Analysing the Vulnerability of Dry Ecosystems to Desertification due to Environmental Resource Degradation in Anantapur: The Need for Enhancing Ecological and Social Eesilience

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Abstract*: Dry ecosystems are natural ecosystems on dry lands that are inherently vulnerable to desertification hazards. They are, however, becoming increasingly vulnerable due to environmental resource degradation in dry lands, which is caused, at least partly, by the socio-economic pressures of human population. As most dry ecosystems have natural resources at margins and experience the recurrence of extreme weather events, they have poor ecological resilience; hence, reducing their susceptibility to desertification hazard becomes is critical for the sustenance of the ecosystems as well as for the inhabiting human populations. At the same time, building social resilience is also important to buffer against the ecological and climatic catastrophes. Anantapur is one such dry land district located in the South-Central part of peninsular India that has been experiencing desertification conditions due to environmental resource degradation, which is conditioned by natural factors and exacerbated by anthropogenic factors. The current paper analyses the vulnerability of dry ecosystems in Ananatapur to the desertification hazards due to environmental resource degradation and discusses the need for mitigating it through a range of institutional and policy interventions. Desertification, in this context, is predisposition of ecosystem to natural vulnerability and an exacerbation in it caused by the above factors. The paper, however, does not venture into establishing direct cause-effect relationships, since these interactions are quite complex and intertwined.*

Key Words: Environmental resource degradation, desertification, dry ecosystems, vulnerability, sustainability and resilience

Introduction

Desertification is a phenomenon in the *susceptible dry lands* characterized by progressive decline and degradation of environmental resources, predominantly land, water and biomass. Dry lands are the areas characterized by hot climate that can be categorized based on the parameters like mean temperature and rainfall. For example, one such classification based on precipitation categorizes dry lands into hyper-arid, arid, semi-arid and dry sub-humid areas. Dry lands can also be delimited by the nature of ecosystems, known as dry ecosystems, which follows the same categorization but includes vegetation types. It is the term used some times referring to variation in topography, climate and soils. The unifying factor is the mean precipitation and biological productivity (Beaumont 1989). However, desertification in dry lands and dry ecosystems are similar in several ways as dry ecosystems prevail upon dry lands. The degradation of dry ecosystems on the dry lands resulting in desertification can be better understood through definition given by Dregne (1983) and Be (1990) (cited in Grainger 1990):

'…Desertification is a phenomenon of impoverishment of terrestrial ecosystem under the impact of man. It is the process of deterioration in this ecosystem that can be ascertained by reduced productivity of desired plants, undesirable alteration in the biomes and diversity of micro as well as macro flora and fauna, accelerated erosion and increased hazards for human occupation….'

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Desertification, in this context, is different from deserts in the sense that it leads to desert like conditions (but reversible) rather than converting into deserts (permanent) (Mainguet 1994). Yet, this transformation can have some significant implications to both ecosystems as well as human systems themselves. On one hand, an accentuation of desertification condition can lead to poor resilience of ecosystems, making them much more vulnerable to breakdown in climatic extremes. The malign effects of the persistence of desertification and drought conditions on the vegetation and ecosystems in the Sahel are well documented (Eriksen 2001a). On the other hand, desertification in dry ecosystems also makes human populations much more vulnerable to climatic failures, particularly when the social resilience of the human systems is very poor.

It is also important to understand that the desertification in dry lands/dry ecosystems is primarily caused by anthropogenic factor, but conditioned by natural factor, as defined by UNEP (1992): '…desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities…' (Noble and Gitay 1996). How these natural and human factors interact to cause desertification is well explained by Hulme and Kelly (1993). They attribute the desertification caused by resource management failures in dry ecosystems, which is again due to poor mismanagement of human activities. Barrow (1985) describes the process of this degradation much more in detail. Large scale climatic failures causing the breakdown of ecosystems is somewhat rarely observed, and it occurs on a very long time horizons, which cannot be easily prevented because of the fact that it is determined by several factors and processes of complex climate systems. Hence, what can be managed is the human use of natural resources, which requires the building-up of the coping or the resilience on the part of ecosystems as well as human systems. This is the central part of the mitigation and combating strategies of African countries affected by desertification (Eriksen 2001b)

