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Full Length Research Article

Catchment Analysis of Integrated Watershed Management in the Upper Jiadhal River Basin: Arunachal Pradesh and Assam, India

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ABSTRACT

The environment and related problems of both the basins (upper and lower basins of Jiadhal river) are different but interrelated. Thus, Integrated Watershed Management is the key to cope up with natural hazards including land and water degradation and accelerated soil erosion, floods, siltation and sedimentation. Integrated watershed management includes the integration of many scattered programs of soil conservation, afforestation, minor irrigation, crop production, tree plantation, fodder development and other development activities into a well prepared watershed project. These are mainly based on climate, land, water and plant resources on the one hand and man and animal resources on the other. It offers hope for bringing about sustained natural resources development. The study area selected for the study is a part of Upper basin of Jiadhal drainage basin, which is a phenomenal river system with huge sediment carrying capacity and intensive flood frequencies making it havoc for the inhabitants of the areas it drained. The delineation of the basin is done using geospatial perimeters including geomorphic, hydrologic and land use and land cover of the region. Open source Landsat: L5135041_04120090111 3_MTL, TA6RFR_A012986-20190901 data from Bhuvan (ISRO) was accessed by ArcGIS tools. The result includes the sub-catchment wise delineation of the Jiadhal river basin with reference to its physiography and hydrological accumulation and flow. The weaker section of the study area is identified by interplaying land use and land cover by supervised model using ArcGIS tool. It focused that upper catchment is more influential by environmental problems rather then human except deforestation activities, as there is very less settlement due to no communication route to interior catchments of the basin. Strategic planning of the watershed management is made on the basis of the natural physiography and environmental issues prevailing in each sub-catchment for a proper plan to manage Jiadhal river basin as a whole. Integrated watershed management could resolve the environmental problems and a joint operation of both the state Arunachal Pradesh and Assam is looked forward for the management of the Jiadhal River Basin, North-East India .

Introduction

A watershed is a topographically delineated area that is drained by a stream system; it is also a hydrological unit, a biophysical unit and a holistic ecosystem in terms of the materials, energy, and information that flow through it (Wang, 2016). Watershed management is a continuous process involving the management of natural as well as social aspects of a geographical unit. The interaction of human over the natural environment is the main force behind these innovative concepts of natural resource management. Integrated Watershed Management is one of the products of the man-nature relationship. The watershed management is the consequences of the continuous observation and empirical analysis of the natural phenomenon occurring in a geographical unit in spite of the diversities in respect of the environmental geomorphology, integrated watershed management builds upon the foundational principles of watershed management to integrate various social, technical and institutional dimensions, as well as conservation, social and economic objectives (German, 2007).

Watershed development means, incorporates the ultimate or optimal use of land, water, plants and animals as well as conservation of natural resources within the geographical unit by human being. Watershed management tries to maintain the balance between the natural resources on the one hand and human being on the other with a concerned plan to cope with the diversities within. It includes the natural calamities, land use/ land cover, landslides, soil erosion as well as agricultural output, which also provides a wider range of allied activities like horticulture, sericulture, dairy, fisheries and agroforestry which owes the economy of the region. Integrated watershed management triggers to curve an integrated plan to sustain and enhance watershed functions that provide the goods, services and values desired by the community affected by a watershed boundary (Rawat, 2014). The management is complex,

including components within the watershed (eg. upstream, midstream, downstream) and even beyond involving human and natural sectors.

The main objective of the paper is to identify the sub-catchment of the upper Jiadhal basin and to find the environmental problems prevailing there. It further triggers to propose a planning strategy for the integrated watershed management of the basin. The early works in the Jiadhal river basin is more or less focused on socio-economy and flood hazard studies mainly concentrates in the lower basin area, which is considered mainly due to accessibility. But the environmental phenomenon prevailing in the basin like flood and siltation has the main sources in the inaccessible upper catchments of the basin. To find a solution to environmental problems of the basin an attempt is made through remote sensing technology to reaches the upper catchment of the basin which is dominated by natural forest with less human population and having no proper route for exploration besides trekking along the river in dry season.

Materials and methods

The paper concerns the studies on environmental geomorphology of the Upper Jiadhal River basin flowing from the hilly terrain of the Arunachal Himalayas to the extensive plain of Assam particularly of Dhemaji District. A field observation method would be applied for the fulfilment of the study followed by Technical use of reparation of maps and comparisons with the help of geographical information technologies GIS and Remote sensing software and images for the analysis. Case study and survey will included to the selected sensitive areas for the ground truth. Primary data in the field are observation, interview, case history method etc. The secondary data is collected from the various documents, journals, news paper, reports and records published by the state government and others agencies.

