Research Journal of Agriculture and Forestry Sciences _____ ISSN 2320-6063
Vol. **3(10),** 1-8, November **(2015)** *Res. J. Agriculture and Forestry Sci.*

Preparedness and Mitigation Measures to combat Agricultural Drought in Kangshabati Irrigation Command Area of West Bengal, India

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Available online at: www.isca.in, www.isca.me
Received 25th September 2015, revised 29th October 2015, accepted 3rd November 2015

Abstract

Agricultural drought is one of the significant natural hazards in the drought prone region. The western part of West Bengal is frequently characterized by agricultural drought which is the outcome of lowering soil moisture level. This situation promotes crop stress and low productivity. The present study area, Kangshabati Irrigation Command Area of West Bengal is dominated by rural population where agriculture is the main stay of economy. To combat the agricultural drought situation some strategies were to be taken on immediate basis in the Kangshabati Irrigation Command Area (KICA). Firstly, an agricultural drought severity map was prepared using RS and GIS for the concerned study area and following the level of drought severity various management options were suggested. Micro-watershed development, water harvesting structure, conservation of soil and water, development of horticulture and social forestry are the major developmental strategies suggested by the author. The study depicts that the community participation in different schemes introduced by Union and State government have a significant role in the progress of KICA. In the mitigation options, not only agricultural sectors but also economic and social sectors were given more importance.

Keywords: Remote sensing (RS), geographic information system (GIS), agricultural drought severity, mitigation and preparedness.

Introduction

Kangshabati Irrigation Command area (KICA) covers a large tract of plateau of West Bengal, India. The region is characterized by varied ground water potentiality, irrigational opportunities, rainfall phenomena, soil moisture availability and consequently agricultural productivity. Some places are registered with higher agricultural production and some places are not. As, the prosperity of economy depends on agricultural production, there is an urgent needs to ensure greater opportunity of high agricultural productivity to the rural farmers. KICA reveals a large numbers of opportunities as well as problems to the common people. There is a reasonable debate among researchers from various disciplines on the definition of the term 'drought'[1-5]. Agricultural drought situation occurs when the soil moisture availability to plants has dropped to such a level that it is not sufficient for normal crop growth and maturation and adversely affects the crop yield. Drought situation can be analyzed considering soil moisture availability on a very large spatial scale[6,7]. The characteristics of potential periods of seasonal agricultural drought varied from one region to another one[8-9]. In the present work, a perception study was conducted in connection to the socio-economic status at household levels, problems existing in the region, relief work available during the drought period, strategies to combat the drought situation, and level of satisfaction over the Government aids. The district produces adequate quantity of Paddy, Vegetable and Potato, while it is lagging behind in production of pulses, oilseeds, and wheat. Attempts have been made to increase the agricultural area and production through different schemes.

Uncertainty of rainfall and lowering of ground water level have created the problem of agricultural production. Attempt should be made to construct Water Harvesting Structures (WHS) and renovate tanks for increasing source of irrigation water, soil conservation, and fisheries. More emphasis is to be put on strengthening self help groups (SHGs). Improved management of waste land and degraded areas should be promoted to avoid further soil deterioration. It may be important to offer farmers seeds as incentive to adapt modern farming practices. Middle men may be avoided from the vegetable market through creation of awareness among farmers, formation of cooperatives and establishment of farmers' markets. Recently various models are being introduced to assess the topograpgy and related earth surface processes[14,15]. Watershed development through soil and water conservation is to be advocated for controlling soil erosion. This will help in the restoration of ecological balance and in situ moisture conservation.

Today land use and land cover is a great challenge to the geographer[16] which continuously modify and change hydrologic character of the landscape as well as agricultural practices. Application of Digital Elevation Model (DEM) to assess flow direction and upslope area[17] and the role of low angled topography of surface water convergence[18] are the dominant controlling factors to assess the agricultural prosperity of a region. Drought management can be accomplished by two kinds of mitigation measures such as by adopting preventive measures and by developing preparedness plan[10].

