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# Impact of Climate Change on Forest Cover: Implications for Carbon Stock Assessment and Sustainable Development in HKH Region-Pakistan

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Nowadays, climate change is the global phenomena and extensively resrached worldwide .However, it is agreed upon to be caused by both natural and anthropogenic drivers such as land use changes, deforestation, green revolution, industrialization and consequent globalization. This study focused on Swat valley, Switzerland of Pakistan in the Khyber Pakhtunkhwa (KPK) province, Pakistan. Geographically, the Swat valley is located in the Hindu Kush-Himalayan (HKH) region, which spread over an area of more than 4.3 million Sq.km. The current research relied on meteorological 36 year dataset from1980-2015. In order to find out the spatio-temporal changes in forest cover, the image classification was used. The results indicate that the forest cover observed declined by 16.3% in first five years and 5.5 % in last five years. The total forest covered area in the year of 1981 was 1316 Sq.km which reduced to 1067 Sq.km and 714 Sq.km in the years of1998 and 2015 respectively. Similarly, Carbon dioxide (CO<sub>2</sub>) emission in 1981 was 0.336 metric tonnes per capita, followed by 0.929 metric tonnes per capita in 2015.Moreover, due to climate change and human induced activities, forest cover is decreasing with the passage of time with increasein Carbon dioxide emission whereas, soil erosion and desertification has also shown increasing trends. The negative effects of the forest cover changes have been observed through an increase in the Carbon dioxide emission. From 2000 to 2015, the forest area observed to the decreasing trend. During the same span, the deforestation found to increase. The trend of the precipitation observed to be declined.The logical evidence and Geo-environmental database are the basic components to control forthcoming challenges of local

and regional climate changes and thus a sustainable forest development.

Climate is the average weather over many decades in any location. Climate change refers to any statistical significant and persistent change in the mean state of the climate over the long period of time. Climate variability may refer from natural internal processes within climate system or from variations in natural or anthropogenic external forces. Recently, the world pass from the alarming condition of the increase the temperature at the rate of  $0.128 \pm 0.026$  °C per year for the period of 59 years (IPCC, 2007a). This increase in temperature leads towards the concept of global warming. Currently, Pakistan is also facing such severe problem of the climate change which, appears to be rising the temperature substantially (Abbas et al. 2018A). Climate has intrinsic variability and has been changed in past decades. Climatic and its results from natural variability and anthropogenic changes in climate which impacts to vulnerability of human and natural systems (IPCC, 2012). Paul et al. (2011) reported that the temperature of the earth is increasing due to increase in concentration of  $\text{CO}_2$  in the atmosphere and change in land use practicing. This increase in temperature indicates adverse impact on our earth. Similarly, Copeland et al. (2010) reported that mostly our climate change occurred due to changes in vegetation pattern and deforestation. The temperature and rain have an adverse impact on the land use patterns. The soil erosion caused by the extension of the extensive agricultural practices, soils is eroded by the water and wind circulations. Such erosion decline the fertility of the soil with respect to elevation. This will damage the soil properties and deforestation (Benediktas, 1994). Mango et al. (2010) has found that current climate change situation in the world has made population more vulnerable and uncertain to future of this planet .Due to increasing understanding of climate change situation and its implication for security, trade, the ecosystem, economy and the human and other species well-being, it attained top priority around the globe at the level of business, community and government.

The flow of the water from the peak and erosion is the basic reason of the conversion of agricultural land through forest. Grimm et al.(2008) stated that variations in climatic patterns are chiefly communal in emerging states; similar land use/land cover variations are produced by persistent socioeconomic development, leading to consequences such as ecological degradation and substantial landscape disintegration. The related environmental variations have so far been diverse in forests covering particular areas. Lately, the human variations, which have been characterized as extraordinary, have forcefully affected the earth's environment and ecosystems (Lambin et al. 2001). Zhaung et al. (1999) described that the agricultural area declined due to increase the trends of urbanization and anthropogenic activities. Ahmed et al. (2007) stated that due to phenomena of climate change, the human based activities on the earth system affected. It's become challenging for human because due this our socio-ecological mobility in the ecosystem. The threat of climate change can be coped with by

