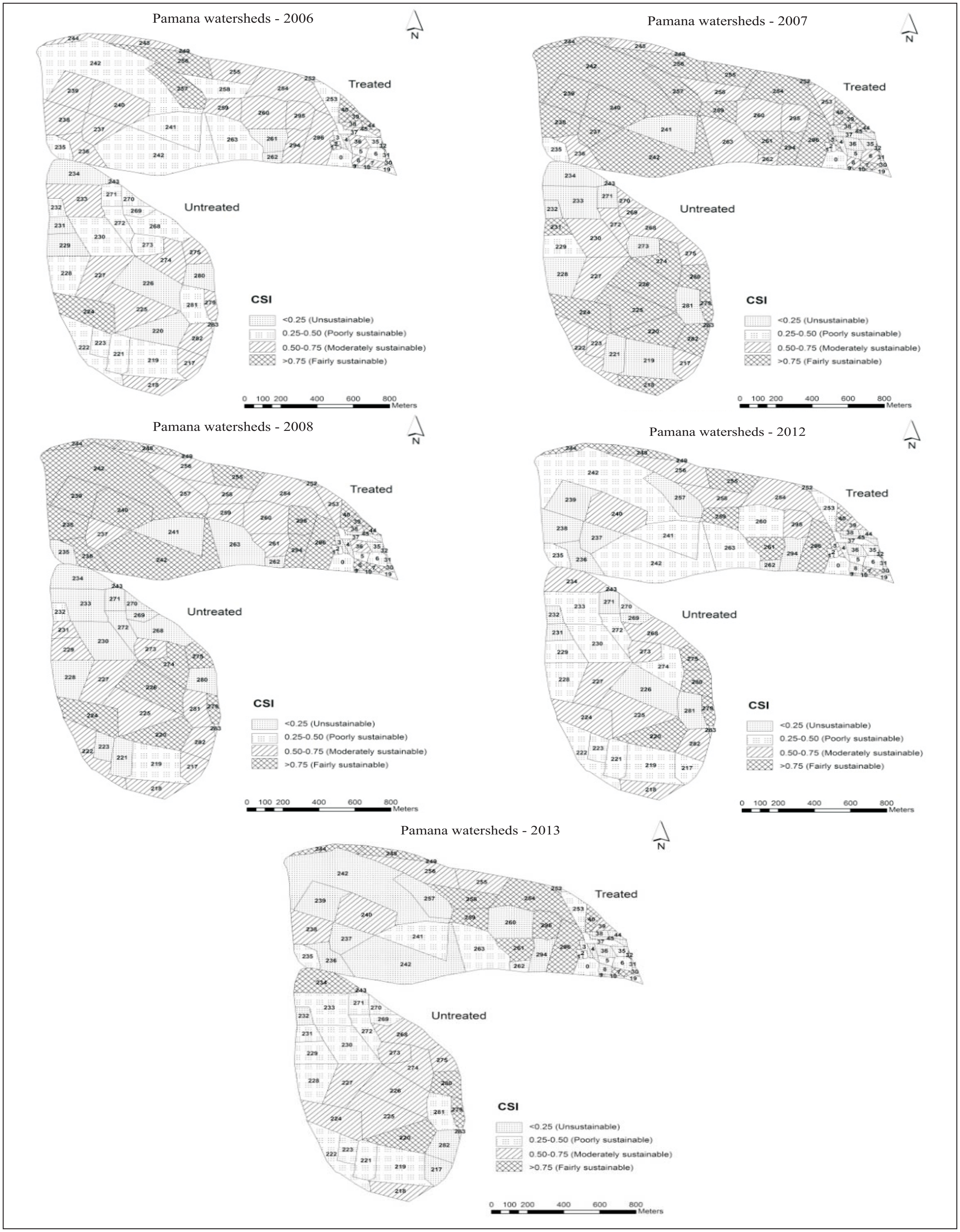
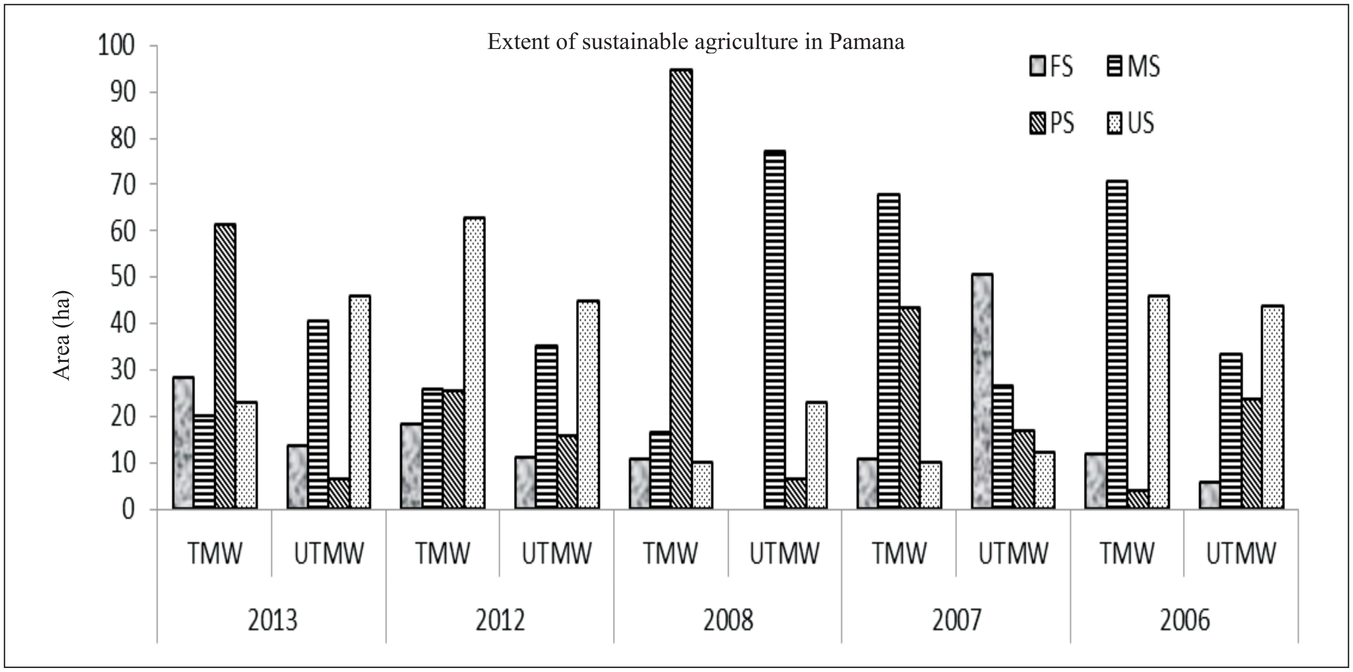


