Watershed development as community coping strategy for climate change impacts in north central highlands of Ethiopia

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Abstract: The impacts of watershed development on various indicators pertaining to biophysical environment are very high as a coping strategy to climate change related hazards. Among others, the watershed development projects conducted in Amhara National Regional State aimed at improving the biophysical and socioeconomic conditions of the area. In addition to the biophysical parameters, a total sample of 240 households from six model watersheds was selected randomly. Accordingly, about 58% of the total sample watershed areas were covered with soil and water conservation works, whereas the project impacts on the socioeconomic aspects were low to moderate in the majority of the cases. The average livestock ownership in number of oxen and total livestock unit by 2006 was found to be 1.76 and 4.70, respectively. This was found to be 1.59 and 4.73 for 2011, respectively. Similarly, the statistical t-test for both of them is statistically insignificant at 95% level of confidence. This indicates that biophysical impacts are more prominent when compared to economic impacts.

Keywords: climate change; coping strategies; watershed development; WSD; Ethiopia; biophysical change.

Reference to this paper should be made as follows: Legesse, S.A. and Prasada Rao, P.V.V. (2015) 'Watershed development as community coping strategy for climate change impacts in north central highlands of Ethiopia', *Int. J. Environment and Sustainable Development*, Vol. 14, No. 2, pp.105–115.

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This paper is a revised and expanded version of a paper entitled 'Impact assessment of model watersheds development in Amhara region' presented at the Erosion and Sedimentation in Tana Basin, Upper Blue Nile, Ethiopia, Bahir dar, Ethiopia, May 2012.

1 Background

A large portion of the area of Ethiopia is dry sub-humid, semi-arid, and arid, which is prone to desertification and drought. The country has also fragile highland ecosystems that are currently under stress due to population pressure and associated socioeconomic practices. Ethiopia's history is associated, more often than not, with major natural and man- made hazards that have been affecting the population from time to time. Drought and famine, flood, malaria, land degradation, livestock disease, insect pests and earthquakes have been the main sources of risk and vulnerability in most parts of the country. Especially, recurrent drought and, recently flood, because of climate change/variability, are the main problems that affect millions of people in the country almost every year. While the causes of most disasters are climate related, the deterioration of the natural environment due to unchecked human activities and poverty has further exacerbated the situation (NAPA, 2007).

Adaptations to climate change vary across livelihood groups and zones. Adaptations are perceived as measures to improve livelihoods, the environment, and rehabilitation of natural resources. Reforestation, water harvesting, use of irrigation, and improved productivity of crops and livestock are the common adaptation measures perceived by the different communities. The adaptation pathways identified by local communities also coincide with the adaptation pathways at the national level (Shiferaw et al., 2004). Although the different global models and downscaling methods have made different climate projections for Ethiopia, there is a general consensus that Ethiopia will see greater climate variability and extreme events in the coming decades. Hence, one of the strategies advisable for Ethiopia is management of climate variability using different local and national level adaptation strategies. This strategy includes improved management of land resources, including soil, water, and forests. The report by the National Meteorological Service Agency (NMS, 2007) in the National Adaptation Program of Action (NAPA) of Ethiopia shows that in the future rainfall will decline in some parts while increasing in other parts of the country.

According to the Intergovernmental Panel on Climate Change report (IPCC, 2001), vulnerability to climate change depends on adaptive capacity, sensitivity, and exposure to changing climatic patterns. In the Ethiopian context, the farming community is the most vulnerable because of its high dependence on rain-fed agriculture for its livelihood. Even within the farming community, small-scale subsistence farmers, and pastoralists are particularly vulnerable to climate change related hazards.

