Chapter # 1

1. INTRODUCTION

1.1 Climate Change

Carbon cycle and climate is a firmly coupled framework, where variances in environment influences the trading of air CO_2 between the biosphere and sea and the other way around. Changes in earthbound carbon cycle are Due to the climatic changes and changes in the terrestrial carbon cycle. Humidity increases and temperature prompting developing season expands due to ascend in CO_2 (Rajbhandari et al., 2015). Consequently, assessing the effects of the changes in climate is a vital factor for the expectation of carbon elements in the ecological systems of agriculture.

Climate and the carbon cycle are a tightly coupled system, in which fluctuations in climate affects the exchange of atmospheric CO_2 between the terrestrial biosphere and ocean and vice versa. Changes in terrestrial carbon cycle are likely to come because of the climatic changes. Rise in CO_2 leads to increases in temperature leading to growing season and increasing humidity (Thompson et al., 2004). Therefore evaluating the impacts of environmental change is a key factor for the prediction of carbon dynamics in ecosystems (Hui et al., 2016).

1.2 Climate Change Trends and Impacts

According to recent observations, the environmental change issue triggered a widespread concern around the world. Scientists and government organizations in many countries have been committed to resolve this issue (EBNCCA, 2011). Now as compared to the preindustrial era, planet earth is warming at a faster rate. The fifth assessment report of Intergovernmental Panel on environmental Change suggest that the global surface air temperature has increased by 0.8 ^{0}C between 1800 – 2015 and from 1951 – 2015 the warming rate was 0.12 ^{0}C per decade (Intergovernmental Panel on environmental Change, 2013). Current climate shows a control over the natural distribution of an ecosystem. Field et al., 2014 observed the current global climate mainly increasing temperatures has a substantial impact on many natural ecosystems.

The exchange of carbon between oceans, land and atmosphere is very important in order to know that the carbon dioxide emitted by the fossil fuel- combustion is absorbed by the terrestrial and marine ecosystems (D.S. Schimel et al., 2001). A carbon sink is a process in which more carbon is absorbed than it releases back in to the environment. Soil is known as the third largest reservoir of carbon. Globally soils are approximately store 2400 peta-grams (1 Pg = 10^{15} grams) soil organic carbon (SOC) in the top 2 meters (Kirschbaum, 2000). There are many underlying processes that contribute towards the terrestrial carbon sink. In terms of environmental change, mitigation is the main challenge of 21st century in order to secure the livelihoods and to protect the surrounding ecosystems. However, the partitioning of the terrestrial carbon sink in terms of bio spheric carbon uptake and emission from land use change remains poorly controlled (Le Quere et al., 2014).

Scientists and policy makers around the world are trying to estimate the carbon budget, because there's a lot of uncertainty regarding the terrestrial sink, moreover it’s a challenge for them to find out how long it can continue to absorb at its present capability (Tong et al., 2020). Conversion from natural vegetation to agriculture generally result in an observed long-term decrease in soil carbon stocks (Guo and Gifford, 2012). The majority of the earlier research indicates that vegetation productivity and the photosynthetic activity are increasing at a global scale. Here the DGVM LPJ-GUESS was applied to categorize the effect of agricultural processes on terrestrial carbon sink (Pugh et al., 2015). The model adopts the crop functional type (CFT) approach (Lindeskog et al., 2013).

The delicate balance between the uptake and release fluxes of carbon controls the biosphere. Therefore, the future projections of environmental change are likely to influence the exchange of net carbon between biosphere and atmosphere (Ahlstrom et al., 2012).

1.3 Agricultural Contribution to Climate Change Mitigation

Climate change is one of that severe challenge we will face in 21st century. The progressions in climatic occasions, for example, temperature and precipitation fundamentally influence the yield of harvests (Abeydeera et al., 2019). Globally, the two most important natural carbon sequesters are vegetation and oceans. Climate change threatens the agricultural sector in a way that it increases the potential for soil erosion, reduce soil quality, lower agricultural productivity and negatively impact food security. The temperature increment is found to lessen the yield, while the precipitation increment is probably going to balance or decrease the effect of expanding temperature. The amount of carbon sequestered is determined by the time an ecosystem act as sink or a source of carbon, which is dependent on the ecosystem ability to absorb atmospheric CO_2 (Keenan and Williams, 2018). As affected by climatic factors when seen in Iran, crop efficiency relies upon variation capacities and yield type, environment situation, and CO_2 preparation impact. The net income of ranchers is found to diminish fundamentally with a lessening in precipitation or expansion in temperature. Such factor and helpless strategy making have prompted low interest for farming fares, accordingly causing vacillations in the income of nation. Factual proof shows the temperature influences espresso crop farm in Mexico. The impact of environmental change on the harvest yields fluctuates as indicated by the space and water system application. Harvest yields can be expanded by growing inundated regions, which can detrimentally affect the climate. The ascent in temperature is probably going to lessen the yield of numerous harvests by diminishing their term. Wheat, rice, and maize is relied upon to diminish if both the mild and tropical areas experience a warming of two degree for the total production (Kaur and Kaur, 2016). Change in climate overall merely affects tropical locales, as tropical harvests stay nearer to their high-temperature optima, and along these lines experience high-temperature stress during raised degrees of temperature. Change in climate is a worldwide danger to the food and dietary security of the world. As harming substance emissions in the climate are expanding, the temperature is likewise ascending because of the necessary impact. The normal worldwide temperature is expanding persistently and is anticipated to ascend by two degrees until 2100, which would cause significant financial misfortunes at the worldwide level (Chen and Sun, 2018).