Fig. 6. Evaluation of agricultural sustainability in Pamana watershed projects



Note: Degree of sustainability FS: Fairly, MS: Moderately, PS: Poorly, US: Unsustainable

Fig. 7. Extent of impact of WDP on agricultural sustainability in Pamana

4. CONCLUSIONS

Based on temporal analysis of watershed program in four villages in Nalgonda and Rangareddy districts in Telangana located in AESR 7.2, it may be stated that watershed development program in Chintapatla had achieved more when compared to other two watersheds, namely Gollapalli and Pamana. In Pamana, situation in untreated micro-watershed seemed better due to gains from proximity to the treated micro-watershed and also market in upland of Hyderabad. Six critical monitoring and six critical evaluation indicators were used to study impact of watershed projects on five aspects of agricultural sustainability *viz.,* agricultural productivity, livelihood sustainability, economic viability, environmental protection and social acceptability. The results obtained from two levels of monitoring and evaluation, *viz.,* empirical (Level-1) and spatial (Level-2) procedure was found to be comparable. While Level-1 procedure based on empirical analysis could be used by PIA who do not have access to GIS facility, Level-2 of the procedure provides a powerful tool to monitor and evaluate watershed projects using Geo-spatial tools and techniques like never before. The critical indicators identified for monitoring and evaluation of watershed projects could be used in other parts of AESR 7.2 by the PIA to carryout mid-term corrections on one hand and by funding agencies to assess the impact of watershed projects against investments made thereof on the other. The procedure developed and described herein helps in comparing the impact of watershed projects like never before. The scorecard developed for the list of sustainability indicators helps in measuring agricultural sustainability in a unit area *viz.,* field or watershed-level. The methodology for monitoring and evaluation developed under the study is robust, objective and replicable as shown in the paper. Study indicated a positive impact of watershed program in Telangana where rainfed agriculture predominate underlining the need for implementation of watershed development projects with emphasis on the aspects indicated through critical indicators identified in this study.