Desertification of dry ecosystems also assumes importance because of the scale and extent of it: it affects as much as 40 per cent of global land (Dregne 1986). The United Nations Conference on Desertification, 1977 was first attempt to bring forth this issue faced by the African countries, and it received a renewed interest in United Nations Conference on Environment and Development, 1992 in the sustainability debate (Eriksen 2001a). It might be surprising to note that, even in India, dry lands comprise as much as two thirds of land and are under the threat of desertification (Nadkarni 1985). Although several studies documented the various aspects of dry lands (e.g., Jodha 1991, 1995), desertification conditions in areas other than Western Rajasthan did not receive much attention in literature; whereas the work done in case of Western Rajasthan is well known (e.g., ICAR 1977, Jodha 1980, and Sen and Kar 1989). The studies by Jodha (1980), Chakraborty (1990) and Valdiya (1987) are noteworthy for their contribution to the understanding of desertification in arid lands, plain areas and mountain areas respectively in the Indian context. The study is perhaps the first of its kind in the peninsular South India, which focused on analysing the vulnerability of dry ecosystems to the desertification hazard due to the environmental resource degradation. Desertification, in the study area, has been analysed in terms of the degradation of environmental resources – land, water, bio-mass – due to anthropogenic pressures. This paper provides the case analysis of dry ecosystem degradation in Anantapur, and suggests the institutional as well as policy measures that need to be undertaken for enhancing the resilience of natural and human systems in order to mitigate the resource degradation and its impacts. We present the analysis of the resource degradation in the next section.

Analysis of Desertification Due to Resource Degradation in Anantapur

Desertification in dry ecosystem is caused by the interplay of human activities and natural resources in not a synergistic manner but in an antagonistic manner. This process can only be well explained by analysing the causal interactions with the help of supporting data and interpreting the current patterns and trends, which is what attempted in the following sub-sections. However, it is also important to understand the concepts of vulnerability, thresholds and resilience, which are used frequently to explain the causal interactions in the following. Vulnerability refers to the susceptibility of systems (humans or regions or ecosystems) to any external force or

event, here desertification. Thresholds, or margins, are extreme points or areas beyond which the breakdown is most likely to take place. Resilience refers to the capacity to withstand repetitive stresses and strains, of both natural and human systems. In socio-economic systems it is better understood through the concepts of coping i.e., resilience is the ability to cope or withstand the catastrophic events.

Conditioning by Climate and Location

The geographical location of the district in the rainfall shadow zone renders it with low amount of rainfall and hot temperatures. With an average annual temperature of 38^0C and mean annual rainfall of 520 mm (BSE 1995) this area has more of semi-arid type of climate. However, if the evapo-transpiration is given consideration it falls into arid zone climate (CAZRI 1983). The temperature and rainfall vary widely over space and time. This is reflected in the temperature extremes ranging from 15^0C to 45^0C (BSE 1995) and rainfall extremes ranging from less than 200 mm to more than 900 mm in a year. High temperatures are recorded in summer, when the atmospheric particulates are also high; and high rainfall is recorded in the monsoons over a short period rendering it with high rainfall intensity (16.08 mm/day) and, correspondingly high soil loss. Interestingly, the amount of rainfall varies over space with the higher amount observed in the South East part and lower amount observed in the South West part of the district, which can be explained by the vegetation cover differences. The prevalence of hot and dry climate conditions the region's vulnerability to desertification hazards due to resource degradation. The frequent recurrence of droughts (once in two and half years) implies the fragility under which these ecosystems are functioning and their susceptibility to desertification hazards (Ramakrishna 2001).