Assessments of impacts and adaptations to climate change seeks to enhance capabilities in developing countries in responding to climate change by building technical capacity, advancing scientific knowledge, and integrating scientific and policy communities with local level indigenous knowledge. United Nations Environmental Program (2001) defined adaptation to include all responses to climate change that may be used to reduce vulnerability. Watershed development (WSD) programmes play a vital role in managing and sustaining land and water resources as well as enhancing economic development and poverty alleviation efforts as an option for the current and future climate change. While a lot has been done in terms of understanding the micro-determinants of farmers' decisions on watershed resource conservation, there is little attempt to understand the current climate change impacts on crop and livestock production in the Ethiopian highlands.

Ethiopia is heavily dependent on rain-fed agriculture, and its geographical location and topography in combination with low adaptive capacity of the rural people entail a high vulnerability to the impacts of climate change. Historically the country has been prone to extreme weather variability. Rainfall is highly erratic, most rain falls with high intensity, and there is a high degree of variability in both time and space. Since the early 1980s, the country has suffered seven major droughts – five of which have led to famines – in addition to dozens of local droughts. Major floods also occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996 and 2006 vulnerable groups identified through community discussions included asset-poor households (Aklilu et al., 2006).

Watershed management simply means improving the biophysical and socioeconomic situation of a watershed or a catchment area, for instance, by building contour bands, water harvesting structures (check-dams), field bounds (raised edges), supplying drinking water, building health care facilities, etc. Biophysical interventions facilitate higher land productivity through improved moisture and water availability for agriculture. Watersheds transcend households, communities and even villages, and so their sustainable development is critically linked with both inter household and inter village cooperation (SWHISA, 2009).

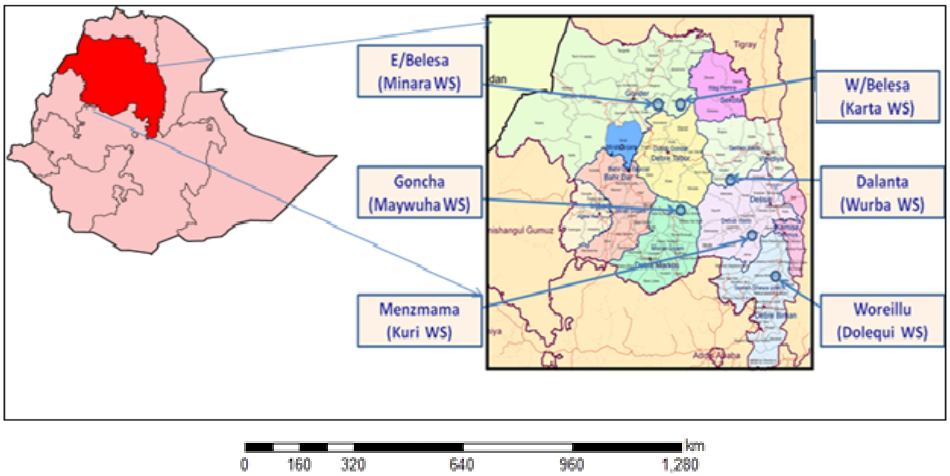
WSD programme in rain-fed dry land agriculture in Ethiopia has been introduced to ensure the sustainability of the surface and groundwater resources by harvesting rainwater, and to improve the livelihoods of farmers as an adaptation strategies of climate change. A number of artificial water storage and diversion structures were established in the last few years as coping mechanism of the impact of climate change. In this paper, it has tried to assess the integration of biophysical and socioeconomic impacts of WSD as an adaptation strategy in the central highlands of Ethiopia. The specific objectives include quantifying the impacts of the WSD strategies on the socioeconomic and biophysical changes and the percentage area covered with biological and physical conservation measures.