Table-1
Preventive measures and mitigation plan[10]

Preventive Measures	**Preparedness Plan**
Dams/reservoir to store water	Improvement in agriculture through modifying cropping patterns and introducing drought resistance verieties of crops.
Watershed management	
Water rationing	
Cattle management	
Proper selection of crop in drought affected area	Management of rangeland with improvement of grazing patterns, introduction of feed and protection of shrubs and trees.
Leveling soil conservation technique	
Reducing deforestation and fire-wood cutting in the drought affected areas	Development of water resources system with improved irrigation, development of improved storage facilities, protection of surface from evaporation and introduction of drop irrigation system.
Alternative land use models for water sustainability	
Checking of mitigation and providing alternate employment	
Education and training to the people	Animal husbandry activities can help in mitigation with use of improved and scientific methods.
Participatory community programmes	

There are large numbers of opportunities available in the Kangshabati Irrigation Command Area (KICA) and on the basis of which the concerned study area is treated as one of the significant spatial unit in terms of resource potentiality. The region provides following favourable conditions for agriculture.

Suitable weather for growth and development of diversified crops. Spatial distribution of Viandhayan Alluvial Soil that is, fertile soil for cultivation of all types of crops. Scope for cultivation of profitable crops instead of conventional crops. Proper environmental condition for production of vegetable, potato, oil seed and pulse. Availability of affordable agricultural labour force. Suitable environment for introducing HYVs and Hybrid crop varieties. Better marketing facilities for agricultural goods. Ample opportunities for Organic Farming.

However, Despite, the existence of several opportunities in the Kangshabati Irrigation Command Area (KICA), there are some prevalent problems which retards the agricultural production. The problems include among others: Farmers in KICA mostly belong to small and marginal group because of the fragmented land holdings.

Low level of awareness amongst farmers about diversification and utilization of the modern agricultural technology. Inadequate market facilities in the district blocks still persist. Inadequate infrastructure for agricultural extension, farmers training and capacity building. Limited agricultural mechanization. Inadequate irrigation facilities in most of the remote segment of Kangshabati Irrigation Command Area. Unavailability of quality seeds in remote villages. Lack of awareness regarding seed treatment facilities amongst farmers. Lack of adequate storage facilities for grains in the remote villages. Illiteracy of the farmers inhibits the dissemination of improved agricultural knowledge. Poor income group farmers have no access to adopt modern agricultural technologies.

The Kangshabati Irrigation Command Area receives prolonged meteorological drought and drying of reservoirs, streams and rivers and fall in ground water levels which causes depletion of soil moisture during growing season to support healthy crop, leading to stress and finally to agricultural drought phenomena.

Kangshabati project was located in the western part of West Bengal. The area is relatively dry in comparison to other part of Bengal. After independence, the recommendation for suitable site for the construction of Kangshabati Dam was taken up in right sense and suitable site was identified. The project was then framed to irrigate an area of 3,40,750 hectares during kharif and 60,629 hectares during rabi. Kangshsabati Project was constructed with two major objectives: i. irrigation and ii. moderation of flood. A Provision was also made for supplying drinking water for the human and cattle consumption, as the area is very much susceptible to domestic water crisis during pre-monsoon period. In the lower areas the Kangshabati River has innumerable flood protective embankment covering a total flood area of 1600 sq. km. The designed peak flood discharge at the dam site is 10,600 cusecs.