Study Area

The study area selected for the research is a river basin of district Dhemaji, Assam, which is havoc in the form of river system. Jiadhal covers an area of 1851.43 km^2 having latitudinal and longitudinal extensions of 27^o 08' N to 27^o 45' N and 94^o 15' N to 94^o 38' E respectively. Out of its total basin area 1851.43 km^2, Arunachal Pradesh occupies 370.63 km^2 i.e. 20 % of the total basin area and rest 1480.80 km^2 i.e. 80 % of the basin area drains to the state of Assam. The basin is adjacent to Moridhal river basin in the east and Subansiri river basin in the west. Rising from the West Siang district of Arunachal Himalaya or Siang formations at an elevation of 1247 m and the area receives an annual rainfall of 3,500 mm as receded (Gogoi, S and Chetia, 2011). The Upper Jiadhal basin in mainly delineated in consideration of the physiographic division of the river basin, as it is occupied by mountainous region with identical environmental geomorphology at separate it from the lower river basin which is a feature less extensive flood plain. The causes of natural hazards in the plain has real root in the upstream so the area selected for study considers that, the stable upstream would reduce natural hazards in lower basin area as well, mainly geomorphological. Multispectral Landsat file of the region is obtained from open source portal of Bhuvan (ISRO) viz. L5135041_041200901113_MTL, TA6RFR_A012986-20190901, compiled to identification of study area by implementing geomorphological and hydrological parameters with geospatial platform in ArcGIS and QGIS. The Jiadhal basin was identified by using watershed delineation technicians by following hydrological perimeters of accumulation and flow direction of drainages. The basin was further delineated to sub-catchment for micro observation. The Jiadhal river basin has vast physiographic variation as the source region is mountainous and occupying the areas in Arunachal Pradesh and the downstream is low feature flood plain of Assam. Thus it is considered into two broad division viz. Upper Jiadhal and Lower Jiadhal Basin. The lower basin is mostly affected by flooding in each year with huge sand casting and siltation. Environmental geomorphology of the basin defines it as consequences of environmental problems in upper basin resulting hazardous lower basin. To find solution to environmental problems of a watershed each sub-catchment wise of upper Jiadhal basin is considered to be the study area under integrated watershed management programme. The physiography of the study area is followed to understand the environmental factors prevailing in the area. The multispectral data were analyses for land use and land cover using supervised classification followed by field observation following Rawat (2011), Chorley (1965,1967), Goudie (1990), Gragory and Walling (1979).

Results

Sub-Catchments Of Upper Jiadhal Basin

The Jiadhal Drainage System that drains the study area is a young mountainous river system originated in the hilly terrain of Siwalik Himalayas of Arunachal Pradesh, particularly the West Siang District. The basin is adjacent to lower eastern mountainous part of Subansiri River, and later it drains as its largest tributary in the plains of Assam. The Drainage Basin or Watershed of Jiadhal River has the areal extension of 1851.43 sq.km. The Drainage basin is divided into two geographical units mainly due to the physiographical difference in comparison to the drainage system prevailing as, Upper Jiadhal Basin and Lower Jiadhal Basin. The Upper Jiadhal Basin is extended in the hilly tracks of Arunachal Himalayas and has a rough terrain with bisected river system. The stream dissected the terrain in numerous ridges and isolated with different drainage characteristics. The Jiadhal Upper Basin consists of 370.63 sq.km of aerial extension. The mapping indicated the highest width of the basin recorded as 38.07 km. from east to west extent and 18.48 km from north to south extent. Comprising mainly three tributaries joining together and the Jiadhal originated from the Tri-Junction.

1. Sido Catchment: The Sido catchment is a more or less a circular block with Subansiri basin in the eastern margin, toward the north and north-east lays the Sika catchment and to the south-east lays the Jia catchment. The southern periphery is associated with the Lower Jiadhal basin. The Sido has a perimeter of 52.41 km with highest length of 17.82 km of east to west and 10.21 km of north to south extension comprises a drainage area of 110.52 sq. km.

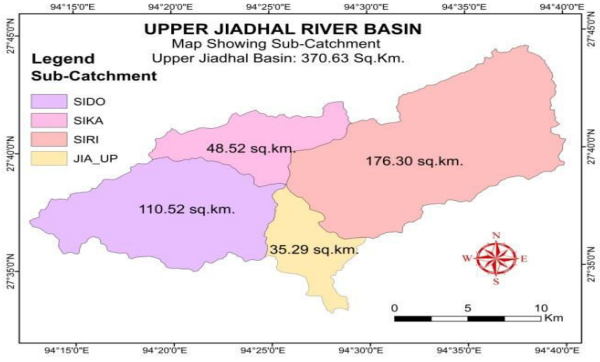

Fig.1. The Sub-Catchments of Upper Jiadhal Basin.