2 Materials and methods

2.1 Study area

The Amhara National Regional State (ANRS) covers 11% of the total area of the country. It is located at 9°–14°N and 36°–40°E. The region is divided into three major agroclimatic zone: highland (above 2,300 m above sea level), semi-highland (1,500 to 2,300 m above sea level) and lowland (below 1,500 m above sea level) accounting 20%, 44% and 28% respectively. This varied ecology led itself well to diversified agriculture. The region's topography includes plains, gorges, plateaus, hills, and mountains and its altitude ranges from 500 m to 4,620 m. The Ras Dashen Mountain, which is found in North Gondar administrative zone, is Ethiopia's highest mountain and Africa's fourth highest mountain. The region's rivers also have high potential for irrigation development and electric power generation. The region's biggest rivers include Abay (the Blue Nile), Beles, Tekezie, Angereb, Athbara, Mile, Kessem, and Jama. The region is one of the historically rich and worth visiting regions of Ethiopia. It has a wide variety of both natural and synthetic attractions. The region has considerable investment potentials to benefit for themselves and the region as well.

Figure 1 Study areas of the model watersheds in ANRS (see online version for colours)



Six representative sample watersheds were selected randomly from each agro climatical zones from six different districts namely, Minara (East Belesa), Karita wuha (West Belesa), Maywuha (Goncha), Kuri (Menzmama), Dolequi (Woreilu) and Wurba (Delanta) (Figure 1). All watersheds are entirely rain fed; where in Menz Mama, Wore Ilu and Delanta have a bimodal rainfall and produce twice in a year (belg and Meher) while in Goncha, West Belesa and East Belesa, it is a uni-modal rainfall and produce once in a year which are experiencing moisture stress and recurrent drought. The model watersheds have many things in common and differences in a number of biophysical characteristics. The common landform nature of all the watersheds is classified into four major features including flat plain, rolling foot slopes, hills/hill sides and mountains.

Table 1 Agro-climatic characteristics of the watersheds

Watershed	*Altitudinal range (m.a.s.l.)*	*Average min. temp (°C)*	*Average max. temp (°C)*	*Rainfall range (mm)*	*Traditional agro-ecological classifications*
Minara	1,700–1,900	17	32	780-850	Dry woena dega
Karita	1,700–1,900	16	30	800–880	Dry woena dega (drymid-alltitude)
Maywuha	2,600–2,700	12	22	1,200–1,500	Woina Dega to Dega (humid highland)
Kuri	3,160–3,260	5.51	19.61	861–1,000	Dega to Wurch
Dolequi	2,750–2,930	15.5	22.5	766–1,250	Dega
Wurba	3,000–3,545	4.5	16.53	880–1,200	Dega to Wurch

Source: District Agricultural Offices (2012)

As the runoff from the mountains and adjacent foot, slopes pass through those landscape units; large gullies were formed at several locations.

Regarding the socio economic description, the total population in all watersheds were 6,290, of which 3,188 were male and 3,102 female. The livelihoods of farmers in all watersheds depend on mixed farming system. Crop production and livestock are very important source of income for the watershed communities. Land degradation, as a result of high pressure on farmers and cattle population, soil erosion, poor agronomic practices and inappropriate application of organic fertiliser lead to low productivity of crops and animals. Especially, Karita, Maywuha, Minara and Kuri watersheds are severely degraded and yield is becoming less and less year after year. Surface runoff from hills and undulating areas, where land degradation is pronounced, has significantly increased due to the clearing of natural vegetations and removal of other physical obstacles. Such high surface runoff has caused erosion of cultivated as well as grazing lands in the lower catchment. These areas were used to be forestland for many years back and their conversion to grazing and cultivated land not only causes loss of fertile topsoil, but also negatively affects the availability of other resources such as potentially available water resources used for livestock and irrigation purposes.

3 Methods

Research methodology including detailed impact assessment tools and survey instruments were conducted. Baseline and watershed development plan documents were used as a benchmark for the assessment sets of indicators comprising both conventional signs of productivity and those relating to less tangible factors.