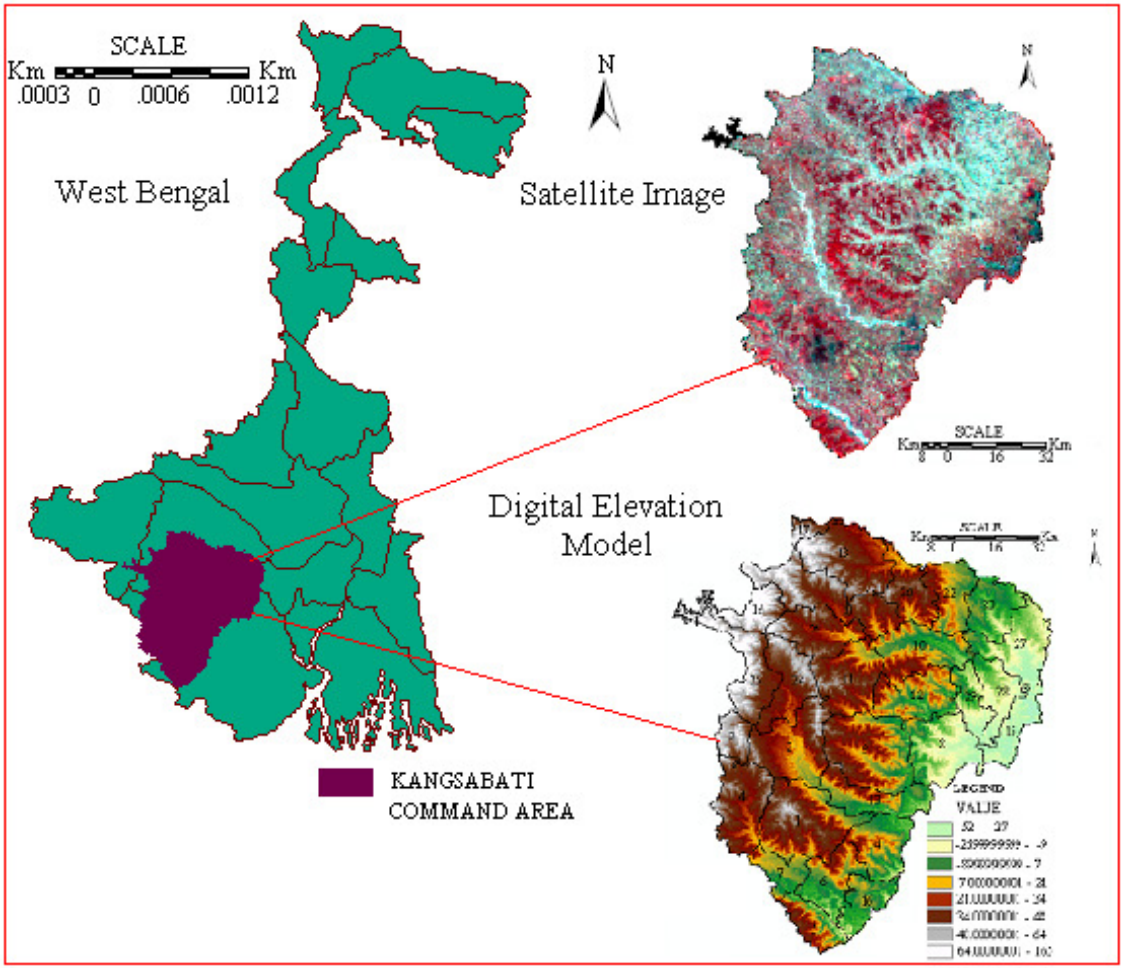

Figure-1
Location of the study area with DEM and Satellite Image

After construction of the Kangshabati dam, paddy continued to be grown as the major crop in the command area during kharif season and in due course low yield variety has been replaced by modern high yielding varieties in most of the period. The agricultural production is dependent upon the monsoon rainfall, after the construction of the dam too. The irregular nature of monsoon rainfall in the Kangshabati Irrigation Command Area sometimes welcomes the agricultural drought which retards the socio-economic development of the region. To promote the developmental programme and to combat the agricultural drought severity, various developmental strategies are to be adopted considering geomorphic, geo-hydrologic, and socio-economic aspects of the KICA. The present study aims at this.

The major objectives of the study are: To identify the agricultural drought severity district blocks in the Kangshabati Irrigation Command Area (KICA). To provide strategies for mitigating agricultural drought severity considering geomorphic, geohydrologic, socio-economic and people perception prevalent in the Kangshabati Irrigation Command Area (KICA). To determine perception induced mitigation option from a representative district blocks, Garbeta-I, Paschim Medinipur.