2. Sika Catchment: The north central part of the upper Jiadhal basin lays the Sika Catchment with a perimeter of 48.52 km. Geometrically Sika catchment is elongated with a bulge in central part extending to 6.82 km width from north to southward, and 14.20 km length from east to west is the fardest extension occupying a area of 48.52 sq.km. The northern and north-western margin is associated with the Subansiri Basin, while in the east, south-east lays the Siri catchment and towards the south, south-west lies the Sido catchment.

3. Siri Catchment: The shape of Siri catchment is rectangular with Subansiri basin in the northern periphery, toward the east and south lays the upper reach of Moridhal basin, towards the west and south-west lays the Sika and Jia catchment respectively. The Siri has a perimeter of 66.54 km with highest length of 20.71 km of east to west and 11.56 km of north to south extension comprises a drainage area of 176.30 sq. km.

4. Jia Catchment: The south central part of the upper Jiadhal basin lays the Jia catchment with a perimeter of 35.32 km. Geometrically Jia catchment is elongated north to southward with a highest extension of 11.80 km and 7.12 km of highest width in the central portion. Jia catchment occupies an area of 35.29 sq.km. The northern point of Jia catchment lays the tri-junction of the three catchment viz. Sido from the west, Sika from the north and Siri from the east. The southern portion is submerged with the Lower Jiadhal basin like a peninsula.

Environmental Problems

The Upper Jiadhal Basin is occupied by the rough and lofty mountain ranges with deep down cut valleys with different magnitude of landforms associated with the dynamic fluvial action of a river system during the youth stage of its life span. The rivers are mainly rainfed and the water is naturally occur from springs which are prone to dried up during winters. The rainfall intensity determines the perennial flow, as the rainfall in summer and monsoon season is more. Thus the river system is activated in the upper basin even by a small surface runoff. The unavailability of rain water in winters reduces the stream flow to null in many initial streams in the headwater catchments of the basin. The irregular stream flow of the headwater is responsible for the high degradation in the headwater areas and the upper catchment in comparison to the lower basin areas. The Upper basin is accompanied by four sub-watersheds and dominated by dense forest cover with less human interference in respect of human habitation but other human activities are prevailing to degrade the environmental geomorphology of the watersheds. The table No.1 below illustrates the environmental as well as geomorphological characteristics of the watersheds and the aspects of management plan to be implemented for the sustainable development of the region. The major concern in the upper basin is the topography and difficult accessibility to upper reaches, as there is no transport facility. Only manual tracking along the river in winter season is the mode of transportation. Therefore the upper reaches are settlement free from human habitation and the agroforestry and lumbering activities are practiced extensively in accessible areas. Apart from the geological and geomorphological characteristics of the basin the deforestation is the prime concern led to issues regarding the activation of sediment source areas, massive landslides, soil erosion, slope failures and subsequent sediment loads in the river which is the cause of frequent floods in the lower basin. The region receives heavy rainfall during summer and cloud burst is common phenomenon, increasing the river flow during rainy season, and in dry season the water level reduces to nominal. The range of water level is extreme which ranges 15-16 meters of height as the recorded data of the Water Resource Department of Dhemaji, Assam.

Table 1. The Geographic characteristics and Watershed Management attributes of the Sub Watersheds of the Upper Jiadhal Basin

Catchments	Environmental aspects	Physiography (%)	LULC	Aspects of Management Planning
Sido	High Intensity rainfall, Cloud Burst, Deforestation, Landslide, Soil erosion, Sediment source region, exposed river slopes.	Piedmont (5), Highlands (35) Mountainous (42), High Mountainous (17)	Dense Forest-69, Degraded Forest-30,	Slope reclamation measures, Afforestation in degraded areas, Agro-forestry
Sika		Piedmont (4), Highlands (11) Mountainous (46), High Mountainous (36), Peak (3)	Dense Forest-69, Degraded Forest-31, Bare exposed-1.	Engineering structure to retain foot loose of slopes, Headwater treatment
Siri		Piedmont (5), Highlands (37) Mountainous (41), High Mountainous (15), Peak (2)	Dense Forest-42, Degraded Forest-57,	Headwater treatment, Slope reclamation, afforestation in degraded areas, Agro-forestry, Horticulture, check dams to control sediment supply
Jia		Piedmont (29), Highlands (36), Mountainous (27), High Mountainous (8)	Dense Forest-20, Degraded Forest-59, Sand-Silt-2, Rural Dev-1, Fallow Land-6, Net Sown-9, Wetland-1 and Waterbody-1.	Slope reclamation measures, Afforestation in degraded areas, Geo-netting of exposed slope