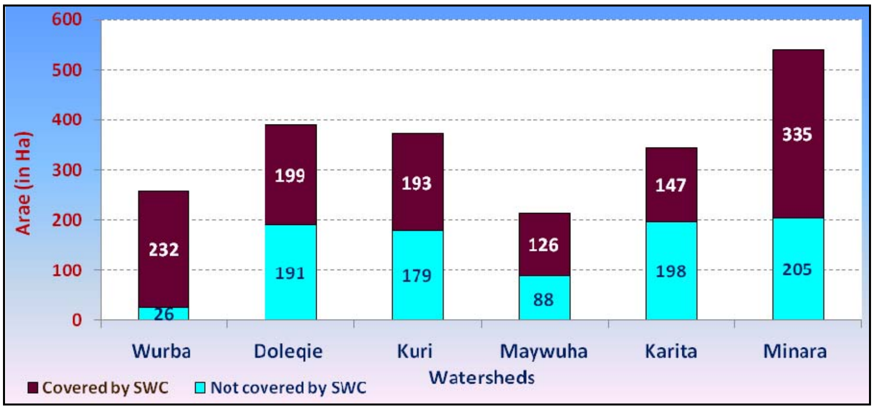
A total sample of 40 households from each sampled watershed were selected randomly. Generally, a total of 240 (40 × 6) sample households were considered. We selected 40 households for better comparison using statistical tests and to minimise the sampling errors. By including questions that could describe the past and the present situation in the questionnaire and data sheets, the researcher could assess the ‘before and after’ cases simultaneously to capture the changes due to the advent of WSD projects in order to understand the impact of the programme. The total sample household number is nearly quarter of the total number of households in the watersheds.

The primary data collected using a structured questionnaire has been analysed using SPSS computer software. The data collected from secondary data and using a reconnaissance survey has been narrated and supplement the quantitative analysis. The analytical statistical methods were descriptive statistics and statistical tests like t-test, chi-square and ANOVA. Moreover, institutional and stakeholder analyses related to the intervention evaluation, sustainability assessment and possible replication of project approach were made to draw policy and institutional recommendations.

4 Results and discussions

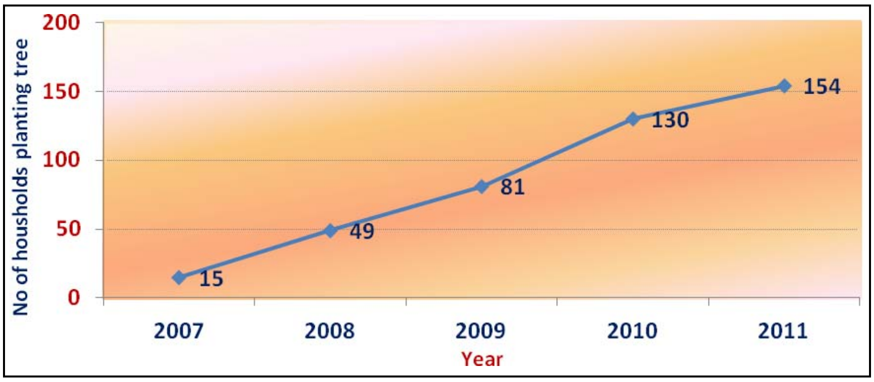
The development work executed in the watersheds was encouraging. In Wurba watershed, with soil and water conservation (SWC) works covered 90 % of the land. Similarly, 62, 59, 52, 51 and 43% of the land were covered by SWC works in Minara, Maywuha, Kuri, Karita, Doleqie and Karita watersheds, respectively (Figure 2). The degraded part of these watersheds has shown improvements within a short period. It is estimated that on average, more than 58% of the degraded part of the watershed are now covered by SWC works in these sample watersheds. This is a great achievement when compared to its initial target to cover 25% in the WSD plan. As the farmers explained, the moisture condition of the degraded and the downstream part of the watershed were improved as well. One of the indicators, as the farmers mentioned, was that the grass grown in the lower part of the watershed was green even in the driest months of the year.