Material and Methods

The Kangsabati Irrigation Command Area (KICA) is bounded on the North by Birbhim district, South by Purba Medinipur district, East by Haora and Hoogly districts of West Bengal and West by Singbhum district of Jharkhand. The command area lies between $20^0 00' 00''$N to $23^0 10' 00''$N and $86^0\ 10' 00''$E to $87^0 10' 00''$E with an aerial extent of 9632.3 km^2 covering Survey of India Topo-sheet 73 I, 73 J, 73 M and 73 N at 1:250,000 scale. The study area is consisting 13 blocks of Bankura, 21 Blocks of Midnapur and 1 Block of Hoogly districts in the State of West Bengal**.**

To carry out the whole study remote sensing data, others ancillary data, GIS Software (ERDAS IMAGINE 9.0, ARC MAP 9.1) were used in the right sense. The specifications of the satellite and others ancillary data used in the present study with full care stated in table-2.

Table-2
Satellite and Ancillary Data Source

<table>
<tr><th colspan="6">Satellite Data Specification</th></tr>
<tr><td rowspan="7">Landsat 7</td><td>Path</td><td>Row</td><td>Date – of - pass</td><td colspan="2">Sensor-landsat TM</td></tr>
<tr><td rowspan="6">139</td><td rowspan="6">44 and 45</td><td rowspan="2">26th November 2007</td><td>Spatial Resolution</td><td>30M</td></tr>
<tr><td>Radiometric Resolution</td><td>8 BIT</td></tr>
<tr><td rowspan="2">11th October 2007</td><td>Swath (Km.)</td><td>185</td></tr>
<tr><td>Temporal Resolution</td><td>16 DAYS</td></tr>
<tr><td>20th November 2009</td><td rowspan="2">Spectral Bands (μm)</td><td rowspan="2">B:0.45-0.52; G: 0.52-0.61; R: 0.63-0.69; NIR: 0.77-0.90; SWIR: 1.55-1.75; TIR: 10.5-12.5; MIR: 2.09-2.35; PAN: 0.52-0.90</td></tr>
<tr><td>8th October 2009</td></tr>
<tr><th colspan="6">Ancillary Data Used</th></tr>
<tr><td colspan="2">Data</td><td colspan="4">Source</td></tr>
<tr><td colspan="2">Toposheets</td><td colspan="4">Survey of India toposheets of West Midnaore region - at scale 1:250,000 (toposheets no: 73 J,73 N,73 M)</td></tr>
<tr><td colspan="2">District Statistical Handbook, 2007</td><td colspan="4">Bureau of Applied Economics and Statistics, Department of Statistics and Programme Implementation, Govt. of West Bengal, India</td></tr>
<tr><td colspan="2">District Statistical Handbook, 2010-2011</td><td colspan="4">Bureau of Applied Economics and Statistics, Department of Statistics and Programme Implementation, Govt. of West Bengal, India</td></tr>
<tr><td colspan="2">Landsat TM, path – 139, row – 44 and 45</td><td colspan="4">ftp://ftp.glcf.umd.edu/glcf/Landsat/WRS2/p139/r044/L5139044_04420061117.TM-GLS2005/</td></tr>
</table>

During the perception study, 150 households were surveyed from agricultural drought prone blocks with well structured questionnaires. The Digital Elevation Model (DEM) provides different thematic data layers namely slope, drainage, relief, structural features etc. which are obtained more easily, less subjective and provides more reproducible measurements than traditional manual techniques applied to derive topographic maps[11]. During the early first decade of 21st Century successfully used RS and GIS Technique for the assessment of agricultural drought condition and presented its management proposal that have brought a new horizon in the field of agricultural research [12, 13]. The crop condition assessment was made by comparing the NDVI values of the year 2009 with that of the year 2007. Agricultural drought severity map was prepared for the rainfall deficit year of 2009.

Crop condition at any given time during its growth is influenced by complex interactions of weather, soil moisture, and soil and crop types. It is universally accepted that satellite derived NDVI is an important index to assess crop stage /condition. Crop condition assessment in the study area is made by comparing the NDVI values with the rainfall deficit year (2009) and excess rainfall year (2007). In the first stage from the deficit and normal year NDVI images, percentage NDVI image for deficit year was obtained by applying the following equation:

$$\text{NDVI (\%)} = \frac{\{\text{NDVI image (D)} - \text{NDVI image (E)}\} * 100}{\text{NDVI image (E)}}$$

Where: NDVI=normalized differences vegetation index; D= deficit period image; E= excess period image.

Based on the ranges of NDVI (%) value the crop condition is divided into three classes as shown in the table-3 and crop condition image was generated.