identifying its effects on different socioeconomic sectors of the country. Substantial efforts have been made to establish reliable and accurate records of surface air temperatures of the region (Singh and Sontakke, 1996; Abbas et al. 2018b). The emission of various types of the gases into ecosystem directly affecting the land covers parameters, components like forest cover, soil fertility and agricultural land. It is increasing the risk to human health (Serageldin, 2006). The most important challenge is the climate change in the ecosystem of the 21st century (Crutzen & Stoermer, 2000). The environmental researchers and scientists forecast that similar rate of the depletion of natural resources may cause the catastrophic failures (Steffen, 2004). There are many types of climatic drivers that have the multi-faceted. The soil textures of the Swat district are gravely to gravely, sandy loam and stone, sandy loam and rocks were fine grained and igneous types (Nawaz, 1987). The seven classes of the forest in the Swat district ranged from tropical deciduous to alpine. Many reports in Swat have been published about the medicinal species. According to such reports, it has approximately 1550 species of flowering plants and 56 Pteridophyte. The most area of Swat consists of Flora and Fauna. The 93 plant species are threatened in Swat, which contributes 8 % of the total plant species. Whereas, 11.5 and 7.5 % observed vulnerable and rare species respectively in the Swat valley (Shinwari, 2000).

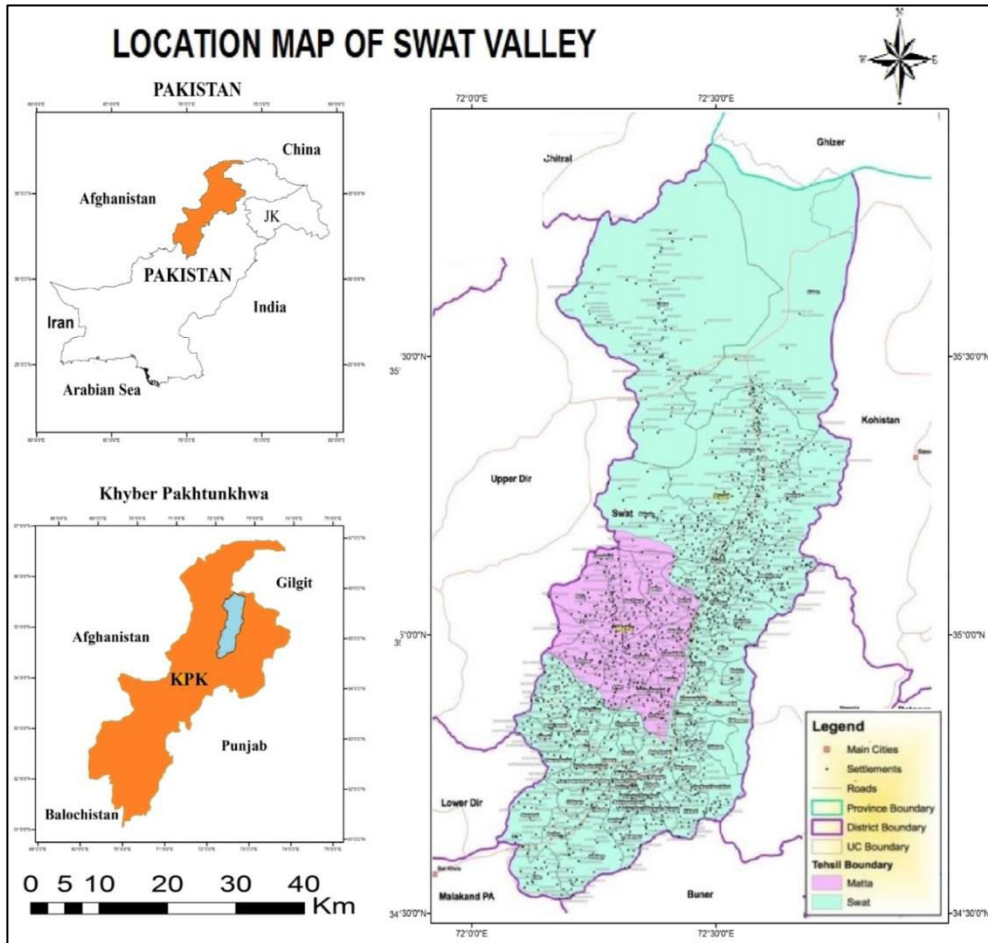
The study highlighted the high rate of environmental degradation by the increasing trend of deforestation in the Swat valley and land converted into the agricultural sector (Khan, 2009; Von Mirbach, 2000). The study of land use change dynamically recorded a significant decrease in forest resources in Kalam, Malam Jabba and Barikot regions (Qasim et al. 2013). Similarly, a study conducted in the Kumrat valley, which lies in the Upper Dir district and borders the study area on the western margin reported a 100 % increase in agricultural land (Ahmad and Nizami, 2015). The trend of deforestation increased due to land conservation for agriculture in the lower of Swat valley. Moreover, pasture face threats due to the increasing trend of overgrazing (Ilas, 2013; Ilyas et al. 2011). Reduce emissions from deforestation and forest degradation (REDD) carry out different types of risks for national and regional population. The Land covers changes in different areas of Swat valley depending on the socioeconomic and ecological conditions. The main objectives of the study is to estimate the forest coverage area from 1980-2015 and the effects of the climate on the forest cover area. Furthermore also to identifying the trend of carbon dioxide emission during different time slots in Swat, Pakistan.

