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Assessment of land-use patterns in Mangla watershed through GIS and RS: A case study of Kanshi river basin, Pakistan

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Abstract

Land-use of an area generally and watershed area specifically is important for sustainable development and natural resource conservation of that particular area. This research was conducted focusing on the importance of land-use practices in Mangla watershed for the assessment of its impact on land and water. For this purpose, mostly social research methods were used, along with a part from quantitative research methods for which satellite images of study area were analyzed using Arc GIS 9.2 and Erdas imagine 9.1. During the field visit, data was collected through questionnaire, interviews, observation and arranging seminar with local youth. Major issue related to land-use practices found in the study was anthropogenic activities. Extensive agricultural practices, population growth, settlement and brick industry have significantly affected the land and water. Deforestation occurred in the past for agriculture and timber needs which has changed the vegetation condition and hence rain fall patterns. It is highly recommended to pay attention to the Kanshi river basin for better land and water resource management to reduce impact of anthropogenic activities. Further development in watershed area, improper agriculture practices, unplanned settlement and deforestation should be completely banned to stabilize the ecosystem. Water harvesting structures should be constructed to fulfill the needs of local community for agriculture and domestic use.

Keywords: Anthropogenic activities, Climate change, Social research, Hydrology, Urbanization, Ecosystem.

1. INTRODUCTION

The Mangla dam was built in 1967 across the Jhelum river and is located 60 km south-east of Islamabad, Pakistan. The water storage capacity of the Mangla dam was 725,004 million cubic meters (mcm) at the time of construction, but now the water storage capacity has reduced to 585,675 mcm. The sedimentation rate is so great that the reservoir has lost 19.2% of its capacity since 1967 because of poor Practices in the catchment areas [1]. The deposition of sediments in Mangla reservoir is increasing which threatened to block free flow between main stem and storages in the side arms. Gross storage capacity of Mangla dam is lost about 20.54% [2].

Land-use is considered by the measures, actions and contributions of people commence in a certain land cover type to produce, change or sustain it. This definition of land use creates a direct link between land cover and the actions of people in their environment [3]. Land-use change is one of the most important indicator in understanding the interactions between human activities and the environment. Although both natural and anthropogenic factors are responsible for land use/cover change, the human modification in land use/cover round the world has recently appeared as unprecedented, profoundly affecting the earth's ecological systems. Information regarding land-use provides spatially defined facts for management of land at national and global levels, typically in the context of climate change, degradation of land, poverty elimination, food security and management of natural resources etc. Moreover, the problems related to water balance could be identified by studying the general land use practices of the watershed [4]. Land-use changes have possibly huge effects on water resources, yet measuring of these impacts has been the more challenging problems in hydrological patterns. Major changes are occurring in land use not only due to pressures for more efficient production of food and fiber to support growing populations but also due to policy shifts that are making markets for biofuel and agricultural carbon appropriation [5].

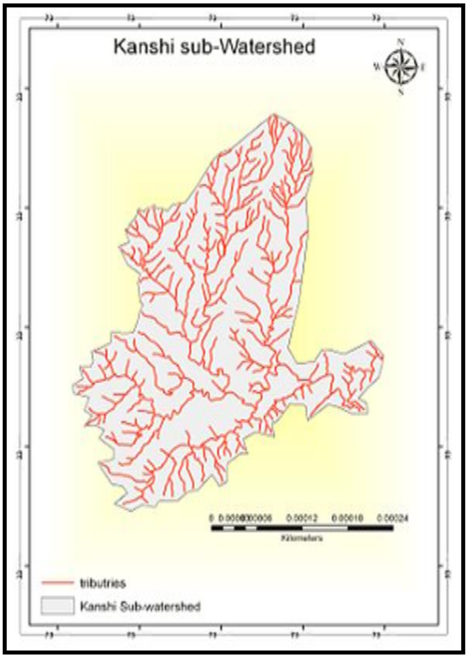

Fig. 1. Map of Kanshi river basin

Considerate the linkage between land use and water quality is important for effective management of water, both recently and in the future time [6] [7]. The quality of freshwater depicts the combined effects of numerous natural processes and the anthropogenic changes of land use [8] [9]. Runoff from watershed areas into water resource is the main cause of nutrients and contaminants [10]. Changes in land use can also disturb quality of water by large-scale change of sediment budgets [11] [12]. Land use change can cause the degradation of soil water, groundwater, and surface water [13]. Mountain ecosystems respond to climatic changes quickly. We have clear signs that fluctuations in temperature lead to enhanced ice melting and snow and have an effect on biodiversity, supply of water, agriculture pattern, and hazards of climatic variations; and that these belongings will in turn have an influence on broad human wellbeing. The delicateness and unapproachability of the mountain countryside, with dispersed settlements and poor infrastructure development, indicate the mountain areas are suffering the most. Increasing demands on ecosystem goods and services from the mountains are putting pressure on the natural resources that they contain [14]. This study presents the various aspects of land-use changes in the Kanshi river basin and discusses their impact in details.