Figure 2 Total area of watersheds and areas covered by SWC works in hectare (see online version for colours)



In other words, as shown in Figure 2, 232 out of 258, 199 out of 390, 193 out of 372, 126 out of 214, 147 out of 345 and, 335 out of 540 hectares of land in Wurba, Doleqie, Kuri, Maywuha, Karita and Minara watersheds were covered by SWC works. Generally, the WSD strategy has had a prominent impact on the intervention of SWC works.

Figure 3 Number of participants on planting trees (see online version for colours)



On the other hand, in all sample watersheds, tree species, which were adapted to the different agro-ecological zone of the area, were planted by the initiation of the programme. The number of participants from 2007 to 2011 increased (Figure 3). Specially, plants which were planted in the area closures were able to provide shelter for wildlife. The number of participants in tree planting and the types of trees in each of the sample watersheds is summarised in Table 2.

The type of trees, which were planted predominantly by most participants were eucalyptus. The reason is that eucalyptus tree is highly resistant to moisture stress once it is adapted and also is fast growing. It can provide fuel wood for household consumption and used for timber production, house construction fences and for farming tools.

Table 2 Types of trees planted in all the model watersheds.

Types of tree	*Karita*	*Maywuha*	*Kuri*	*Doleqie*	*Wurba*	*Total*
Eucalyptus tree	9	33	22	21	36	144
Fruits (including Gesho)	1	0	0	0	0	1
Indigenous trees	15	0	1	5	0	21
Eucalyptus and indigenous trees	3	3	7	3	0	16
Eucalyptus and fruit trees	0	0	1	0	0	1
HHs who have not planted tree	12	4	9	11	4	57
Total	40	40	40	40	40	240

The major socioeconomic indicators potentially considered was explained in wealth status based on the baseline study and the HHs survey questionnaire (Table 3). The major indicators for wealth status classification were livestock ownership, particularly oxen, and land ownership.

Table 3 Socioeconomic impact evaluation of WSD by respondents

Socioeconomic impact	*No and percent*	*Minara*	*Karita*	*Maywuha*	*Kuri*	*Doleqie*	*Wurba*	*Total*
Increased income	No	27	23	29	28	18	33	158
	%	67.5	57.5	74.4	71.8	47.4	82.5	66.9
Clean water provision	No	33	32	9	20	20	26	140
	%	84.6	80.0	23.1	57.1	51.3	65.0	60.3

Table 3 Socioeconomic impact evaluation of WSD by respondents (continued)

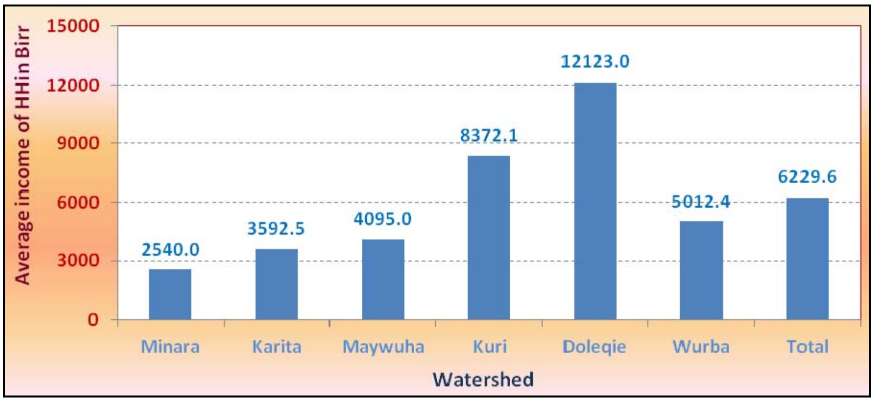
Socioeconomic impact	*No and percent*	*Minara*	*Karita*	*Maywuha*	*Kuri*	*Doleqie*	*Wurba*	*Total*
Diet adjustment	No	26	18	30	22	19	29	144
	%	65.0	45.0	76.9	62.9	50.0	72.5	62.1
Participation of women	No	35	27	22	30	37	33	184
	%	92.1	67.5	56.4	78.9	92.5	84.6	78.6

These were also found to be important during this assessment in addition with house type of the households. Therefore, land ownership is excluded in the analysis by considering as a fixed asset. Data on the livestock ownership before the project intervention and year of house construction has been collected in this assessment. The average livestock ownership in number of oxen and TLU in 2006 was found to be 1.76 and 4.70, respectively. This was found to be 1.59 and 4.73 for 2012, respectively. Similarly, the statistical t-test for both of them is statistically insignificant.