## **2. Material and Methods**

### **2.1 Study Area**

The Swat district is the part of the Khyber Pakhtunkhwa Province. It is situated in the Malakand Division. Swat lies in the north-west of Pakistan (Figure 1). The Swat valley bordered by the Chitral in the northwest region, Gilgit district located in the north-east, Shangla in the east, and Malakand division in south-west direction. According to Physiography, Swat valley has a hilly terrain with elevations ranging from 682 to 5821 meters that continuously remained above the

mean sea level(msl) because of mountainous nature of the area form south to north inHindu Kush mountain rangeand its foothills.



**Figure1.** Study area map of the Swat valley

The region naturally covered with Swat River. This valley consists of the forest cover, fruits, terracing and the agricultural land. The Green Valley of the Swat is wealthy in special species like the flora and fauna. The population census organization deliberated (2017) that the total area of Swat district is 5367 km<sup>2</sup> and population density is 430.4 per km<sup>2</sup>. However, total population of Swat 1.2 million around, while average annual growth rate is 3.37. Due to intense population and urbanization trend and the coarse texture, it is less cultivated.

According to Development Statistics of the KPK(2014) population growth rate was low as compared to 2017 census due to high migration towards urban areas for better livelihood prospects. In the context of climate, the Swat valley lies in the temperate regime. The short season is the summer in the Swat. The cool climate observed in the northern part of the Upper land area of the valley. June is the

warmest month with maximum and minimum temperature of 31.55°C and 26.70°C respectively. January is the coldest month maximum and minimum temperature of 10.5°C and 6°C respectively. The snowfall occurred in the winter season, which is extended from October to March. The winter season is much rely on the rainfall (mm) as compared of the summer season.

The *Balochistan* province is the driest part which receives 210mm on the average. Three-fourth part of the country receives rainfall less than 250mm and 20% of it receives 125mm. Pakistan has four well marked seasons: Cold, from November to February; Pre monsoon (Hot), from March to mid of June; Monsoon, from mid of June to mid of September; Post-monsoon, from mid of September to October. Winter season is harsh. In the context of climatology, Pakistan receives monsoon rainfall in summer and in winter receives rainfall due to western systems. Most of the country is arid to semi-arid except southern slopes of Himalayas and Sub Mountain region where the annual rainfall ranges from 760mm to 2000mm. Summer season is extremely hot and the relative humidity ranges from 25% to 50%. The Day-time temperature in this season remains 40°C and beyond in plain areas. The average temperatures in winter range from 4°C to 20°C.

## **2.2 Data**

The present investigated data which include time series on the list of precipitation, temperature, total forest area and carbon dioxide emitted during the period of 1980 to 2015. The mean serial-time series data of accessible variables were included in the investigation. The main secondary data to investigate were included KPK Development Statistics, Federal Bureau of Statistics, Islamabad, and Pakistan Meteorological Department (PMD). The present investigation was planned to design and categorize the land uses classes in the Swat valley and to enable the observation of the impacts of deforestation caused by natural and human activities on the disruption of the present land-use pattern, forest cover area and water bodies.

Reducing emissions from deforestation and forest degradation (REDD+) is an approach that is developed by the Parties to United Nations Framework Convention on Climate Change (UNFCCC). It creates and establishes a financial value for the carbon stored in the forest sector to reduce emissions from the forested land sector and invest in low-carbon paths to sustainable development. The forest degradation increases the mechanism of the Reducing emissions from deforestation and forest degradation. After the forest cover area observed during the investigated period, the carbon stock measurement becomes reliable for the analysis. The supervised classification method used for the measurement of the land utilization area. Such investigation and focus of the current study is splited into steps mention in the Figure 2.