Crop condition NDVI image is reclassified to obtain the block wise Agricultural Drought Condition. Weighted values for each crop condition were assigned as shown in table-4. In order to arrive at a single value for each block the area falling under each crop condition was multiplied by the corresponding weights and the sum was divided by the total area of the block. Based on these values of each block, reclassification was made to assess drought severity.

Table-3
Classification of crop condition

NDVI (%)	Crop Condition	Weightage
>+100	Mild	1
+100 to -100	Moderate	3
< -100	Severe	5

Table-4
Reclassification of crop condition and drought severity

Reclassification	Drought Severity
1.0 -9.5	Mild Drought
9.5-12.5	Moderate Drought
12.5-27.0	Severe Drought

After assessing extreme agricultural drought severity blocks of KICA, perception study was conducted at household levels to understand the causes and consequences of agricultural drought as well as the strategies to be taken for the well being of the drought affected people. Not only was that various secondary information also incorporated to suggest mitigation options. A report on Comprehensive District Agricultural Plan (C-DAP) prepared by NABARD consultancy service limited, West Bengal was adopted in the present study. Human Development Report of Bankura as well as Paschim Medinipur (2006-2007) and District Statistical Handbook (2010-2011) were taken into account to adopt various strategies to combat agricultural drought.

Results and Discussion

Assessment of Agricultural drought severity: In Kharif season 2009, severe, moderate and mild drought condition were found in six, thirteen and nine blocks respectively (figure-2). It was established that Kangshabati irrigation command area is characterized as Mild drought where groundwater potentiality is moderate to good. Besides the Southern and Extreme Western part of the area are dominated by severe drought condition due to low ground water potentiality. But in Rabi season 2009, another two blocks were added under severe drought condition and large number of blocks came under mild drought condition described in figure-3.

The detail block level distribution of agricultural drought severity and its relation with ground water potentiality are presented in table-5.

Table-5
Block wise agricultural drought severity analysis

Name of the Blocks	Drought Severity in Rabi Season, 2009	Drought Severity in Kharif Season, 2009
Jhargram	Severe	Severe
Binpur-I	mild	Mild
Binpur-II	severe	Severe
Jamboni	severe	Severe
Nayagram	severe	Moderate
Sankrail	mild	Moderate
Gopiballavpur	severe	Moderate
Keshpur	mild	Severe
Salboni	Mild	Moderate
Garbeta-I	Moderate	Mild
Garbeta-II	Severe	Moderate
Garbeta-III	Mild	Moderate
Midnapore	Mild	Moderate
Khaghpur II	severe	Moderate
Chandrakona-I	Mild	Mild
Chandrakona-II	mild	Mild
Goghat	Mild	Mild
Ghatal	moderate	Moderate
Keshiary	Mild	Moderate
Bankura	Moderate	Moderate
Onda	mild	Mild
Taldangra	Mild	Moderate
Simlapal	Moderate	Moderate
Joypur	Mild	Mild
Kotalpur	Moderate	Mild
Sarenga	Moderate	Mild
Raipur	Severe	Severe
Khatra	mild	Moderate
Bishnupur	moderate	Moderate

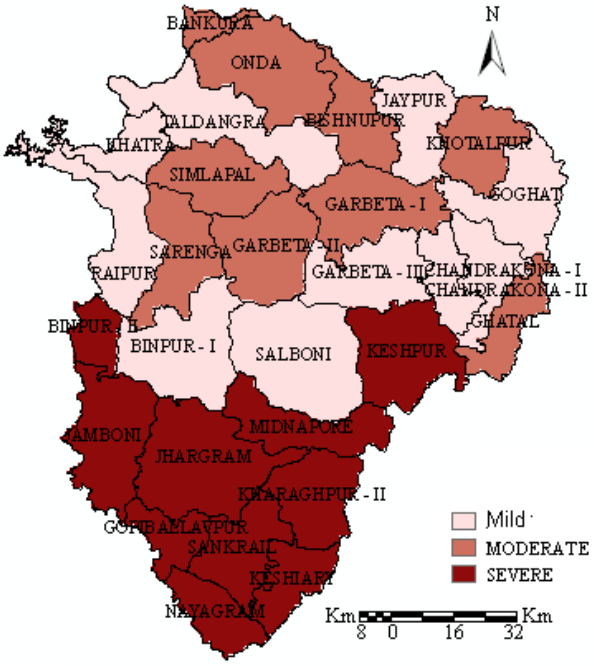

Figure-2
Agricultural Drought Severity Zones (Rabi Season)