2. WATERSHED AREA

Kanshi watershed is sub-watershed of Mangla watershed which is situated in tehsil Gujjar Khan and tehsil Kahuta of Rawalpindi district. Har, Kurri, Missa, Guliana, Phahna, Gulin streams and some other small streams of Kanshi which after joining Kanshi drain into the Jhelum River at 33°14'54.59"N Latitude and 73°36'24.21"E longitude. Map in fig. 1 shows the delineation of Kanshi river and its tributaries. Kanshi River originates from Kahuta and Gujar khan. The Kanshi sub-watershed is delineated from the topographic map of Rawalpindi. Mostly the watershed is situated in Potohar region. It’s the only sub-watershed of Mangla which is situated in Punjab. Gujjar khan and Kahuta are highly erodible regions.

3. MATERIALS AND METHODS

The present study was designed to map and classify present land-use of Kanshi sub-watershed and to assess the role of climate change & anthropogenic activities in disturbance of present land-use and water resources. The study was divided into four phases. Phase 1 involved arrangement and collection of data from relevant authorities e.g. study area maps, satellite images, development patterns, hydrological and geological data, soil formations etc. In phase two, the collected data was analyzed using Arc GIS 9.2 and Erdas imagine 9.1 software. Phase three involved the field visit of study area and interaction and interviewing the locality. A detailed questionnaire was prepared by keeping in mind the possible issues which came out during literature review and data acquisition. Most of the questions were related to land-use, climate change and socio economic conditions of local area. After those three stages, critical analysis of the collected and analyzed information and observations was carried out to point out the key problems and suggest some feasible solutions. Flow chart in fig. 2 shows the steps of research methodology adopted in present study in sequence.

Fig.2. Research Methodology

4. ANALYSIS, RESULTS AND DISCUSSION

In this section various aspects of land-use changes in the study area are discussed in details. First changes in land use patterns and vegetation cover are presented and major hazards and risks associated with the watershed area e.g. flash floods and soil erosion etc. are described. In addition, impact of anthropogenic activities like urbanization, agriculture practices, environmental (air, soil and water) pollution and deforestation is also discussed in details. Finally, hydrology of the study area is also considered in this research.

4.1. Land Capability and Land-use (Past vs Present)

The past land capability map of Soil Survey of Pakistan classified the land of Gujar Khan in to five categories according to land capability potential. According to the land-use map, there were mainly dry farmed lands, rough grazing land, predominantly unused land, predominantly dry farmed land, well- irrigated and dry farmed. The map in fig. 3 shows that mostly there was predominantly dry farmed land followed by moderate predominantly un-used land. Third major land-use was well irrigated dry farmed land and minimum land was used as rough grazing land and un-used bare land.

After the digitization of present satellite images, many land uses were identified. In order to verify the real condition of the study area, a field visit was conducted for ground truthing to exactly identify the features which were seen on digitized map. It was surprisingly found that the condition on ground was contradictory in the sense of features observed on digitized satellite image as most of the area was presenting the different overview as compared to the satellite image. Following the findings of the ground truthing and the digitized land-use map was updated to represent the actual ground conditions which is shown in fig. 4. It was observed that, as compared to past, the increasing urbanization was a common problem. In addition, brick business was a hot issue and caused soil degradation. Moreover, vegetation is only remained near water bodies' e.g. nallahs, ponds or small water storage structures etc. The water table was also found to be falling down with tremendous rate. All these issues are discussed separately in the following sections.