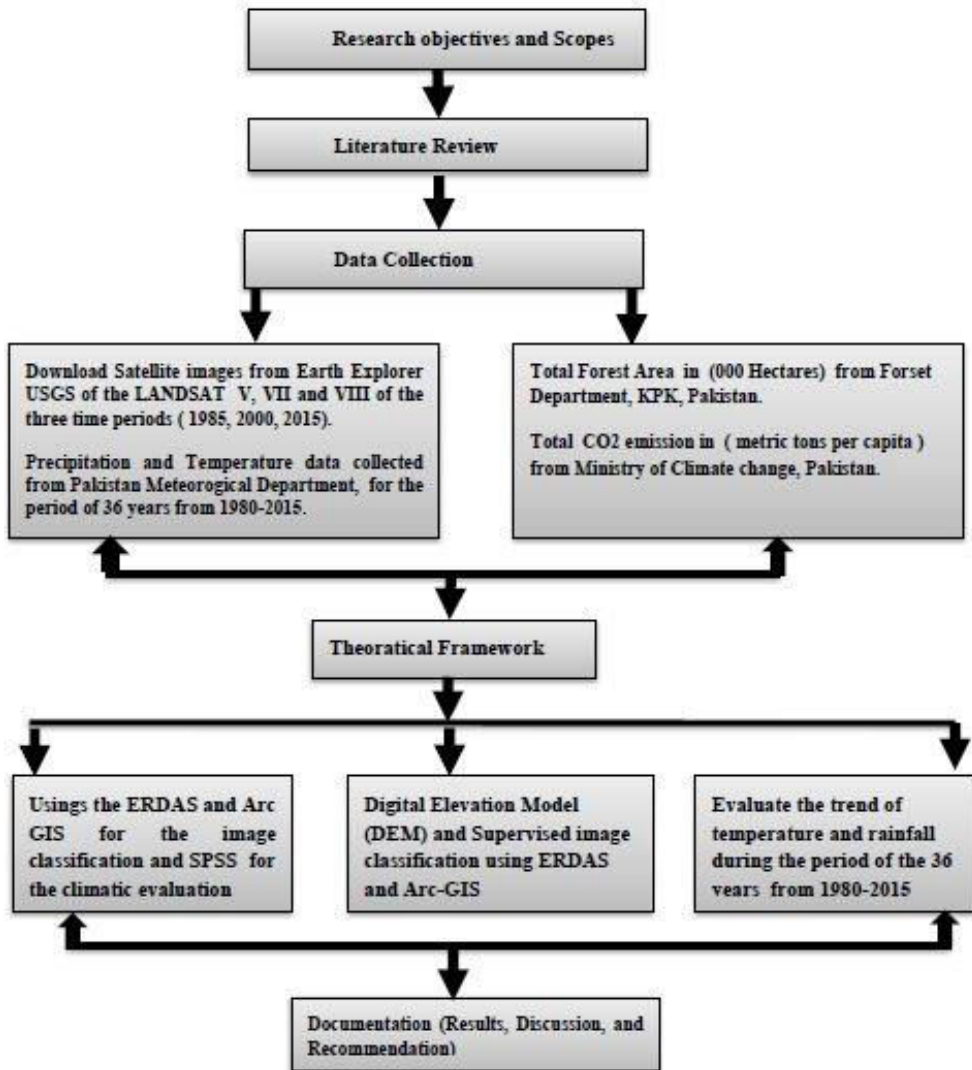


Figure 2. Flow chart of the research

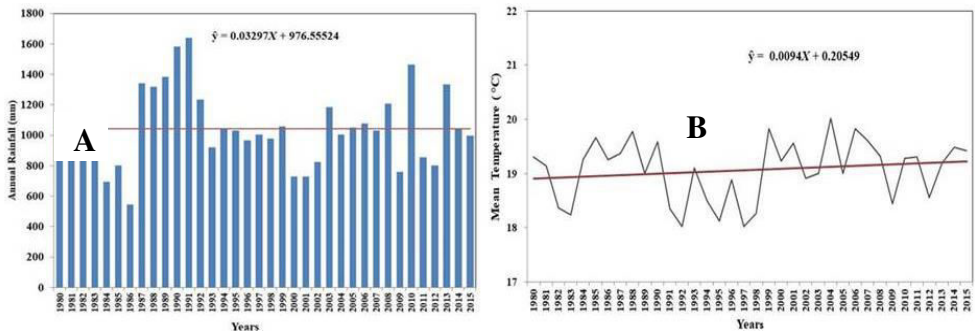
### 3. Results and Discussion:

#### 3.1 Annual trends of rainfall and temperature over Swat Valley

The highest average rainfall recorded in summer is about 102.5 mm in 1991 is much more than 60.53 mm in 2001. Winter season in Swat valley is harsh. The severe climate variability varies from December to March with the annual mean minimum temperature is 6°C. The winter season is the consistent for the rainfall (mm) as associated to the summer season. The highest annual rainfall observed 342 mm in the 1991. Precipitation in the winter season is known as the sporadic, which

is also known as Jarai at the local level. Sometimes, Snowfall has also taken shapes thunderstorms from mid-January to the end of February.