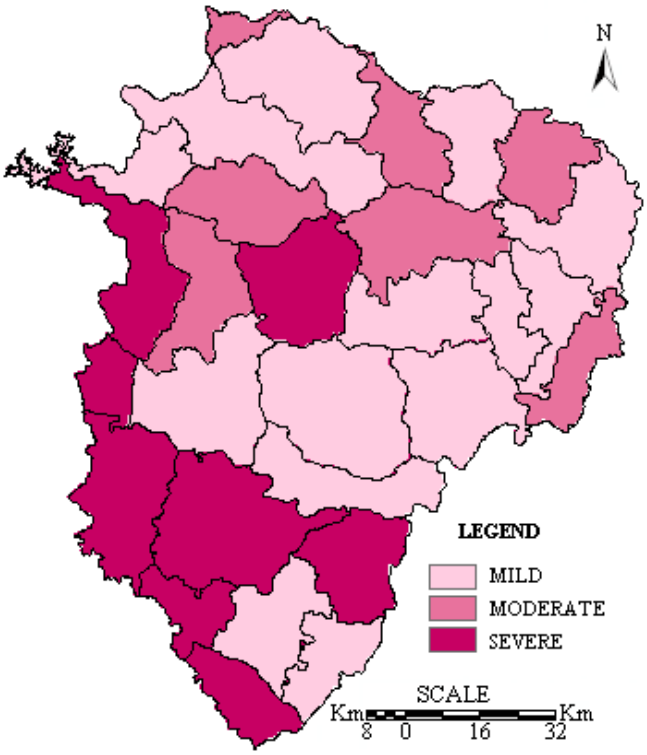

Figure-3
Agricultural Drought Severity Zones (Kharif Season)

Strategies to be adopted in the Kangshabati Irrigation Command Area (KICA): The following Strategies have been put in place to combat agricultural drought situation in Kangshabati Irrigation Command Area (KICA) mainly in the district blocks of severe and moderate drought prone areas (table-5).

Introduction of Diversification of the cropping pattern to meet the ever increasing demand of food crops in the rural areas. Extension of irrigation facilities in unirrigated areas especially in the blocks of Jhargram, Nayagram, Binpur, Khatra, Chandrakona, Salboni where drought severity is high. Establishment of new pods/water bodies and renovation / reclamation of silted up water bodies for accommodating the rain water. Increasing cropping intensity by increasing gross cropped area and by increasing agricultural area. Increasing area under irrigation by constructing deep tube well, shallow tube well and tanks. Development of Self Help Group and Farmers' Clubs and provision of insurance and security to all farmers growing different types of crops because of complete failure of production as a result of drought.

Watershed Development Programme and Soil Conservation Practice for healthy production: The top soil having a depth of 15-20 cm plays a vital role in the production of agriculture crops and other shallow rooted agricultural crops. There are necessities of water and soil conservation in the Kangshabati Irrigation Command Area (KICA). The following measures have been put in place in order to manage the water and soil and to restore agricultural production.

Conservation and proper utilization of natural resources like soil and water, introducing agro-forestry and horticultural plantation, water harvesting structure, farm pond, gully plugging, irrigation channel, and silt detention dam. Improvement of production environment and restoration of ecological balance through scientific management of land and water and moisture conservation. Reduction of inequalities between irrigated and rain fed area. Land reclamation and soil improvement in lateritic and water logged area is very much necessary to increase the areal extent under cultivation. The western part of the district having lateritic soil is often affected by severe drought. The KICA is prone to sheet, rill, and gully erosion which needs to be controlled by different measures such as plantation, afforestation and introducing fast growing grasses.