The management of sub-watershed in upper Jiadhal basin is mainly influenced by the physiography and land use and land cover (Table No.1). The largest sub-watershed is Siri with 176 sq.km of aerial extension and the altitude ranges from 100-1400 and above covering 47% of the Upper Jiadhal basin area. The catchment mainly composite of 5% piedmont, 37% highlands, 41% mountainous, 15% high mountainous and 2% Peak with 42% dense forest cover and 57% degraded forest cover which is mainly due to anthropogenic activities. The degraded forest cover are the main sediment source region porn to loose of top soil due to erosion, land slide and footloose phenomenon. The measures recommended are

Headwater treatment, Slope reclamation, afforestation in degraded areas, Agro-forestry, Horticulture, check dams to control sediment supply as it is the highest sediment source of the river system.

The second largest sub-watershed is Sido with 111 sq.km 30% of the upper Jiadhal watershed. It consist piedmont (5%), highlands (35%) mountainous (42%) and high mountainous (17%) with 69% of area covered by dense forest and rest 30% is degraded forest. Slope reclamation measures, afforestation in degraded areas, agro-forestry are some suitable measures for the Sido sub-watershed. Followed by Sika sub-watershed with 49 sq.km and is only 13% of the upper Jiadhal watershed. It has occupied by 36% of high mountainous area followed by 46% highlands compiling it a highly elevated part of the basin with steep free face and V shaped valleys. Sika has only 3% area under peak and 4% of piedmont areas with an elevation range of 60 to1400 meters. The land cover is dominated by dense forest cover compiling 69% followed by degraded forest cover of 31% and bare soil exposed on only 1% of the total sub-basin areas. The measures proposed for its stability is engineering structures to retain footloose phenomenon of the slope to reduce the soil erosion. The degraded forest cover and the valleys need reclamation of headwater treatment to reduce large sediment loosing phenomenon.

The Jia up catchment posses 35 sq.km and only 9% area of the watershed and mainly has high relief alteration comprising piedmont (29%), highlands (36%) mountainous (27%), high mountainous(8%). Of which 20 % is dense forest, 59% degraded forest, 2 % is covered by sand-silt, 6% is fallow land, 9% is net sown and only 1% of rural dev. area, wetland and water body. It is to southern part of the drainage basin and highly prone to peak flow in rainy season and thus prone to massive erosional due to high velocity as well as heavy sediment load. The aspect of management plan are slope reclamation measures, afforestation in degraded areas, geo-netting of exposed slope to retain sediment loose and landslides.

Discussion

Proposed Planning Strategy

The upper basin area is mainly dominated by the mountains mainly associated with geomorphic processes and resultant landforms. The drainage in the upper basin are not perennial as the streams are mainly associated to natural springs and which went dried up in season of less rainfall. The situation could be basically categorized on the basis of its nature of land strata, landform and river morphology concerns to each river system prevailing.

1. The Sido Catchment

This sub-watershed is associated with deep valleys with steep side walls accompanied with series of fault lines and liniments. These areas are also the sediment source in the watershed, which reflects its fragile condition and thus the sediment load in the river is more. Up to 6 kilometers above the tri-junction the river deposits is dominated by sand bars, pebbles and grabbles associated with big boulders, which reflects that the lower course of Sido is associated with broad river course. The upper course of Sido is narrow and deep valley associate with vertical side walls and the practice of river deepening is active in this section. The tributaries to Sido are natural springs and associated with deep free fault lines bisecting the mountain ranges.

Management Plans: The vegetative coverage plays an important role in the stability of the slope as well as controlling erosion of river course. The deforestation in the name of agro-forestry and lumbering decreasing the vegetative coverage of the area, which led the soil exposed to external forces for extensive erosion associate massive landslides and mass wasting. The side walls of the fault lines are prone to erosion thus the weaken structures should be accompanied by spours and check dams so the toes loss phenomenon could be checked. Terrace and contour plantation will sustain the slopes from mass-wasting and low sediment discharge due to rich vegetative coverage. The tributaries contributing much more sediment have been identified and mini- watershed management plans could be the best option for its sustainability.