Figure 3A presents the decreasing trend of Precipitation over the long term in the Swat valley. The investigated datasets duration (1980-1986) is decreasing the precipitation. While, from 1987 to 1991 precipitation observed decreasing. The results also showed the increasing trend of the precipitation from 1992 to till 2001. After that from 2002 to till 2008, trend is found increasing. On detailed examination, it is found that trend of precipitation in the Swat valley increasing from 2009 to 2015. After the detailed investigation, it is stated that precipitation in the month of June rainfall found to be negative significant. The maximum average temperature recorded in winter is about 14.51°C in 1988 is much more than 7.69°C in 2012. The highest average rainfall recorded in winter is about 147.51mm in 1990 is much more than 28.76 mm in 2001. The highest average rainfall recorded in summer is about 102.5 mm in 1991 is much more than 60.53 mm in 2001.



**Figure3.** Trend of precipitation and temperature of the Swat valley, Pakistan

Figure 3B declares that the trend of mean temperature is found to be increasing slightly in the Swat valley, Pakistan. The results revealed that mean temperature found to be decreased from the 1980 to 1986. After that from 1987 to till 1991 the mean temperature observed to be increasing. The results also exposed the decreasing trend of the precipitation from 1992 to till 2001. After that from 2002 to till 2008, trend is found increasing. On detailed investigation, it is stated that the trend of mean temperature in the Swat valley decreasing from 2009 to 2015. The trend of maximum temperature is found to be increasing in the Swat valley, Pakistan. The results show that maximum temperature found to be decreased from the 1987 to 1991. After that from 1992 to till 2001 the maximum temperature observed to be increasing.

The highest maximum temperature recorded in the 2001. After the detailed study, it is found that maximum temperature increased in the month of the June. From 2002 to onward, the temperature trend found to be fluctuating. The decreasing trend of the minimum temperature also observed. The results describe that from 1980 to 1984, trend of minimum temperature observed decreasing. The results depict the increasing trend of minimum temperature from 1985 to till 1991. After

that from 1992 to till 2008, trend found to be decreasing in sequence. After the detailed examination, trend of minimum temperature found to be decreased from 2009 to 2015.

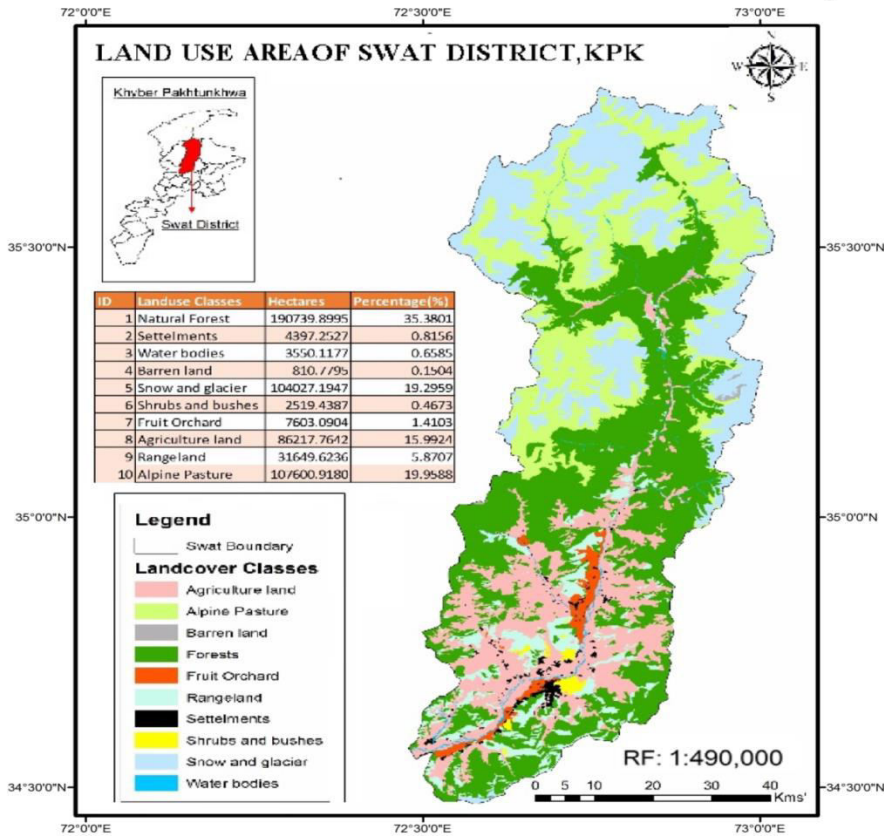
### **3.2 Climate Change and land Cover of Swat valley**

The trend of the forest cover area found to be increased from 1972 to 1988. The results revealed that forest cover area be decreased from 1989-2015. Land use classes included the natural forest, settlements, water bodies, barren land, snow and glacier, shrubs and bushes, fruit orchard, Agriculture Land, rangeland and alpine pastures. The major Land use classes in the Swat valley are natural forest, Alpine pastures, snow and glacier, and agricultural land with a percentage of the 35.38%, 19.96%, 19.29% and 15.99 % respectively (Figure 4). According to the given analysis, the snow cover is almost constant. The water bodies greatly increased from 12 to 26 %. The forest cover decreased due to deforestation and a huge increase in settlements. The land use due to other factors decreased from 37 to 7 %.