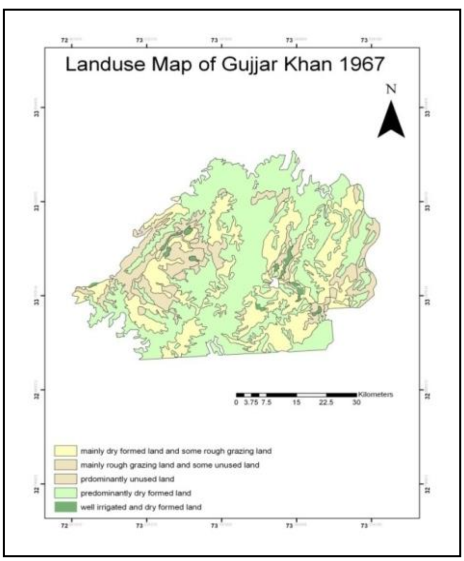

Fig. 3. Land-use of Gujjar Khan in past

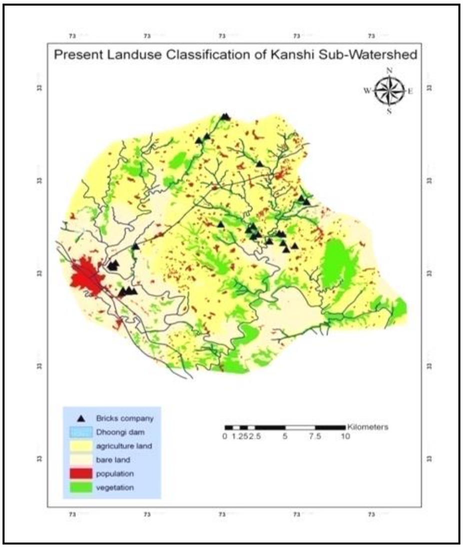

Fig. 4. Present land-use of study area

Source: Prepared on Arc GIS 9.2 from 10x10 meter resolution satellite image taken from a private organization "Jers"

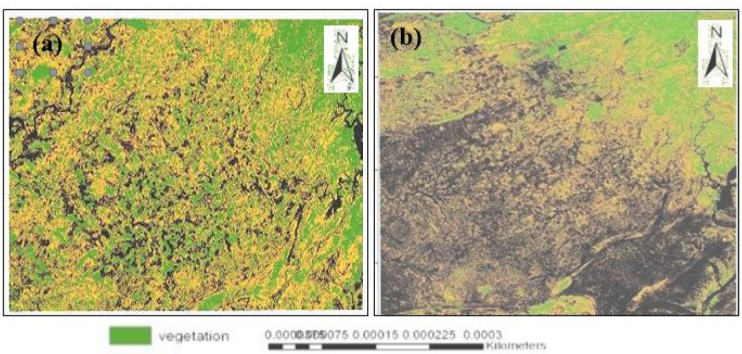

Fig. 5. Vegetation cover (a) Past (b) Present

4.2. Vegetation Cover (Past vs Present)

Comparison of vegetation covers was made based on the accessible data. Fig. 5 shows the satellite images (Landsat TM, 30x30meter resolution) of study are in past (1990's) and present (2000's). It is clear from the figure that the overall change in the vegetation cover is tremendous. The vegetation cover is almost vanished from some of the city areas or minimized up to dangerous level. The total Kanshi catchment which is situated in Gujjar Khan and Kahuta has lost a larger part of its vegetation. The main Gujjar Khan City including surroundings have also considerably lost the vegetation cover which is the result of urbanization, population, settlements, extensive agriculture and deforestation. By now the vegetation is only remained near water bodies. The areas which are near Mangla dam are rich in vegetation cover due to favorable conditions.

Mismanagement of resources and de-forestation are also major causes of vegetation cover loss. Agricultural practices have increased in the area and land is being cleared for farming during last two decades while no attention towards the management of the watershed is being paid. The change in vegetation cover has resulted in soil erosion and increased sediment ratio into Mangla reservoir affecting its capacity and production. Another cause of vegetation loss which is not out of consideration is the changing climate. Unexpected and uncertain precipitation conditions during last two decades have also contributed in loss of vegetation cover.

4.3. Hazards and Risks

The study area is highly vulnerable to the flood and erosion hazards in monsoon (rainy season) periods. During the rainy season the run-off causes flooding in the areas joining the streams. These floods erode the soil and stream banks and carry sediments to the Mangla reservoir. There are almost all types of erosion found in the area. Rill and Gully erosion is most common type of erosion. Survey results showed that most people are in opinion that the precipitation run-off is the reason of this erosion. However the brick industry, settlements, and wrong agriculture practices are also responsible for the erosion.

4.3.1. Flash Floods

Research area is at higher elevation and slope is steep. In the months of June and July, the permanent wind drift enters in to the area and cause high precipitation which results in high runoff so the flash floods occur in this area which wash away whatever comes across their way. As discussed before, lack of vegetation cover is also one of the major causes of flash floods in this area. According to field observations, no engineering structures are developed to reduce the water velocity in order to minimize erosion and sedimentation hazards. Only one retaining wall was observed near Missa-Keswal region. Reasons of this mismanagement are the cost, absence of institutions and negligence or relevant authorities. Even construction of small scale structures cost millions due to the transportation issues at these elevations.