1.4 Carbon cycle (CC)

Carbon is a fundamental component to help living things. Carbon cycle (CC) is the progressions of the carbon between every repository in a trade. Initially, the plants are known as primary producers and convert the energy from the sun to compound energy by the cycle of photosynthesis. First and foremost, the molecules of chlorophyll assimilate the light energy isolating the water particle into hydrogen and oxygen. Also, the CO_2 is changed over to complex carbs. Primary consumers are the herbivores and they feed on plants to acquire dietary parts and energy from them and that energy is additionally passed to carnivores and afterward to decomposers (Manaye et al., 2021).

The carbon is delivered once more into the air by disintegration. It is significant note that not all carbon content is decayed promptly, a portion of the dead plant matter aggregated and secured inside a biological system underground store. After numerous hundreds of years, when various layers of dregs compress this plant material prompting development of petroleum products. CO_2 is delivered once more into the air when petroleum products are scorched widely. The carbon dioxide in put away in rocks and residue and will be either be available in the particles of carbonate and bicarbonate (Ali and Erenstein, 2017). These particles play a significant role by going about as support and keeping the sea-going framework from getting excessively acidic or excessively essential. Moreover, the carbon is disposed of from the seawater when the bones of marine creatures containing carbon in type of limestone. The carbon can be delivered back to the air if the limestone dissolves or is changed in a subduction zone.

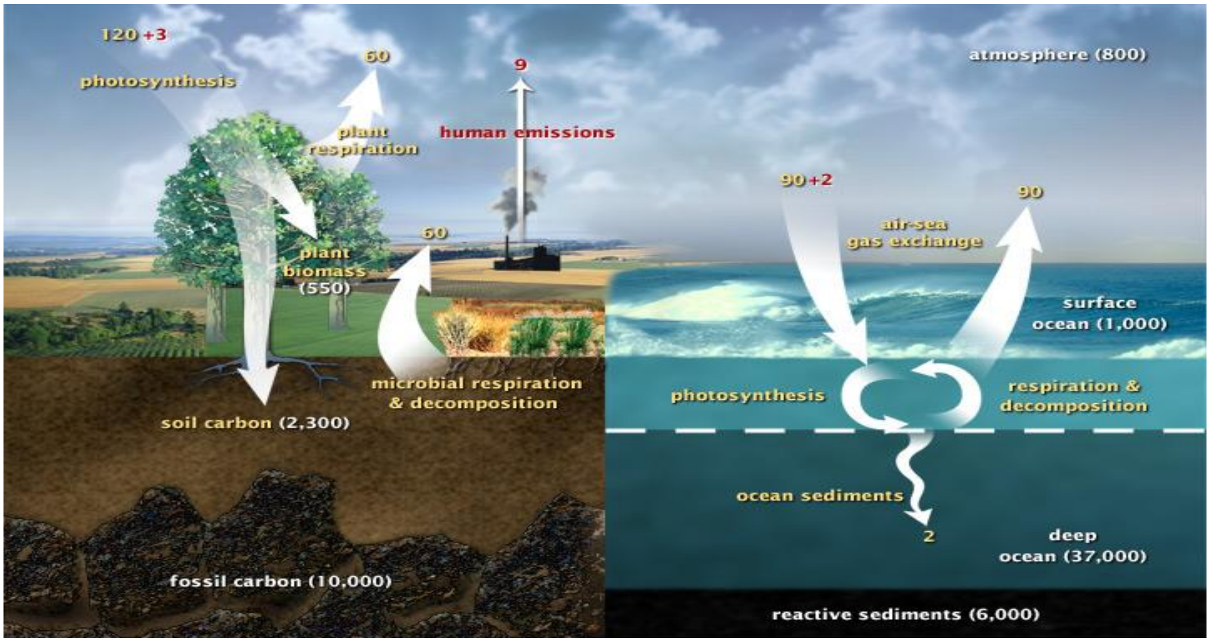


Figure 1: Figure visualizes the ocean and terrestrial carbon cycle

1.5 CO_2 Fertilization

Photosynthesis in trees is increased by the ascend in environmental CO_2 (Kim et al., 2017). The upgrade in photosynthesis is adjusted by the plant breath and microbial decay. Nonetheless, there is high vulnerability of the extent of vegetation carbon transition. However, until this equilibrium is reached, the area is considered to have sink carbon.

1.6 Carbon Fluxes

Agriculture plays an important role in regulating the climate through Carbon Fluxes. Living things to develop, replicate and endure energy is needed. The CO_2 gas to diffuse into the interior pieces of the leaf is empowered by the stomata's function of opening and closing. Photosynthesis processes initializes to diminish sugar that causes Carbon Fluxes to starts in vegetation by CO_2 (Wang et al., 2019). Ra is the uptake of carbon by the interaction of photosynthesis is just brief, half of it is delivered once again into the air by plant breath. Further, net primary productivity (NPP) is consolidated as biomass. Upon heterotrophic breath (Rh) related with disintegration of dead natural matter the subsequent natural carbon is called as the net ecosystem productivity (NEE). Besides, net biome production (NBP) refers to the adjustment of the size of carbon stocks after carbon effect like fire, sickness and changes in usage of land. Carbon fluxes (CF), for example, GPP, NPP and breath are broad cycle controlling earthly climate CO_2 trade having capacity to part of the way balanced anthropogenic emissions. The assurance of the impact of worldwide ascent in temperature on agriculture is getting significant.