Degradation of land resource

Poor soils and their erosion

Under this sub-section, the land degradation and the land use patterns are discussed in the context of study area to implicate the resource degradation leading to desertification. The soils of the district are poor red soils or black cotton soils, with low fertility and highly prone to erosion hazards, particularly the former, which is the dominant soil. Higher rate of soil erosion over the natural rate of soil formation results in the soil loss, which results in the poor minerals and soil organic matter and lead to increased desertification. However, besides the soil type, land use/cover, soil moisture (all of which determine the physical condition of soil) and the rainfall intensity play a major role in the determination of soil erosion. In the previous section, it was well laid that the intense rainfall over short duration results in low soil moisture retention and that the hot and dry conditions prevalence in the district results in the looseness of it, both of which condition easy erodibility of soils by the agents of wind and water. The role of land cover is, however, discussed below. The soil erosion rate in the district varies in the range of 11 to 17 t/ha/yr, which is well above the soil formation rate that varies between 2 to 11 t/ha/yr (Wischimeier and Smith 1978, cited in Noble and Gitay 1996).

Inappropriate land use/cover

Land use, which primarily determines the land cover, is an important feature of land resource in that the allocation of it also determines the status of the region or the ecosystem. Sustainable land use makes use of resilience of a resource, which varies with respect to time depending upon natural season, inter-annual variability, management practices and technologies (Middleton and Thomas 1997). Land use/cover pattern and its changes are often good indicators of desertification, particularly when they are observed over a larger spatial scale or time span. The land use pattern prevalent in the district (shown in table 1) implies a low amount of land resource allocated to the uses of more ecological value (e.g., forests and pastures) and a greater allocation to the uses of more economic value (e.g., agriculture). This might be expected, but a significant proportion of fallow land indicates the pressure on land resource from the uses like agriculture and also a decline in soil fertility observed in the district. Besides this pattern depicting an intensification of the land resource use, the decreasing trend of

barren land's share also suggests extensification of uses like agriculture, leading to the cultivation of marginal areas. The intensive use of land for agriculture and also its extensification result in an increase of soil erosion as well salinity/alkalinity hazard. However, more stronger implications come from the forest cover, which is mentioned as 10.3% of the total geographical area in the official records (BSE 1995); whereas, the actual forest cover based on the crown cover density observed through remote sensing (MEF 1991) is only 2.6%. The discrepancy is not an indication of differences in classification systems, but implies the degradation of forest cover to a great extent, which is not recorded in the official records.

Table 1: Land use pattern in Anantapur

Type of land use	Area (in ha)	Per cent of geographical area
Forests	196 881	10.3
Non-agriculture	158 897	8.3
Barren and Uncultivable	175 750	9.2
Permanent pastures	23 352	1.22
Cultivable wastes	70 350	3.7
Current fallows	216 787	11.3
Other Fallows	107 032	5.6
Net area sown	976 775	51
Area Sown more than once	30 602	1.6
Miscellaneous trees and grooves	28 280	1.47
Gross area sown	1 007 377	52
Total Geographical area	1 913 492	

Source: Bureau of Statistics and Economics (1995)

The above discussion suggests poor soils and resource exploiting land use patterns and its trends, all of which lead to increasing desertification from land resource degradation implied by greater rate of soil erosion and poor soil fertility.

Declining water resource

Water resources are critical resources for both natural and human sustenance. In particular, the availability of water in good quantity as well as quality will have a bearing on human life. In this sub-section, water resource criticality in the district is discussed to imply the desertification due to water resource degradation in case of both surface and ground water.

Increasing water demand

The water resources availability and demands shown in table 2 clearly indicate that, quantitatively, the district had adequate water resources to meet the demands of various uses only till mid 1980s. However, an increasing agriculture, discussed earlier, together with increasing population, to be discussed later, exert a high demand of water. The canal water supply for irrigation, provided water security to the farmers and enhanced their cropping options. But, it has also led to intensification and extensification of agriculture, accompanied by shifts in cropping pattern (a detailed discussion is reserved here for later discussion), towards cultivation of water intensive crops like rice. This has resulted in increased degradation hazards like salinization and alkalinization; besides it could have affected surface water quality through tail water discharges.