In addition, the number of households who constructed in the past two to four years were found to be 39 (16 %) from the households in the total sample watersheds, which is insignificant too.

The major identified socioeconomic impacts identified based on the farming households' response and physical observation of the model watersheds and communities were: the average sample households land and oxen ownership was found to be 1.21 ha and 1.51 oxen with 0.83 ha and 0.62 oxen respectively. The number of sample households that can be categorised under 'rich person' wealth category is negligible and 'middle person' is very small.

Figure 4 Average annual income of sample households in model watersheds by 2011 (see online version for colours)



The average income from different sources, including crop and livestock selling, remittance and aid in Birr. The annual income ranges from 2,540 Birr in Minera to 12,123 Birr in Doleqie (Figure 4). The primary difference in the watershed is particularly related to the participation of farming households in participation of marketable commodities in Doleqie (Woreillu district) and Kuri (Menzmama district). These are livestock rearing farmers in the above watersheds, onion production in Woreillu and animal fattening in Menzmama district and their proximity to major towns of Dessie and Debrebirhan/Addis Ababa, respectively. On the other hand, the contribution of aid in Minera and Karita model watersheds was very significant.

4.1 Potential change in farming system (irrigation utilisation)

One of the additional impacts of the project was related to the potential changes in the farming system by irrigation utilisation (Table 4). According to the HHs assessment, the respondents who have practiced irrigation activities in all watersheds were smaller than the non-participants except in Maywuha and Doleqie watershed. Only 34.58% of the respondents practiced irrigation. Very large numbers of the HHs were depending on rain for agricultural activities. On the other hand, in Maywuha and Doleqie watersheds, 72.5 and 27% of the respondents engaged in irrigation, respectively. Based on the field observation, the level of irrigation was small scale on small plots of land.

Table 4 Irrigation status of respondents

Irrigation practice	*No and % of HHs*	*Minara E/Belesa*	*Karita, W/Beles*	*Maywuha, Gonch*	*Kuri, Menz*	*Doleqie (Woreillu)*	*Wave (Dalanta)*	*Total*
Participants	No. of HHs	4	4	29	3	27	16	83
	%	10	10	72.5	7.5	67.5	40	34.58
Non-participants	No. of HHs	36	36	11	37	13	24	157
	%	90	90	27.5	92.5	32.5	60	65.42

Figure 5 Major crops cultivated by rain fed in the sample watersheds per sample household (see online version for colours)