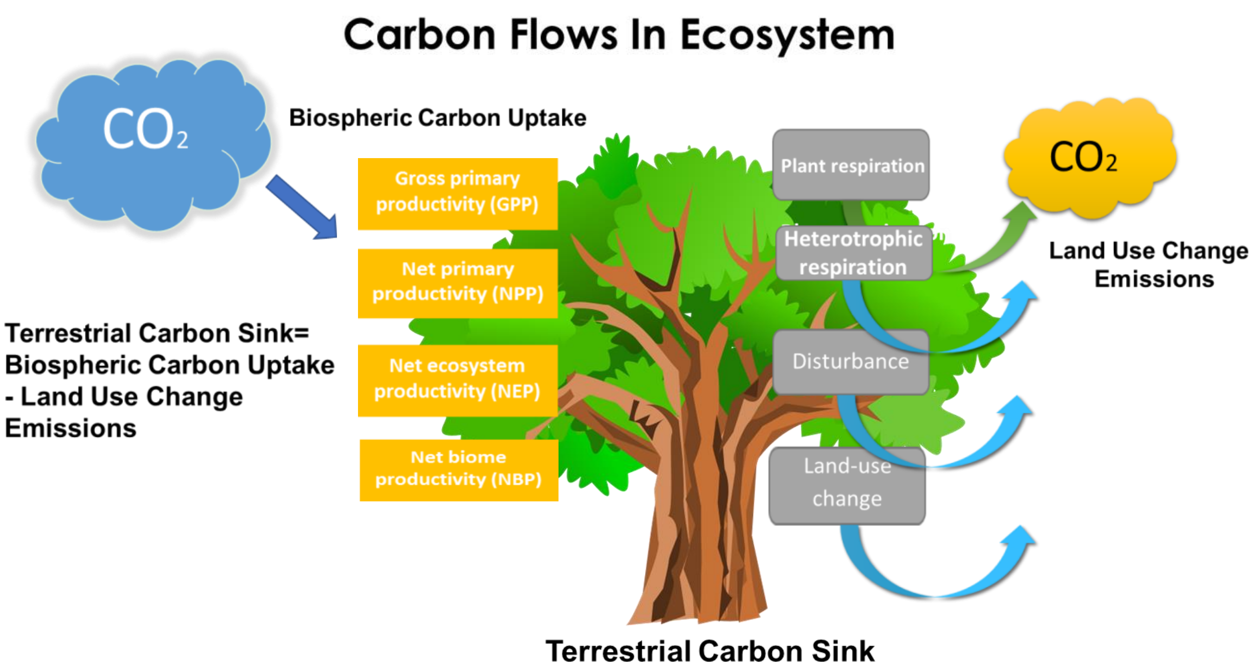


Figure 2: Carbon flows in ecosystem

The effects of the change in climate are probably going to achieve modification in the dispersion of the species and composition of plant, structure of vegetation and ecological system measures. The reaction of agriculture to the change in climate will bring about changes in net carbon uptake, water use proficiency, plant foundation, carbon biomass assignment and reaction to aggravations (Zeng et al., 2020). The intricacy of climatic components impacting the vegetation and the time it takes for the reactions to become noticeable makes it harder to project agriculture reaction later on situation dependent on the analyses of field. Since the mid-2000s, Reproduction models consolidate the hypothesis and exploratory outcomes to extend the input of vegetation to shifting CO_2 and environment (Keenan et al., 2016).

Examinations have shown that the situations based demonstrating assists with foreseeing future adjustments that will liable to occur, subject to the current and future ozone depleting substance fixations. Moreover, demonstrating terrestrial environments as per projected future climatic changes permits to survey whether the biosphere change into a sink of CO_2 (Le Quéré et al., 2018). Demonstrating horticulture biomass fills in as a significant part for strategy creators and directors to manage the alleviation ozone depleting substance outflow and assess changes in the vegetation. Exact approximations of CF and biomass assists with investigating carbon stocks for a more extended term throughout existence, assess the progressions in agriculture appropriation and design and offer information for between examination concentrates among various models. Further, it is seen that there are errors among models identifying with the size and indication of the exchange of net systems of ecology and the circulation of sources and sinks across the topographical territories.

1.6.1 Factors Effecting the Terrestrial Carbon Equilibrium

The equilibrium of carbon between biosphere and the climate is not a stable balance. It is fundamentally because of expanding direct and indirect anthropogenic activities and anthropogenic impact, respectively. Factors that affect the terrestrial carbon equilibrium are change in climate, fertilization of nitrogen, fertilization of CO_2 and changes in land use and land cover change (Schillaci et al., 2021).

1.6.2 Nitrogen Fertilization

In the terrestrial biosphere, the human activities through emission of nitrogen oxides because of ignition of nonrenewable assets, animal cultivation and utilization of manures the accessibility of nitrogen are the reasons behind nitrogen availability (Álvaro-Fuentes et al., 2012). As often as possible, the plant usefulness is restricted by accessibility of nitrogen. Close to the equator, the tropical and boreal locales are less influenced, as they are further from the nitrogen emitting sources, the backwoods are compelled by absence of phosphorus and calcium.

1.6.3 Land Use and Land Cover Change (LULCC)

The fundamental activities of LULCC incorporate degradation of ecosystem, practices in agriculture, and environment and management of fire. The fields for crop farming and domesticated animals' field have gotten one of a significant reason for CO_2 discharge once again into the climate because of LULCC.

1.7 Models Used for Predicting Carbon Cycle for Carbon Fluxes

A significant role has been played on the prediction of impacts of climatic changes on agriculture productivity by models. The introduction and outputs of diverse approaches of modelling has to be transcribed accordingly. Six broad heads of models along with the vital variance between them are classified as explained further.

1.7.1 Process-based Models

An equivalent stand of agriculture stand restoring the physiological operations that spike changes in agriculture is represented by this model. The ingestion of carbon during photosynthesis, carbon loss along with the carbon allocation to various tissues of plants are included in the simulation of these models. Many environmental factors like solar radiations, temperature, carbon dioxide and humidity have direct effect on these processes (Medlyn et al., 2011).