Table 2: Water balance status in Anantapur

Source	*Water balance at 50% dependability*		*Water balance at 75% dependability*	
Irrigation Commission, 1972	-794.68	-1268.64	-1210.68	-1702.64
National Commission on Agriculture, 1975	-2214	-4280.02	-2630.8	-4696.02
Master Plan	-	887.13	-	471.13

Source: National Water Development Agency (1995)

Declining ground water and its quality

The intensification of agriculture exerts pressure on water quantity not only of surface source but also of ground source, which brings forward additional complexities. The ground water is increasingly used to irrigate the cropland, particularly during the non-monsoon period and in the off-canal areas. Technological improvements in deep well digging has led to increase in the extraction of ground water beyond the sustainable yields of aquifers (details shown in table 3), while also posing water quality degradation problems. As the geological formations of the deep underlying rocks in the district are rich in fluoride, which come into contact with water due to the increase in drawal and result in ground water quality degradation. The widespread prevalence of fluorosis in this district clearly indicates this problem.

Table 3: Forest Offences in Anantapur

Year	Illegal Browsing cases	Other forest offences
1981-82	480	1219
1982-83	419	1171
1983-84	560	1405
1984-85	394	4422
1985-86	602	1748
1987-88	756	1481
1988-89	820	1590
1989-90	808	1650

Source: District Forest Office, Anantapur (1995)

The above discussion implies that the scarce water resources are under pressure from demands for it (predominantly, agriculture and population); particularly, increase in agriculture affects surface and ground water quantity as well as quantity, while also leading to other degradation hazards. Summarily, water resource criticality is affected by the human uses to reach the margins of thresholds and also pose discernible degradazation hazards that may lead to exacerbation of desertification conditions.

Threatened biological resource

In this sub-section, the status of degradation of forest cover, which forms the major biological resource, is discussed; although agriculture and pastures also produce biomass, it is not as high as that of forests and also they lack several other features like ecological services and biodiversity, however, their status is discussed in the subsequent section.

Degradation and fragmentation of forests

The land use statistics indicating a constant area under forest cover vis-à-vis low forest cover of good crown density suggest the degradation of forest resources. According to the remote sensing classification criteria, forests are those with crown cover density more than 40 per cent. The forests with crown cover density less than it but more than 10 per cent are called as degraded forest, whereas the forest with crown cover density less than 10 per cent are called open forest (MEF 1991). Historically, the district was endowed with good forest cover with wild life centuries behind, but the human pressures have resulted in a gradual decline of it, which was also reflected in the study of Rao and Rajeskar (1994). It is well documented that a decline in the vegetation cover would alter rainfall producing convection circulation leading to a decline in rainfall and also it can lead to a decline in the runoff due to a greater loss of moisture in evaporation (Eriksen 2001a). The degradation of forest cover has led to its fragmentation into forest patches and succession to non-forest land, which is also indicated by the spatial spread now concentrated in the hilly South-Eastern part. Incidentally, this is perhaps the residual forest cover, which still renders this part of the district receive good amount of rainfall.

Threatened habitat for wildlife

The fragmentation of forests also led to habitat loss and prey loss, which resulted in the disruption of ecological food chain. The increase in number of attacks of wild hyena on the nearby villages might imply this (figures shown in table 4). This clearly indicates the degradation of the forest resource not only in terms of vegetation cover or biomass alone but also in terms of wild life loss. Moreover, the human and livestock pressure on forests for fuel wood and fodder has also led to an increase in forest offences like illegal cutting and felling as well as browsing cases over time (figures shown in table 5).

Table 4: Wildlife attacks in Anantapur

Year	No. of cases	No. of deaths	No. of wounded
1985	19	14	5
1986	3	2	1
1987	12	9	3
1988	29	11	18
1989	16	13	3
1990	11	2	9

Source: District Forest Office, Anantapur (1995)

Table 5: Population Growth in Anantapur

Year	Population	Growth rate
1901	1 025 322	-
1911	1 053 449	2.74
1921	1 046 116	-1.26
1931	1 138 081	9.41
1941	1 273 060	11.86
1951	1 483 591	16.54
1961	1 767 464	19.13
1971	2 115 321	19.68
1981	2 548 012	20.48
1991	3 180 863	24.94
1996	4 700 000	47.76+
2001	5 720 000	21.7++

+ projection of trend ++ trend projection for 5 years

Source: Bureau of Statistics and Economics (1995)

Socio-economic pressures

In this sub-section, the environmental resource degradation due to socio-economic pressures is analysed, although it is difficult to establish a direct correspondence between them and resource degradation. However, an understanding of these pressures on the resource degradation is provided through relevant arguments.