The soil of forest highly depends on carbon stocks which based on biomass. Further, it also relates to sustainable agricultural practices which including agro-forestry (Smith et al. 2014). The reliability of the growth period depends on resource sequence which is usually more effective than plant species for carbon dioxide emission (Calfapietra et al. 2010). Reinstatement and restocking of trees get well the forest cover management that consists of Agro forestry (Bright et al 2009). The temperature and precipitation change pattern effect is a serious matter in the Swat valley. The anthropogenic activities are a major cause of severe the climatic situations which cannot be negligible. Therefore, inappropriate and unreliable land use practices are harmfully disturbing the environmental surroundings, foremost to the climatic variation like rain patterns, extended dry and wet periods and extreme temperature situation (Betts et al. 200; Abbas et al. 2016). The anticipated temperature ascends all through Pakistan in one decade from now might be ascribed to provincial atmosphere changes, an unnatural weather change and nearby land utilize structures from extreme actions that are likely to occur during the valuable life of such substructure on the other view (WMO, 1983).

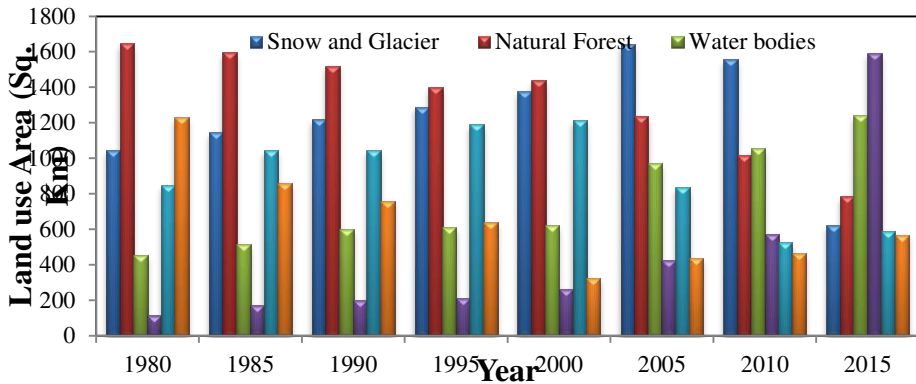
Figure 5 represents the trend in the land use area in the Swat Valley of Pakistan from 1980-2015. The land cover area of the snow found to be increasing in the first 1980 and after that in 2015, found to be decreasing. The trend of Agriculture land seems to be declined above 2000 to 2015. This is generally likely due to increasing the temperature at the global level. The settlement area found to be increased in the last five year span, whereas the settlement area is found to be decreasing at the beginning of the investigated span. This increase in settlement is due to increase the population pressure.





**Figure 4.** Land use area map of the Swat Valley, 2015.

The water bodies found to be increased, while the melting of the snow observed increasing. After the detailed study, it is stated that there is a sharp increase of the water bodies in the last span. From 2000 to 2015, the forest area observed to the decreasing trend. During the same span, the deforestation found to increase. The trend of the precipitation found to be declined. The trend of the temperature increased investigated during this span. Research during the past decade has documented changes in climate and atmospheric responses that may affect the agriculture and forest sector. These changes including the increasing temperature, changing precipitation regimes and shifting seasonal cycle. This increase will heighten the negative impacts of reductions in food production due to weather affecting the forest sector. Tropical agricultural systems are very sensitive to change in evapotranspiration and monsoon summer movements.