1.7.2 Terrestrial Biogeochemical Models

Similar to the process-based models, these models undergo the employment of better simplification over a larger scale from region to the whole world. Simulation of carbon, water and cycle of nutrients in earthbound ecosystems is done in these models. For the simulation of NPP, carbon flux and storage such models are further used (Keenan and Williams, 2018).

1.7.3 Hybrid and Carbon Accounting Models

Individual stands and regional scales are analyzed on this model. Such models are related closely to the industry of agriculture and implies practically and effects of climatic changes on agriculture are forecasted easily with the help of these models (Medlyn et al., 2011).

1.7.4 Gap models

Evaluation of the interaction of species and vegetation changes at a fine structural measure over day-to-day to yearly time steps, is done by these models. Disturbances preceded by the agriculture succession is examined thorough such models (Prentice and Cowling, 2013).

1.8 Dynamic Global Vegetation Models (DGVMs)

Mass and energy factors among the surface and the atmosphere are quantified through these models. In order to understand the variance of carbon and nutrients fluxes and pools these models are interconnected with the schemes of forecasting of climatic models. Besides, such models can be used on stand-alone basis to gauge these variances. As per the concept of dynamic global circulation model applied by the global change and terrestrial ecosystems project, six independent groups constructed and presented the simulations of historical and future projections with DGVMs (Cramer et al., 2001). Models proposed by various researchers are combined into a stand-alone model, that is DGVM. Biogeography, biogeochemistry and vegetation dynamics models are the main incorporations of the DGVMs from the previous models. Different processes incorporated are corelated by coupling in these models, like updating of daily time steps is for photosynthesis while annual updating is for vegetation dynamics (Prentice and Cowling, 2013). Simulation for few models is carried out on leaf level at hourly steps while few undergo at a complete canopy level at monthly step. The assumptions of real time climatic changes derive the results from models as the models depend on these changes (Medlyn et al., 2011). Modelling and interpretation of the vegetation adaptations to environmental oscillations in all times is assisted by DGVMs. Various DGVMs have been proposed by several researchers globally. Few of which are, HYBRID developed by U.K, IBIS developed by U.S, SDGVM developed by U.K, LPJ-GUESS developed by Sweden 29, SEIB-DGVM developed by Japan, MC1 developed by U.S, TRIFFID developed by U.K and LPJ developed by Germany, Sweden.

Taking account of changes of land use by agriculture, various studies have focused on the productivity of agriculture. Like, in order to quantify the time carbon stays in soils and vegetations and the NPP, 16 DGVMs were utilized and the results revealed a rise in NPP due to increased carbon dioxide saturations over a historical period, leading to a rise in carbon storage in soil and vegetation (O'Sullivan et al. 2019). Due to the changing of agriculture to shorter vegetation the LULCC resulted in decrease of the carbon input over the historical period.

Above Ground Biomass (AGB) density measured from satellite-based analysis was compared with the agriculture aboveground biomass from nine ensemble DGVMs as per trendy which provided with the result that an overall consistency between both datasets exists Yang et al. (2020). Yet, since different assumptions taken by each model showed a wide variation of spread among models at biome scale. Many studies show a lead towards an uncertain projection in the ecosystem carbon equilibrium due to a large gap in present understanding for the quantification of biomass carbon stock (Wu et al., 2017; Ahlstrom et al., 2012).

1.9 LPJ-GUESS

Out of various dynamic models of vegetation one is known as Lund-Potsdam-Jena General Ecosystem Simulator (LPJ-GUESS) (Smith et al., 2001). Providing a flexible mechanism to portray terrestrial ecosystems at landscape, global and regional levels, this model's origin is Potsdam Institute for Climate Impact Research. These models are very helpful for the quantification of the net primary production and biomass of agriculture since it consists of allotment of assimilated carbon to roots, sapwood, heartwood and leaves and plant photosynthesis representation (Zhang et al., 2017). Plant functional types are distinguished on the terms of growth form, niche, pathway, life history and phenology, in this model.

The LPJ-GUESS models consider both annual and day-to-day time steps. Input data to this model is consisted of climatic variables like CO_2 mix ratio, shortwave radiation, temperature precipitation and soil type. The first phase known as "spin-up-phase" is the first phase in which carbon litter pools and soil gather to reach to a state of equilibrium under the constraints of climate and forcing of CO_2. The future climatic change that can be simulated is the end phase and is known as "scenario phase". The vegetation types, carbon pool, carbon fluxes, leaf area index and carbon biomass are related to the outputs of LPJ-GUESS.