Population growth and Urbanization

Population growth increases not only the demand for food, water and land but also the demand for several economic goods, which are accelerated by urbanization. This, in turn, results in greater demand for these goods through exploitation of resources even in a subsistence economy. However, increasing access to markets and the marketization of economies also lead to intensification of degradation in dry lands through greater resource consumption and increased market risks (Sen 1985), which was evident in the case of Rajasthan (Jodha 1980). Urbanization increases the access as well as the pace of market expansion, thus increases resource consumption. The district has been showing a trend of increasing population and urbanization; this is despite a relatively low

population density in the district. The population growth over the last century is shown in table 6. The urban population has shown a higher growth rate than that of population taking a share of 38.36 per cent of total population (BSE 1995).

Unsustainable agriculture crops and low food supportive capacity

Agriculture plays a vital role in the societal development by providing food for human beings and fodder for livestock but at the same time it can be linked to resource utilization. Dry lands traditionally have subsistence agricultural practices that impose restraint on resource use; but they also have subsistence levels of food production and consumption. However, dry lands are different from others in that they are sensitive with respect to environmental resources due to the thresholds, surpassing of which may lead to serious disruptions. Economic development through increasing access to markets and marketization lead to the breakdown of subsistent conditions, but it also increases the risks as well as the costs of external damages (e.g., Jodha 1995). From this view point, the management of dry lands, particularly the agriculture use of it, assumes greater importance, since the failure to do so shall eventually lead to desertification (Ridley 1990). Although this can be understood conceptually, it is very difficult to prove the linkage between agriculture and environmental resource degradation in a straightforward manner. As mentioned earlier, unsuitable cropping practices, such as rice cultivation, resulted in increasing use of water that also affected water quality. However, this resulted not only with the advent of canal water availability alone but also due to the increased access to markets and marketization which led to the abandonment of subsistent crops like pulses that are more suited to this climate. However, the impact of market forces is more evident in the case of groundnut cultivation, which is the major crop cultivated in the district (as high as 50 per cent of cropped area). The market price of groundnut being high and the crop easily cultivable in the dry lands, it has become the favourite crop of the farmers in the region. This risk reduction strategy, however, comes along another risk of pests and diseases due to mono-cropping. Moreover, groundnut crop does not provide an effective canopy and the field operations like deep ploughing will affect soil moisture and increase soil erosion hazard. The advent of market forces also affected the food consumption and life style leading towards an increase in resource consumption.

Table 6: Matrix of tactical interventions

Resource	*Resource component*	*Intervention (s)*
Forest/biological resource	Agro forestry	Encourage multiple cropping, crop mulching and relay cropping methods of farming
	Social forestry	Establish norms for management of commons like woods, pastures and plantations
	Forest conservation	Enhance the skills and methods of forest conservation through use of information technology and biotechnology
	Shelter belts	Implement tree plantations along the infrastructures like roads, railway lines, and water tanks for reducing the erosion
Land resource	Crop land	Impart training in soil conserving farming methods like multiple cropping, minimum tillage and crop mulching; encourage the complementary use of both organic and inorganic fertilisers
	Pastures/fallow land	Institute mechanisms based on community management to avoid overgrazing
	Barren/rocky land	Avoid land conversion for agriculture use; when it is used ensure the use of soil and water conservation methods like bunds, contours; use it for plantations
Water resource	Water availability	Promote water harvesting by means of infiltration wells, check dams and water tanks
	Water management	Ensure mechanisms in place to avoid poor water management impacts like soil salinity/alkalinity

Livestock growth pressure on pastures

Livestock breeding is not a major occupation in the district, but the livestock number is quite high. Livestock is rather seen as a toiling animal for cultivation and an asset easily disposable in the times of severe drought. The livestock's demand for fodder is exceedingly high, whereas, as observed earlier, the land use pattern implies very low allocation of land to pastures implying very high incidence of grazing. As compared to the permissible grazing index of 0.55 cow units/ha, the actual grazing index in the district is 4.7 cow units/ha, which is 7.5 times more than the optimal grazing index. This clearly indicates the amount of pressure from livestock grazing, which results in the transfer of this stress on forests through illegal browsing. In the past decade it is observed that there is an increase in the number of illegal browsing cases as well as the forest offences in general (figures shown in table 6).