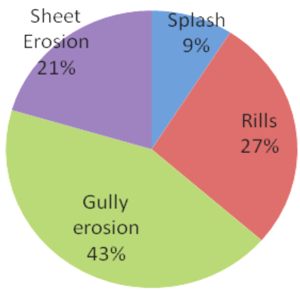

Fig. 6. Type of erosion observed in the study area

4.3.2. Erosion

Erosion is dominant problem because of soft geology, steep slope and higher elevation. Hydraulic gradient is also high and as a result erosion hazards are increased in greater extent. The common types of erosion in the study area are shown in pie chart in fig. 6. Gully and rill formations are most common types caused by issues mentioned above. This soil erosion results in loss of top fertile layer consequently many acres of unproductive land.

4.4. Impact of Anthropogenic Activities

Impact of anthropogenic activities related to land-use practices is a one of the most critical issues to be studied in detail. The present data and ground facts and figures support the impact of anthropogenic activities on the study area resulting in the climatic variations and other related hazards. Land-use practices are the result of human activities such as urbanization, agriculture, developments and deforestation. Results of survey also showed that 85% people are in support of the opinion that the change in overall climate and land-use is the result of anthropogenic activities. Others said that it is the natural process of changing and it will continue in the same way.

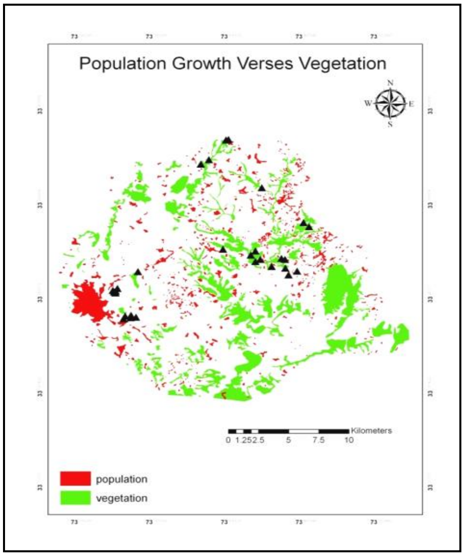

Fig.7. Population to vegetation ratio in the study area

Source: Prepared from the satellite image using Arc GIS 9.2

Anthropogenic activities are accelerating and disturbing the natural processes and local ecosystem. Urbanization is one of the major factors which is mainly responsible for the use of bare land. People are attracted towards urban areas. So, settlements pattern are congested and population growth rate is high in cities. Comparatively, in rural areas, the population is scattered with low population density per unit area and its growth rate is also low. The main reasons for dense population in urban areas are education, health, water, sanitation and livelihoods opportunities. Fig. 7 shows the vegetation and population ratio of study area at the time of study. The vegetation cover is decreasing at high speed and the population is growing fast, resulting in increased agriculture and construction activities. The balance between population and vegetation cover is disturbed.

Since currently there is no source of storing rain water so the water table is falling down. The whole area is rain fed and mostly receives water from monsoon rains. The water table is also decreasing because surface water resources are not enough for the local community and they are totally dependent on ground water. Extensive wrong land-use and agricultural practices are source of land degradation and sewage waste disposal into the streams is severely contaminating the water. Although the soil is naturally fertile but due to the lack of awareness among formers they can't obtain high yield from the crops. Therefore, they use a large amount of pesticides, insecticides and fertilizers to improve their production which also cause the natural resources degradation. During rainy season, these chemicals are drained into the nearby streams along with the rain water and increase water contamination. All the domestic and sewage waste is also discharged into the close by streams. So, the water quality of the Kanshi River is not so good.

The forest cover is almost depleted due to deforestation which is also responsible for soil erosion. Along with all these reasons urbanization, developments, roads and other infrastructure are increasing, as a result land-use of study area is being disturbed. Consequently, anthropogenic activities are contributing a large part in the disturbance of natural process and local eco-system.