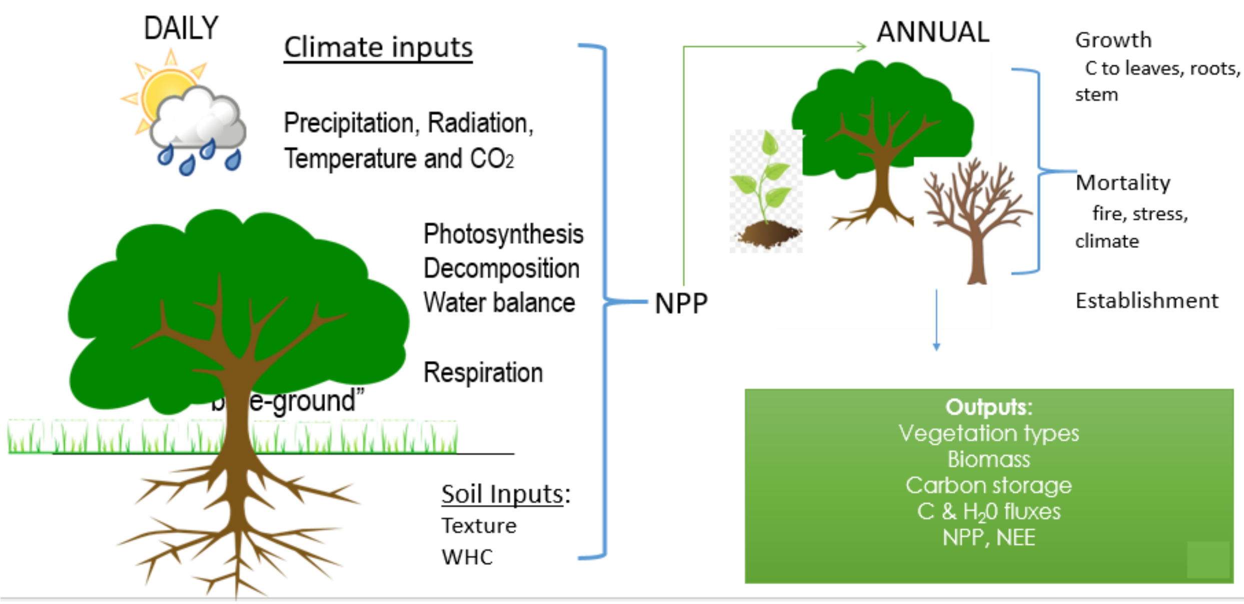


Figure 3: Diagrammatic representation of LPJ-GUESS

Chapter # 2

2. LITRATURE REVIEW

2.1 Atmospheric Carbon dioxide

The GHG effect is the series that leaves an impact on temperature and atmosphere of the earth. The basic temperature and atmosphere that is required and supportive for living is negatively impacted. In the atmosphere of earth, radiation is absorbed by the GHG that increases the temperature of the earth. This absorption of heat is increased due to the rise in CO_2. This rising concentration of CO_2 in the atmosphere is due to the anthropogenic sources, resulting in the increase of negative impact on humans (Ahmed et al., 2018). In the atmosphere, the least time of single CO2 molecule is five years. In comparison with the other GHG effect, such as nitrous oxide (N_2O) and methane (CH_4), CO2 is less compared as the global warming potential (GWP). In any case, as because of the lasting time of CO2 and focus in the air prompts extra warming of the world's lower atmosphere. It has been seen that the ascent in climatic concentration of CO2 has brought about the greater part of the imbalance in the energy causing temperature increase. Contrasted with the previous 650,000 years, the air has arrived at top degree of CO2, methane, nitrous oxide and tropospheric ozone as concentration of air (Miller et al., 2018). Since the mid-twentieth century, these GHG are perceived as the principal drivers of a dangerous atmospheric deviation (Ainsworth et al., 2020). The figure below depicts the level of CO2 concentration rise in the atmosphere for the long periods of 1960 till present.

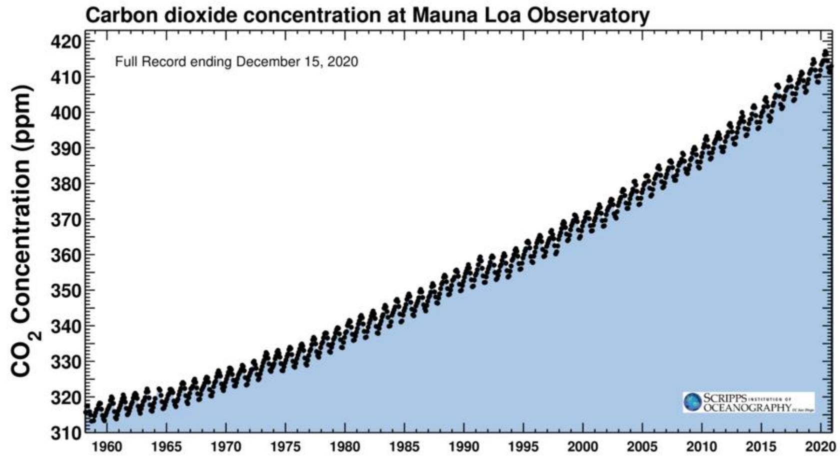


Figure 4: Carbon dioxide concentration at Mauna Loa Observatory

(US Department of Commerce)

2.2 Role of Agriculture in CO_2 cycle

Over decades, agriculture land has been exhausted of their unique supply of carbon. Agriculture has a striking ability to assimilate CO_2. The most suitable administration practices to build carbon catch in rural soils fluctuate locally, contingent upon both natural and financial variables. Horticulture has a significant task to carry out towards a work to relieve the environmental change because of the enhancement of CO_2 and other GHG (Ali et al., 2017). In spite of the normal insight, scientific farming can be an answer for natural issues yet uniquely to decreasing the pace of enhancement of CO_2 in the air (Liu et al., 2017). The extant literature has suggested some strategies that incorporate transformation from furrow till to no-work, crop rotation, liberal utilization of harvest buildups and biosolids, manure/composts and prudent utilization of manures must be included as nutrient, management of pest integration (Reuter et al., 2017).

Technologies helps in increasing the capture rate of carbon in soils of agriculture. Moreover, this capture rate depends on the structure and management of soil, intensity of rain, systems of farming, methods of cultivation and temperature (Yang et al., 2018). Techniques to expand carbon pools in soil incorporate the soil restoration and the woods regeneration, cultivation, the yield deposits from the supplements for soil, the utilization and typology of manure, method of gazing, conservation of water, proficient water system, practices of agriculture, and energy developing harvests on spare terrains (Aslam et al., 2018). The significance of farming activities in potential of carbon mitigation, showing a full record of farming costs for emitting GHG.