Occupational structure and land holding

The occupational structure and land holding structure shall influence resource degradation if the pattern of the structure has a bearing on resource consumption and resource sharing arrangements. The occupational structure has a majority of the population as agricultural labourers and non-workers living on the subsistence means of income and a minority of it in agriculture and other services sectors, which characterise a feudal structure. A similar picture emerges in case of land holding pattern, which has a peculiar structure: small and marginal farmers constitute 55% of total population share less than 25% of the land, while large farmers constitute 13.4% of total population share half of the total cultivated land. This is an inequitable pattern that suggests the lack of implementation of land reforms as well as fragmentation of land holdings that results in intensification of agriculture on it. The institutional arrangements for resource sharing and conservation are not easily discernible and go well beyond the scope of this study. However, the occupation and land holding patterns reflect the subsistence conditions and poverty, which lead to continued dependence on natural resources and result in the degradation due to the pressure of human activities.

The Need for Enhancing Ecological and Social Resilience

The above analysis of trends and patterns of resource degradation leading to desertification conditions in the dry ecosystem of Anantapur underline the need for mitigating these effects through appropriate interventions/measures. These measures would reduce the vulnerability of the systems to the external forces, such as droughts, and enhance the ecological and social resilience (Subbaiah 1993). These measures shall be (i) strategic interventions at policy and decision-making and (ii) tactical interventions at local and block level. Besides identifying these measures, their implementation needs to make use of existing institutions, creating new institutions and designing an institutional framework for achieving the end results.

Strategic Interventions

The dry land ecosystems degradation and its exacerbation through human interventions can be ascribed primarily to the lack of appropriate resource management practices at farm level, block level and regional level. Measures that enhance these practices and achieve resource conservation shall prove to be very useful in enhancing the ecological resilience. However, a lack of effective mechanisms of coping makes the people more vulnerable to crop failures due to climatic and ecological pressures. Interventions such as income generation through supplemental work through public spending and designing crop insurance mechanisms will enhance the crop as well as human security (Ramakrishna 2001). The creation of such mechanism of public support would greatly enhance the social as well as ecological resilience. Also, the provision of alternative livelihoods that provide economic opportunities is a critical element of enhancing social resilience and making policies that aim towards the creation/revamping of such industries is very vital to achieve it. In fact, concentrating on pure agronomic

measures like drought resistant crops cultivation by those African countries that have been affected by desertification did not yield the right results due to lack of demand for such crops and difficulty in pursuing the farmers to cultivate them (Eriksen 2001b). While some efforts are needed on a sustaining basis to do this, efforts also need to be made to enhance the agro-ecosystems and set up agro-processing as well as cottage industries in order to create new livelihoods and, thus, enhance the coping of humans.

Reducing ecological vulnerability

As dry ecosystems are threatened by the human mismanagement, attention needs to be made to correct these actions through well-targeted large conservation programmes. Watershed based conservation of soil, water and vegetation would result in restoration of their losses through human activities like agriculture, livestock grazing and using biomass as an energy fuel. This strategy needs to have the elements of (i) conservation agriculture and horticulture e.g., water conserving crops, crop rotation, crop mulching and the use of genetic and irrigation engineering methods (ii) efficient use of water through inter-row water harvesting in the form of ridge and furrow irrigation and deployment of water conserving technologies like drip irrigation (iii) enhancing soil water availability through rain water harvesting and enhancing tank storage and supplies (Swaminathan 2004). These activites can be planned as a major activity across the district by delineating the watersheds and prioritising them for phased targeting. Already, mapping of the watersheds has been done and prioritisation was in the due course, then the design of programmes for resource conservation needs to be planned with the help of experts in agriculture, soil sciences and water resources. This integrate approach to resource conservation would yield better results than the conservation measures for one resource component.