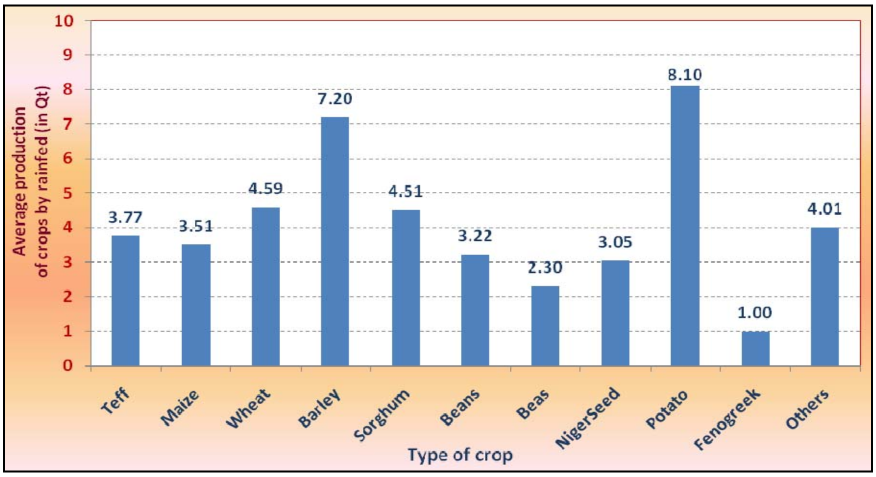


Table 5 Sources of irrigation water and respondents

Irrigation water source	*No of HHs and %*	*Minara*	*Karita*	*Maywuha*	*Kuri*	*Doleqie*	*Wurba*	*Total*
River	No. of HHs	3	4	23	0	7	9	46
	%	75.00	100.00	79.31	0.00	25.93	56.25	55.42
Springs	No. of HHs	0	0	4	1	19	1	25
	%	0.00	0.00	13.79	33.33	70.37	6.25	30.12
Stream	No. of HHs	0	0	2	0	0	1	3
	%	0.00	0.00	6.90	0.00	0.00	6.25	3.61
Hand dug water	No. of HHs	0	0	0	0	0	4	4
	%	0.00	0.00	0.00	0.00	0.00	25.00	4.82
Harvested water	No. of HHs	1	0	0	2	0	1	4
	%	25.00	0.00	0.00	66.67	0.00	6.25	4.82
Others	No. of HHs	0	0	0	0	1	0	1
	%	0.00	0.00	0.00	0.00	0.04	0.00	0.01
Total	No. of HHs	4	4	29	3	27	16	83
	%	100	100	100	100	100	100	100

The sources of water for nearly 76 % of the irrigation user sample households are rivers and springs (Table 5).

5 Conclusions

Despite the progress in achieving the above results and strong community ownership, some problems remain that might affect future sustainability. The continuity of technical assistance and support to communities by DAs and district experts' got disrupted usually due to expanded workload. The watershed management committee is not yet empowered enough to independently carry on the development process and depends on DAs and districts for advice and resources. Erratic rainfall in mid latitudes and the occurrence of frost in upland watersheds, unequal reception to technologies, un-stepwise technology intervention, dependency syndrome, staff turnover, financial management, poor monitoring/follow up of the interventions, Focus on area coverage than quality, and Low quality of farm inputs distributed in SWC works were the challenges of the development plan. On the other hand, Presence of different polices, programmes and strategies supporting the WSD approach, ample labour force, conducive agro ecology, presence of NGOs were the opportunities of the development plan.

The watershed committees had been actively involved in the implementation of watershed programmes in all the sample watersheds. It was realised that the participation of local community members were key implementers of the WSD plans. Participation also enhances community empowerment. The participation of beneficiaries in the planning and execution of the watershed was seen in rural households.

The impacts of WSD on various indicators pertaining to bio-physical environment were very high. About 58% of the total sample watershed areas were covered with SWC works. Whereas the project impacts on the socioeconomic aspects were low to moderate in the majority of the cases. The biophysical impacts were more prominent when compared to socioeconomic impacts. This indicates that biophysical and institutional impacts were not translated into economic impacts. It was also found that majority of the households across all the study areas had reported a slight improvement in their standard of living. The benefits of WSD have not been fully translated into disposable income or net gains to improve the standard of living. There are certain positive trends towards the growth of vegetation cover control of gully, soil regeneration capacity, vegetation cover livestock production, etc. However, social and economic achievements have not been easily perceived and significant due to earlier evaluation of the project. Generally, strengthen monitoring and evaluation system, reduce dependency syndrome, establish data base system, strengthen experience sharing, create a market outlet and increase market success, complementarities with districts, stepwise introduction of technologies and designing of the staff retention system were recommended for the WSD sustainability and success in the ANRS.

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