Moreover, covered up costs of manures and pesticides, and dangers of expanding emanations of nitrous oxide and methane. Hence, improving use effectiveness of these sources is significant. According to Chen et al., (2018), rebuilding of corrupted soils and biological systems is a significant methodology of sequestration of soil organic carbon (SOC). It is seen that mostly the degraded soils lose a huge part of the first pool of SOC, and it very well may be improved through remedial ways. Water and wind erosion of soil is the most inescapable degradative interaction on a worldwide scale. Measure that could be effective in adopting the conversation methods can reduce soil erosion incited discharges and recharge the drained pool of SOC. Quality of soil and pool of SOC can be increased by easing of soil-related imperatives to biomass creation (Elouissi et al., 2017). Indeed, there exists a nearby between connection between SOC pool and soil quality and strength. The perpetual quality of soil relies upon the coherence of the strategies. Moreover, the most common strategic practice is rotational plowing. This practice prompts exhaustion of the SOC sequestered. Such practice adoption with continuation, notwithstanding, the sequestered C stays for a generally prolonged stretch of time in the soil and diminishes the pace of improvement of environmental concentration of CO_2 (Keenan and Williams, 2018).

2.3 Land Use and Land Cover Change (LULCC)

Assessment of carbon pool under LULCC give a significant knowledge into the projection and appropriation of sequestration of CO_2 in soil over the long run (Eldering et al., 2017). Constituents of the soil carbon and vegetative carbon are the characteristics of the terrestrial ecosystem of the carbon pool. The carbon stocks shift progressively and are reliant upon components, for example, deforestation and changes of land usage (Heymann et al., 2017). Agricultural lands are transformed from forest that prompts evacuation of trees making enormous measure of carbon be uprooted prompting decrease in biomass. In a dynamic global vegetation model, Pugh et al., (2015) evaluated the impact of management of farming area. For the purpose of computations of emission of usage of land, tillage, grazing and harvest inclusions.

Carbon uptake by agriculture brings about decline in the pace of carbon buildup in the environment bringing about decrease of rate at which environmental change happens. Nevertheless because of changes in climate, there has been a noticed vacillation in the net equilibrium in exchange of carbon (Slevin et al., 2017). Environmental change act significant dangers like well as promising circumstances for agriculture at a worldwide scale (Htut and Shrestha, 2016). Precise assessment of the agriculture carbon concentration and its distribution geological at a provincial scale is vital as they hold an enormous sum in the concentration of carbon of the systems of ecology on earth.

Currently, analysts and makers of policies are centering to comprehend the progressions in climatic patterns and related effects under the activities of anthropogenic (Iqbal et al., 2018). The process of industrialization and urbanization pace increases that has prompted worldwide environmental change (Jung et al., 2017). Because of land use and cover change, the rising surface temperatures has been a significant worry.

The change in climate regionally is significantly affected by the trends of global warming. From the past investigations it can be seen that LULCC has contributed an expected of 68% of warming patterns (Khan and Tahir, 2018). An enormous loss of agricultural cover is caused by the establishment of buildings, infrastructure and roads on the area of agriculture regular land surfaces. The worldwide mean surface temperature has ascended by 0.84°C as indicated by IPCC fifth Assessment Report (IPCC, 2013). Late investigations have extended an expected increment of 0.27 mean surface warming each century because of LULCC. Subsequently, it is critical to assess the impacts of LULCC particularly in those locales that are more helpless against environmental change impacts.

2.4 Agricultural land use in Pakistan

In Pakistani Economy, agriculture is contributing as the backbone. It is utilizing 43% of the labor force and adding to about 20% of the absolute GDP (Kumar, 2016). More than 66% of Pakistan's populace lives in village regions, and their occupation keeps on spinning around agribusiness. There have been some primary changes over the long run, yet the commitment of agriculture items keeps on keeping up its relative significance, offering catalyst to the generally financial turn of events and development of the economy. Over 75% of the worth of absolute yield by cotton, wheat, rice, sugarcane, maize, leafy foods represent.

Agribusiness is significant for guaranteeing security of food and lessening poverty. In any case, expanding climate inconstancy and environmental change have compromised the agrarian area and consequently, have become significant hindrances to accomplishing security of food and hardship is reduced in Pakistan (Mahmood, 2016). The expansion in temperature can influence farming through its effect on seasons, the increment in evapotranspiration, water system necessities and pressure of stress on vegetation and agri-items. The utilization of brief span crop assortments and change in planting time may decrease the unfriendly effect of the previously mentioned climatic dangers. Drylands and semi-arid lands in districts of Pakistan that are short of resources and are more powerless against environmental change, including Sindh and Baluchistan, particularly to diminished precipitation, expanded evapotranspiration and dry season.

To adjust to environmental change chances in agribusiness, ranchers utilize a few variation techniques. Transformation estimates like a change in time of sowing, utilization of stress-lenient yield assortments and moving to new harvests (such as high tolerance of pressure, or with more limited or longer cycles of harvest), could altogether decrease weakness to change in the weather (Deng et al., 2016). Transformation practices can include changes in plans and schedule of planting, manure utilized, water system, plant breed or different parts of harvest the executives and the development cycle and have crop explicit ramifications. These transformations activities normally decrease hazard and are bound to limit the seriousness of the effect of environmental change. Consequently, agronomist families utilizing variation rehearses are bound to be food secure contrasted with those not receiving.

Pakistan has encountered outrageous environmental changes like less than ideal and heavy precipitation and floods in mountainous districts making huge harm the harvests and properties of agronomist (Farooq and Gheewala, 2019). It is expected that these conditions will increment as a component of environmental change. Remembering the significance of agribusiness to the economy and rural occupations, the meaning of environmental change strategies of transformation and adaptation is critical.