Enhancing the economic security or coping

As the dependence on agriculture and allied activities for living is predominant in the district, their vulnerability to crop failures becomes much more stronger. This can be corrected through mechanisms of public intervention - both direct and indirect. In the direct intervention, the support can be extended by the way of distribution of chosen minimum (or subsistent) levels of food through public distribution system or by the way of distribution of cash for purchasing either food grains or crop implements. While food distribution can be done through existing administrative channels and can be invoked during the times of drought, distribution of can be done more efficiently through a creation of crop insurance system, with public payment of premia, which would step-in during the drought related crop failure. Another effective method of economic support would be providing waged employment through rural infrastructure building programmes. These programmes can be targeted to create either physical infrastructure, such as roads, irrigation canals, power lines etc., or social infrastructure, such as schools, hospitals and community centres. This indirect suppport can have a long-term benign effect on the rural economy, society and its upliftment.

Creating alternative livelihoods

Agriculture is still the dominant occupation to both farmers and workers in the district. With the given distortionary land holding rendering disadvantageous for small farmers, they shall not be able enhance their incomes without resource degrading agricultural practices, which in turn shall affect their long term sustainability. Likewise, farm workers also receive low wages due to poor returns on income to farmers. This situation can only corrected by creating opportunities in non-agriculture sectors and providing incentives for setting-up of the industrial units. This need not to focus on manufacturing alone, but several other industrial activities, such as those based on rock-cutting, agro-processing and food processing, can become good activities that extend the operations beyond farm level. The cottage industries can also be revamped through cooperative institutions. But, most importantly, creation of effective education, training and credit facilities is vital for the revamping of the cottage industries as well as other basic industries.

Tactical Interventions

While strategic interventions are required for bringing about the large-scale changes for mitigating the resource degradation, several micro-level interventions can be planned and given as a priority to the village and block level administrative units. Table7 gives the range of interventions that can be planned with respect to the management of the resource. Implementing these measures would require greater amount of participation of local people and local institutions as well as good amount of cooperation between public and local institutions. In fact, it was shown elsewhere that even small scale projects that enhance pastoral development can yield positive results (Pratt *et al*, 1997), but enough care needs to be taken to ensure that it would not mean overgrazing of public commons.

Institutional Framework for Resource Management

The above interventions can only be implemented through the formation of an institutional framework, identifying the institutions responsible for implementation. This needs to make use of existing institutions, both formal and informal, and new institutions. As mentioned earlier, there is a need for creating a monitoring agency within the authority of the district collectorate which would coordinate the data generation and analysis on land, water and biological resources and execute management and improvement plans in liaison with the agencies such as departments of agriculture, land, water resources and forests. This would also require the inputs of spatial information acquired through satellite and other maps. When it comes to support programmes like giving cash, the direct support needs to be implemented through village panchayats and monitored through block level administration, whereas the public distribution system is already in place for the distribution of food grains. Creation of alternative livelihoods is possible through appropriate policies and incentives in the form of targeted subsidies for industrial growth as well as enhancing the access to credit. The micro-interventions call for identifying the means of establishing cooperation between the public authorities and local community so that they would implement the measures in a harmonised manner.

Conclusions

Desertification due to environmental resource degradation in dry ecosystems has different dimensions, and it is driven by both natural and human factors. In this study, it is described in terms of the degradation of environmental resources that are conditioned by natural factors and exacerbated by anthropogenic factors. It was analysed by observing the patterns and trends in the degradation of resource components - land resource, water resource – in the light of socio-economic pressures. The continuation of these patterns and trends would increase the resource degradation further, and enhance their vulnerability to the external forces like droughts as well as put them on the brink of collapse in the event of crossing of thresholds. This calls for combating through public intervention by the way of appropriate institutional and policy interventions for enchancing ecological and social security. This needs to be complemented by the cooperation and support at grass root levels as well.

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