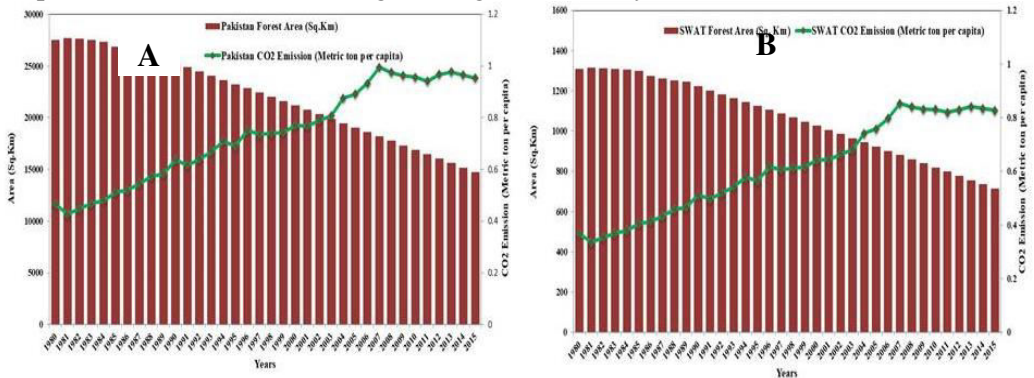
**Figure 5.** Show land use area of the Swat Valley, Pakistan from 1980-2015.

The climate change has an adverse impact on the forest cover and sustainable development (Food and Agriculture Organization, 2010). Sustainable development consists of three dimensions like stability, social harmony and environmental integrity. However, climatic variables like temperature and rainfall are very important for forest cover growth and its efficiency measurement (Mitra and Bhatia, 2008; Semenov, 2009). The climatic parameter like precipitation directly affects the carbon stock and economic growth that creates the problem of forest security (Spash, 2007; Kirby et al. 2016). The climatic change directly affects the frequency and intensity of the forest sector disturbances, including the storms, insect epidemics and wildfires. So, the distribution of forest sector depends on the variation of the temperature, precipitation and carbon stock. The forest cover shows the density level from above the 50 % level and its others value.

The forest covers density greater than 50%, 26-50 % and 10-25% been investigated. The greater than 50 % density of the forest cover was observed mostly started from Kalam to Madyan. The parameters for these forest classes' densities, the disturbed class with regards to capturing capacity and land use were obtained from the application of classification. The impact of climate change is different from region to region. Expected impact of change in global temperature, rising of sea level, change in rainfall setup may cause an increase of deserts in the subtropics. Other consequences are likely to include more frequent extreme weather events including heat waves, droughts, precipitation and heavy snowfall, flooding, ocean acidification and endanger fish species due to shifting temperatures can create the issue of deforestation and land degradation. The most important solutions to explain the effects of climate change are the forests and environmental degradation. Forests are considered the stabilizing force for the phenomena of climate change. It plays a vital part in the carbon cycle, regulation of ecosystem, protection of the biosphere, to prevent from the biodiversity loss, livelihood support mechanism and sustainable growth in biosphere. The forests act as two fold approach. This approach act as the source and a solution for the greenhouse gas emissions and energy sector.

### 3.3 Climate Change and REDD Plus:

The forest area change in the Pakistan at high resolution and a growth rate of forest was less than 1 % during 1990-2000 (Hansen et al, 2008). The World Bank estimated that total forest area of Pakistan was 27653 Sq.km in 1981. Whereas it reached 21160 Sq.km in 2000 and remains 14720 Sq.km in 2015 (Figure 6A). The CO<sub>2</sub> emission in Pakistan was 0.42 metric tons per capita in 1981 that reached 1.11 metric tons per capita in 2015. In the detailed examination, it is stated that CO<sub>2</sub> emission is observed high in 2007 due to decline the forest area. The forest area generally decreased due to the less rainfall observed in the Pakistan. The temperature also observed the high during this similar year.



**Figure 6.** Swat forest area and CO<sub>2</sub> emission, 1980-2015.

Most areas of Swat have a coniferous tress. In Swat, the total forest area covered in the year of 1981 was 1316 Sq.km and reached 1067 Sq.km in the year of 1998 and remains 714 Sq.km in the year of 2011(Figure 6B). Due to the declining trend of forest cover, carbon dioxide emission is increasing that will become dangerously for species which takes a shape in the deforestation and degradation of the environment. However, it increased the risk of ecosystem and sustainable forest management. However, the forest decreasing trend was observed due to increasing CO<sub>2</sub> emissions. According to Forest Department KPK indicated that the increasing trend of CO<sub>2</sub> emission was investigated. In 1981, CO<sub>2</sub>emission was 0.33 metric tons per capita as compared to the 1990 was 0.47 metric tons per capita. Similarly, CO<sub>2</sub> emission was 0.63 and 0.88 metric tons per capita in 2000 and 2015 (Figure 8A). The aspects of the all-biological species like resilience and recognition of the potential parameters of species to access the involvement of Reduced Emissions from the Deforestation and forest Degradation (REDD-plus) mechanism. In the detailed investigation, it is specified that CO<sub>2</sub> emission is observed high in 2007 due to decline the forest area. The forest area generally declines due to the less rainfall observed in the Swat. The mean temperature also be observed the high during this similar year.