The extant literature has explored that the global warming resulted in rise of temperature. This rises in temperature and pressure of heat results in crop damaging. As suggested in a study by Naqvi et al., (2019), a rise in one degree of temperature damages the crop of field to seven percentage. Likewise, humidity in the weather causes an increase in the wheat production; however, a decrease of nine percentage is observed for the areas having arid, semi-arid and sub-humid weather (Ahmad and Nizami, 2015). Same scenario is noticed for the crop of rice in Pakistan. Expansion of heat stress and temperature in the field of rice will cause the decline in its production. A study predicted that by 2099, the rise in temperature will cause 36% decline in the production of rice (Xu et al., 2019). Apart from this, the intensity of precipitation increments and decline results the production of agri-business too. The requirement of net water increases by twenty-nine percentage, if the six percentage of rainfall reduces in Pakistan. 1.3 million of agricultural lands and farmers will be affected due to the decrease in precipitation.

2.5 Modelling Agriculture Response to CO_2 concentration

Due to the diverse crop and ecosystem proceedings involved in spatial and temporal scale, the measurement of varying agricultural response with a specific environmental variable is a challenging task. Hence, integration and quantification of significant reaction processes of agriculture to the changes in climate, requires simulation models. Numerous literatures cite a wide range of models to analyze the agricultural productivity. Depending upon numerous suppositions of feedbacks among terrestrial ecosystem and atmosphere, climatic change predictions are estimated from coupled carbon-climate models. The expansion in carbon dioxide is one basic input bringing about carbon uptake by the biosphere, thus hindering the pace of increment of climatic carbon dioxide due to the fossil fuel driven anthropogenic activities (Norby et al., 2005). However, due to different model builds, process representations, locations, species, input scenarios and scale of application, it is noteworthy that each model is different from each other (Medlyn et al., 2011).

2.6 Role of Dynamic Global Vegetation Models (DGVMs)

Mechanistic process and time-independent process representation is done by dynamic models such as DGVMs. Vegetation as 'Plant functional types' are represented by DGVMs, which further represent various types of ecosystem process related parameterizations. The complexity of the dynamics of vegetation is represented by DGVMs in a comprehensive manner. Acquisition and simulation of variations in carbon fluxes and vegetation cover and provision with a representation of vegetation dynamics to GCMs is the main property of DGVMs (Quillet et al., 2010).

Six different DGVMs (HYBRID, IBIS, LPJ, SDGVM, TRIFFID AND VECODE) were used and terrestrial carbon ecosystem response was assessed by Cramer et al., (2001). DGVMs has various types which vary in terms of complexity and focus on numerous assumptions. The changes in ecosystem function variable (for e.g., exchange of carbon) and the build of vegetation with respect to changing concentrations of atmospheric CO2, link each model's simulation. The total carbon increments were taken as the net ecosystem production estimates. The evaluation of climatic change impacts with the assessment of the shifts of agriculture vegetation and NPP under RCP4.5 and RCP8.5 was done utilizing IBIS and LPJ that are two forms of DGVMs by Chaitra et al. (2018). Huge variations in transformations of vegetations are announced in the projections of LPJ and IBIS. This is ascribed towards the distinctive portrayal of hidden cycles and diverse number of PFTs consolidated in the DGVMs. A minor arrangement was found in NPP by IBIS and LPJ.

2.7 LPJ-GUESS Simulations of NPP, Biomass and Carbon pool

In order to settle the impacts of environmental and climatic changes on vegetation and ecosystems, analysists have employed LPJ-GUESS model. In order to analyze the climatic impacts across Europe LPJ-GUESS ecosystem model driven by a regional climate model was used and the results showed the NPP increase in the whole Europe caused due to increased temperature, extended growing season and physiological effects of increasing concentration of CO_2 concentration in the atmosphere. The rate of net photosynthesis spikes with increased temperature and increased CO_2 levels (Morales et al. 2007). In order to estimate the potential agriculture NPP and biomass LPJ-GUESS with 8 plant functional types of New England's agriculture lands was implemented and the data was compared with numerous observations. There was a decrease of biomass from 1901-1949 at the rate of 0.11 Mg ha-1 while from 1950-2006 it increased per year at the rate of Mg ha^{-1}. For the investigation of the effect of use of land on net ecosystem balance of carbon and evaluation of the ability of the model to reproduce vegetation build trends in Africa, LPJ-GUESS was implied and the results showed well coherence between the satellite observed NDVI and crop yields and modelled FPAR (Lindeskog et al. 2013). In another study, LPJ-GUESS with the outcome from 18 ESMs constituting in CMIP5 under RCP8.5 was implemented. The study focused on the effect of variation of climate under given atmospheric CO_2 on terrestrial carbon fluxes. In the vegetation model the pastures and croplands were considered as natural grasslands. Simulations of LPJ-GUESS has given arrangement of the indication of the yearly net ecosystem trade across the northern half of the globe. Note that the variety in simulated earthbound carbon cycle between various earth framework models emerges because of the distinctions among environment models implanted in the earth framework models (Ahlström et al., 2012). The earthbound biosphere results in CO2 enhancement by becoming a net source, showed 10 out of 18 simulations. While there was an increased sink of carbon, showed the remaining simulations.

Another study used an updated version of the LPJ-GUESS with the dynamics of nitrogen in soil and plant and the model's performance was predicted using the carbon and nitrogen dynamics (Wärlind et al. 2014). Moreover, the LPJ-GUESS was used to estimate the GPP and NPP and results matched the values acquired from MOD17. This study showed that the GPP from remote sensing was larger than compared to the dynamic vegetation model. While on the other hand the NPP estimates came out to be lower than dynamic vegetation model.