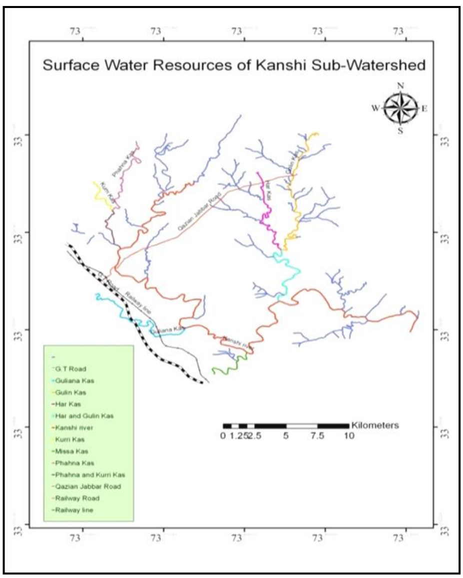

Fig. 8. Main Kanshi River and its stream network in study area

Source: Prepared on Arc GIS 9.2 from satellite image

4.5. Hydrology

Kanshi River flows in a southerly and then in an easterly direction to join the river Jhelum. There are six main tributaries of Kanshi River namely Gulin, Guliana, Kurri, Phahna, Har and Missa which finally drain into the Kanshi River (Fig. 8).

The maximum discharge occurs in July, August and September with a subsidiary peak early in the year as the result of winter rains. The flow in Kanshi River is seasonal. Due to deeply incised nature of river ground water over most of research area is mainly derived from precipitation. Lower level of river course in comparison with the general land surface prevents infiltration of river flow to general water table. Where the ground water is lower than the riverbeds, it does not recharge from surface flow when it occur. .The water table of Kanshi watershed is very low and ranges from 80-300 feet.

4.5.1. Ground Water

Ground water is the main source of fresh water for domestic use but the water table is very low throughout the study area and due to its drilling cost it cannot be used for agriculture purposes. The water table varies from zone to zone due to water availability conditions on surface, varied topography and settlement patterns. Figure 8 shows the typical water table depths in different zones of study area. The water table of Qazian zone is observed approximately from 150-200 feet. Water table is found between 100-120 feet in Dongi zone. Some of the wells in Dongi zone have the water table at 80 feet. Water table in Missa-Keswal zone ranges from 250-300 feet along the rail track up to Sohawa and found 120-130 feet in Guliana zone.

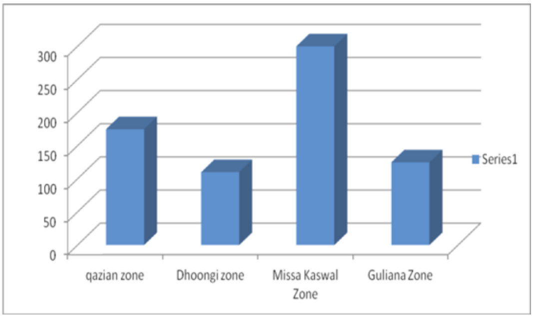

Fig. 9. Shows the variation of water table in study area

5. CONCLUSIONS AND RECOMMENDATIONS

Land is most important of all the natural resources and unique, being the mother of all resources. A healthy watershed needs a healthy environment and a healthy environment needs a healthy land. Therefore, the landuse of any area generally and of watershed area specifically should be managed & well planned. It is observed in the study area that there is no participatory approach among different stakeholder of landuse and authorities as well. Due to the lack of mutual co-operation and participation the issues related to land and water are same as they were in past decades.

More and more land is being converted into agricultural land which causes severe soil erosion problems as the topography of the study area is not stable. As a result of population growth, settlements are increasing faster. Hence, the agricultural land is being converted into settlements and bare land to agriculture. Soil degradation and water contamination is important issue because of increasing brick business, agriculture, settlement and lack of vegetation cover. The waste water of the whole area is drained into nearby channels, contaminating the water quality. Lack of water harvesting structures are resulting into low yield agricultural practices and high drop of water table thus the socio-economic condition of common people is getting poorer. Forest clearing and lack of institutional involvement for betterment of environment is causing severe environmental issues like uncertain rainfalls or temporary drought conditions. These conditions have significantly affected the discharge of Kanshi River. Anthropogenic activities are disturbing the natural eco-system badly.
It is strongly recommended to ban the further unplanned development and infrastructural measures related to landuse and especially, the bare land should no more be used for agriculture purpose and settlements. As an incentive the present agricultural land should be subsidized for cultivation. From management perspective there is a need for institutions to participate for the betterment of local community and natural resources. An integrated approach with the participation of community is required to solve the local issues and to sustain the natural resources of watershed. Capacity building and trainings of locals especially youth is suggested on urgent basis so that upcoming generation may understand the responsibilities of being a watershed community.

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