Reducing emissions from deforestation and forest degradation (REDD+) is an approach that is developed by the Parties to United Nations Framework Convention on Climate Change (UNFCCC). It creates and establishes a financial

value for the carbon stored in the forest sector to reduce emissions from the forested land sector and invest in low-carbon paths to sustainable development. The forest degradation increases the mechanism of the reducing emissions from deforestation and forest degradation. Such increasing the trend of the carbon dioxide emission leads to create hurdles in the sustainable forest development in the Swat that exerted a direct and indirect impact on the climate of the region. Through, sustainable forest development reduced carbon emission and minimizes temperature and increase the rainfall pattern. It also controlled the floods intensity and land degradation (Lagerquist, 2016). Similarly, protection of forests and ecosystem in the environment, reduce the loss of biodiversity and cultivation of crops minimized the environmental stress (M.E.A, 2015).

The area observed to be declining in the Swat and carbon emission increasing. So, it increases the natural disasters like floods that lead towards the removal of the fertile soil. Schaffer et al. (2019) reported human have influenced the activities of the ecosystem. Deforestation pattern observed to be increased due to anthropogenic activities and change the land use pattern. The increase the water body movements increase the mechanism of the REDD plus due to removal of the fertile soil, land use pattern change and the removal of the plants. Therefore, forest degradation and removal of the forest cover are very complex and dynamic processes that vary from region to region. Local communities also play vital role in such dynamic process of the REDD plus. Settlement growth was categorized as the second reason of forest deterioration in the Swat valley. In Kalam, road development and settlement were other causes. These drivers of the REDD plus were related to population stress and development. Another fundamental aspect is the Swat river transportation, because it provides better access for people to come and go from the valley (Bong et al. 2016).

#### 4. CONCLUSION

*The climatic* changes affect growth and productivity of forests through changes in the temperature and rainfall. The current study investigated the climate change impact on the land cover classes like forest cover and identifying the trend of carbon dioxide emission for the period of 36 years from 1980 to 2015 over Swat valley in KPK Pakistan. Reducing emissions from deforestation and forest degradation (REDD+) is an approach that is developed by the Parties to United Nations Framework Convention on Climate Change (UNFCCC). It creates and establishes a financial value for the carbon stored in the forest sector to reduce emissions from the forested land sector and invest in low-carbon paths to sustainable development. The forest degradation increases the mechanism of the Reducing emissions from deforestation and forest degradation. The land use area be classified using the supervised classification in the Arc-GIS. The DEM also be used to find out the elevation of the investigated study area.

The land cover area of the snow found to be increasing in the first 1980 and after that in 2015, found to be decreasing. This is generally likely due to increasing the

temperature at the global level. Similarly, the settlement area found to be increased in the last five year span, whereas the settlement area is found to be decreasing at the beginning of the investigated span. This increase in settlement is due to increase the population pressure. The water bodies found to be increased, while the melting of the snow observed increasing. After the detailed study, it is stated that there is a sharp increase of the water bodies in the last span. The forest area during 2000 to 2015 observed to the decreasing trend. During the same span, the deforestation found to increase. The trend of the precipitation found to be declined. The trend of the temperature increased investigated during this span.

The snow, agriculture and forest cover area shows that the highest percentage was founded in 2005 and lowest in 2015 as compared the water bodies had the maximum percent was in 2015 and the lowest was in 2000. The rainfall had been decreased by 6.9 percent during 2010-2015, therefore forest cover decreased by 7.2 percent approximately. Whereas From 2005 to 2010, the rise of temperature changed the least by 0.36 percent, forest degradation the least by 5.5 percent and increased the rainfall most by 27 percent. In 1981, CO<sub>2</sub> emission was observed in Swat is 0.33 metric tons per capita as compared to the 1990 was 0.47 metric tons per capita. Whereas, CO<sub>2</sub> emission was 0.63 and 0.88 metric tons per capita in 2000 and 2015. The trend shows that increase in carbon dioxide emission decreased the forest cover in Swat valley. Climate change and global warming are the main threats to nature about natural resources depletion and life.

Deforestation pattern observed to be increased due to anthropogenic activities and change the land use pattern. The increase the water body movements increase the mechanism of the REDD plus due to removal of the fertile soil, land use pattern change and the removal of the plants. Therefore, forest degradation and removal of the forest cover are very complex and dynamic processes that vary from region to region. Local communities also play vital role in such dynamic process of the REDD plus. Settlement growth was categorized as the second reason of forest deterioration in the Swat valley. In Kalam, road development and settlement were other causes. These drivers of the REDD plus were related to population stress and development. Another fundamental aspect is the Swat river transportation, because it provides better access for people to come and go from the valley.

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