Micro-watershed approach: Watershed developed program in catchment of the river Kangshabati would be taken up on high priority basis by the Soil Land Use Survey, Government of India. Analyzing the relief, slope, geology, geomorphology, soil, drainage, land use and land cover, rainfall character, and cropping pattern, it is inferred that development of micro-watershed is the significant aspect of the development strategies. A watershed is referred to as the drainage basin or catchment area of a particular stream or river. Simply it refers to the area wherefrom the water to a particular drainage system comes. The micro-watershed covers an area of about 500-1000

hectares of land. Watershed development refers to the conservation, regeneration, and judicious use of human and natural resources within a particular watershed. To mitigate agricultural drought problems, watershed development is needed in the concerned Kangshabati Irrigation Command Area. Under Rashtriya Sam Vikas Yojana (RSVY) micro-watershed planning for number of watersheds in the Kangshabati Irrigation Command Area has already been completed and others are under process. The basic development philosophies were kept in mind to recognize micro-watershed based micro-planning:

Create people's organization and strengthen the existing grass-root organizations. Create development models and methodologies. Create an asset base through savings from the execution of the programme for maintenance. Provide technical inputs through participation of the various departments.

In the watershed area, the availability of water is caused as a result of rainfall and get disposed off through surface run-off, seepage and evapo-transpiration. In most of the places of western part of the Kangshabati Irrigation Command Area (KICA), due to undulation of landscape and soil condition, most of the water gets drained out to lower ridges and finally to sea through rivers along with the eroded top-soil and nutrients. The soil in the region is porous and water leaches out fast. In this situation the development of ponds in the drought prone section is of utmost important for soil saturation as well as irrigation.

Introduction of Water Harvesting Structures: In the KICA, the construction of *water harvesting structures* should be given priority to serve the water to the rural poor during the severe drought period. Two important models, such as *5 percent model* and *30-40 models* could be adopted in different drought severity locations. The major objectives and structure of the models are discussed below.

Percent Model: This model is locally called as 'Happa'. In this model a ditch is constructed with 5 percent land of the total land holdings of the family in rectangular shape with stairs up to a depth of 10 feet (Human Development Report, Bankura and Paschim Medinipur District, 2006-2007). The constructed ditch can arrest rain water during rainy period and can help to produce maize, arhar, bitter guard and bottle guard etc. the remaining period of the year.

30-40 model: In this model a water collection pit is formed which is divided to 30 to 35 feet × 40 feet. Hence the area of each pit would be 1200-1400 square feet and the volume of the pit would be around 100 cubic feet. The earth cutting from the pit is used to construct the micro-bund on the plots. The prepared land is used for orchard plantation and social forestry. In the KICA, such structures have been formed under the employment guarantee scheme and found very useful. A total of 23 hectares of land in Saltora block of Bankura district was covered under this model.

Development of social forestry: The continuous degradation of natural resources, severe erosion, depletion of ground water reserves, low agricultural productivity, low wage rate are some of the crucial problems in the command area. The KICA provides huge forest resources. The planned participatory management of land, water and forest resources would ensure sustainable livelihood of its people. A social forestry programme should be implementing in the areas based on the following recommendations:

Encourage farmers to use waste land for growing forestry species like Neem, Karanja and jatropha. Also promoting vegetation on barren land may be done through farmers. Protect the forest by empowering the local community through Joint Forest Management arrangement.

Conclusion

The drought affected people must voluntarily come together accept full responsibility for regeneration of their environment by actively participating in the planning and implementation of restoration program. The real challenge is to bring in cohesion in the community, especially in areas which are sparsely populated. The development of micro-watershed plan is an empowering tool for the poor and agricultural vulnerable people in the Kangshabati Irrigation Command Area (KICA). The watershed development programme involves continuous interaction and exchange between various sectors and components. There is prevailing impact of the environment on the human community living within in the KICA, as they depend on it for food, fodder, fuel and water. It is necessary for the people living in the KICA and those that are affected by agricultural drought to understand the relationship between their problems and the degraded environment in which they reside. The watershed development programme should provide opportunities for people find economic alternative and be able to let their land regenerate/rejuvenate. However, environmental regeneration is only possible, when the local community appreciates the current challenges, enjoys full control over resource mobilization, management and conservation as well as actively participating in the planning processes.

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