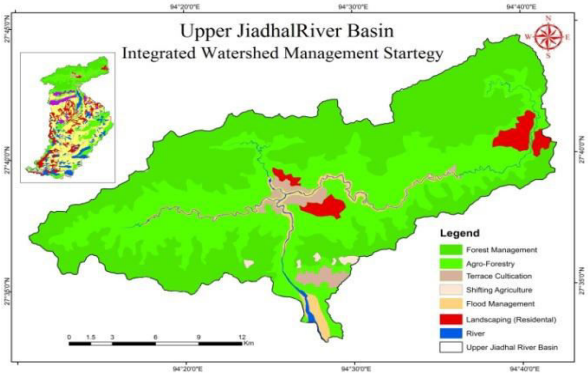

Fig.2: Integrated Watershed Management strategy for Upper Jiadhal River Basin

2. The Sika Catchment

The sub-watershed is characterized by the narrow stream channel in the upper course and associated with Rocky River bed, which reflects that the Sika sub-watershed has potential of high sediment yield due to fragile mountain system. The river course of the Sika is free from fine grained sand deposits mainly with boulders and big sized grabbles and low sand along the river bed. Thus, Sika is a contributor of course sediment load to the main stream.

Management Plans: The fragile structure of the mountain system in the upstream part of Sika sub-watershed is the most vulnerable and high sediment source area and prone to erosion mainly in the south facing slope of the basin. The Check dames would regulate the down cutting of the Sika, while the foot loose problem of the slope could be checked. The Sika is free from fine sediment load so the river produces less suspended load.

3. The Siri Catchment: This sub-watershed of upper Jiadhal River basin is the longest and largest tributary of the tri-junction to form Jiadhal. It is associated with tremendous fine sand deposit along the river bed as well as the side of the meander points through the river system up its upper ridges areas where it flows along deep gorges with less width and depositional features. The tributaries to Siri is accompanied to Joints and Fault lines in the mountain system yielding great amount of sediment load ranging from fine sand and silt to boulder to the main stream. The steep and free faced side wall reflects that the river deepening is extremely pronounced in this section. The terraces along the river course reflects that the river is turbulent as well as erosive so its river course get modified in times due to the characteristics of the geological structure of the area.

Management Plans: Siri basin is associated with larger basin area and thus contributing the highest sediment loads to the main stream. The river gorges of Siri are free faced with less vegetation coverage yielding great sediment loads. The land use in the lower terraces of the basin should be managed so that even in submergence in water in rainy days the soil didn't erode. The river meanders and point bars along the river course have tremendous fine sand deposits are vulnerable to erosion in peak flow. Check dams with boulders across the river could manage the siltation of the river bed and check the sediment load flow (Fig .2). Forest conservation, agroforestry are the basic measures to control the environmental geomorphology of the upper Jiadhal basin. Landscaping includes residential areas, but as the entire basin is free from human settlement, these sites are projected to be suitable for settlement in regards to its accessibility from either side of the basin (Fig,1).

4. The Jia Upper Catchment: This sub-watershed is located south of the tri-junction which is associated with deep gorges and narrow river width ranging 12-15 meters. The river sides are steep side wall and are free from vegetative coverage and composed of large sedimentary rocks. The vertical side has rich coating of mosses and grasses which keep the soil unexposed to external elements, but the natural structure of faults and weathering is pronounced and the slopes are prone to mass wasting, landslide and rock fall.

Management Plans: The Slope failure and soil the resulted erosion is common in upper Jia, as the river is a trance-mountain, it flows through a narrow and deep gorge across the southernmost range of Arunachal Himalayas. The mountain is composed of large sedimentary blocks and associated with conglomerates. The tributaries to Jia cuts deep gorges to reach the main stream and produces high sediment load in form of big to small boulders, conglomerates and course to fine sand. Deforestation in the upper catchment should check to improve surface runoff and infiltration of water to ground aquifers. Slope treatment in the gorges could be possible from geo-netting and retreating walls in vulnerable sites to erosion. Series of check dam could reduce the stream sediment flow and raise the stream depth, which will restrict the stream sediment and foot loose phenomenon in the river banks.

Conclusion

The watershed management of the upper catchment areas of a river basin is more or less dominated by the nature of environmental surroundings, including land use and land cover as well as the physical and hydrological characteristics for the region. The prospects of catchment development are possible with a collective effort of the both government the Arunachal Pradesh and the Assam counterpart. Measures for the environmental problems are needed to be furtherer studied in scientific way and management processes could be incited with the mass participation of the stakeholders involved for the sustainability of the Jiadhal River basin both upper and downstream areas.

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