ACKNOWLEDGEMENTS

The authors are grateful to ICAR for award of National Fellow scheme to the first author. They thank Director, CRIDA for providing facilities to carry out research under the National Fellow scheme.

REFERENCES

Anonymous. 2008. Common Guidelines for Watershed Development Projects. Govt. of India. 57 p.

Gomez, A.A., Swete Kelly, D.E., Syers, J.K. and Coughlan, K.J. 1996. Measuring Sustainability at the farm-level. In: *Methods for assessing soil quality,* SSSA, Special Publication No.49, Soil Science Society of America, Madison, USA, pp 401-409.

Kaushalya Ramachandran, Gayatri, M., Satish, J., Praveen Kumar, V. and Thilagavathi, N. 2013. Measuring Agricultural Sustainability in Rainfed Regions in India Spatial evaluation of watershed projects. *Indian Cartographer,* 33:287-295.

Kaushalya Ramachandran, Mandal, U.K., Sharma, K.L., Gayatri, M., Bhaskar, V., Venkataravamma, K. and Karthik, P., 2009. Methodology for evaluating livelihood security of farm households in treated watersheds. *Ind. J. Soil Cons.,* 37(2): 151-163.

Kaushalya Ramachandran, Mandal, U.K., Sharma, K.L. and Venkateswarlu, B. 2010. Evaluation Methodology for post-facto Assessment of Watershed Development Projects a multi disciplinary, multi-aspect approach. CRIDA, Hyderabad, 99 p.

Kaushalya Ramachandran, Venkateshwarlu, B., Rao, K.V. and Mandal, U. K. 2011. Application of Geomatics in Watershed Prioritization, Monitoring and Evaluation CRIDA's Experience. In: *Use of High Science Tools in Integrated Watershed Management.* (Wani, S.P., Saharwat, K.L. and Saushal, K.G., Eds.), ICRISAT, ISBN: 978-92-9066-540-3,CPE 169, pp 49-65.

Mandal, U.K., Kausahalya Ramachandran, Sharma, K.l., Satyam, B., Venkanna, K., Udaya Bhanu, M., Mandal, M. and Masane, R.N. 2011. Assessing Soil Quality in a Semiarid Tropical Watershed using a Geographic Information System. *Soil Water Manag. Cons.*, 75(3):1-17.

Sharda, V.N., Pradeep Dogra and Dhyani, B.L. 2012. Indicators for assessing the impacts of watershed development programmes in different regions of India. *Ind. J. Soil Cons.,* 40(1): 1-12.

Sikka, A.K., Madhu, M., Subhash Chand, Singh, D.V., Selvi, V., Sundarambal, P., Jeevarathanam, K. and Murgaiah, M. 2014. Impact analysis of participatory integrated watershed management programme in semi-arid region of Tamil Nadu, India. *Ind. J. Soil Cons.,* 42(1): 98-106.

Wani, S.P., Roy, P.S., Kesava Rao, A.V.R., Barron, J., Kaushalya Ramachandran and Balaji, V. 2011. Application of new science tools in integrated watershed management for enhancing impacts. In: *Integrated Watershed Management in Rainfed Agriculture* (Wani, S.P., Rockstrom, J. and Sahrawat, K.L., Eds.), Chapter 6, CRC Press Pub. ISBN: 978-0-415-88277-4, pp 159-204.