These variations may be due to the design of the model and sensitivity of the temperature. GPP was investigated utilizing LPJ-GUESS forced by different data sets of climates, due to which a notable uncertainty was reported on the simulated GPP. It was moreover suggested to increase the research efforts to build perfect datasets of the climate so that the assess to the global carbon cycle and sequestrations becomes easier. In order to find out the impact of LULCC to evaluate the carbon sink capacity of different habitat between 1992-2015, the earth observational data and the LPJ-GUESS was compared. The results revealed a great carbon sink capability in the tropical and boreal lands, owing towards the CO2 fertilization effect. The investigation inferred that the land use changes greatly affected the tropical agriculture. By the consolidation of variables, for example, supplement cycling in LPJ-GUESS demonstrating will serve better to improve our comprehension of patterns in carbon sinks and sources (Tagesson et al. 2020).

2.8 Aims and objectives of the study

The objectives of this study are:

1. To assess the effect of land use changes in bioshperic carbon uptake using past, present and future climate change scenario.
2. To compare modelled land use carbon emissions with observed carbon emissions of Pakistan.

Chapter # 3

3. METHODOLOGY

3.1 Study Area

Pakistan is the 33rd largest country by area, spanning 881,913 square kilometers. Pakistan is an agrarian country and its agriculture area is 79.6 million hectares. With the increasing population and changing consumption patterns, the demand for food has also increased. Crop productivity and environmental change are directly linked together as the climate effect the crop yield.

Pakistan is 5th most vulnerable country to the environmental change (GW,2020) and has suffered 141 extreme weather events in the last decade. Pakistan requires 7 – 14 billion dollars annually for environmental change adaption (Sheikh, 2017). The average mean temperature of Pakistan has also increased almost 0.5 degree Celsius in the last 5 decades. Pakistan emitting 0.8% of the total greenhouse gases (MoCC,2016).

To measure the effect of environmental change and land use changes in Pakistan LPJ-GUESS model was used.

Figure 5:

The latitude of Pakistan is 30.3753° N, and the longitude of the country is 69.3451° E.

Together, these points indicate that Pakistan is situated to the north of the equator.

The major steps involved in the study and key stages are show in Figure 7.

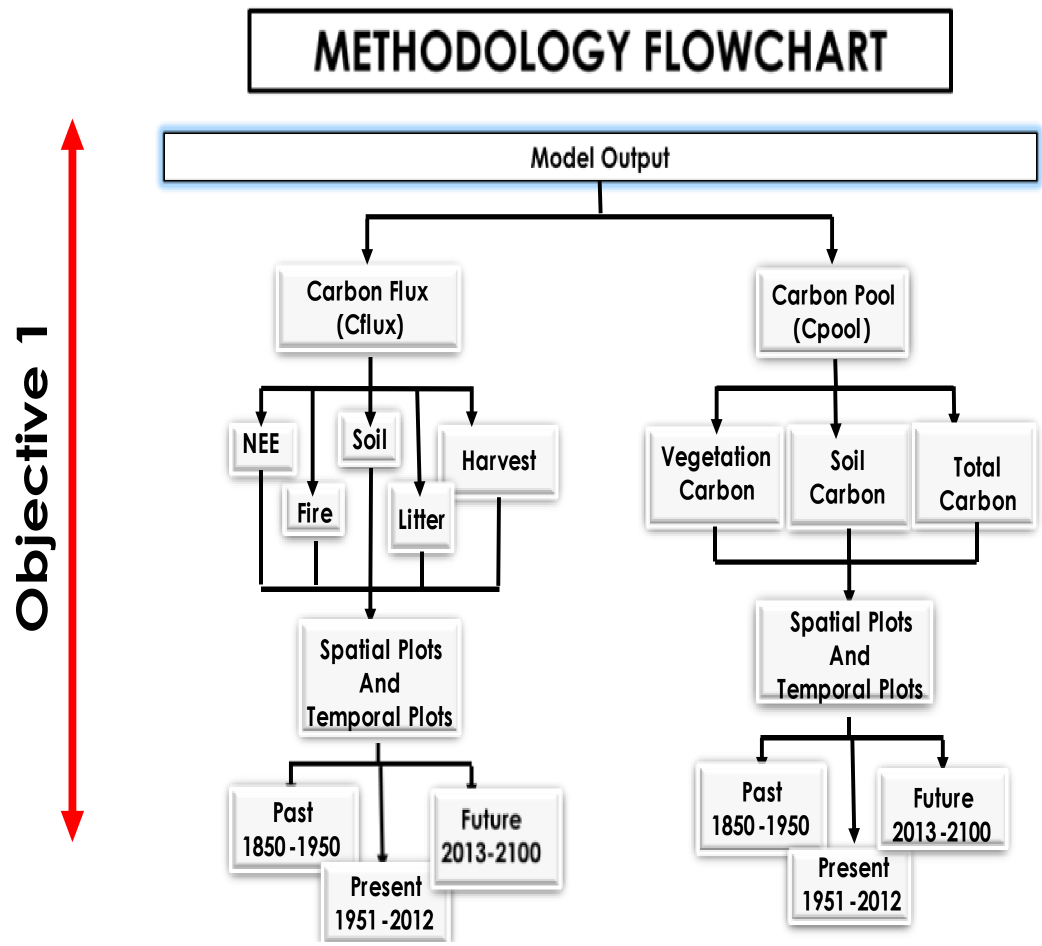


Figure 6: Methodology Flowchart for Objective 1

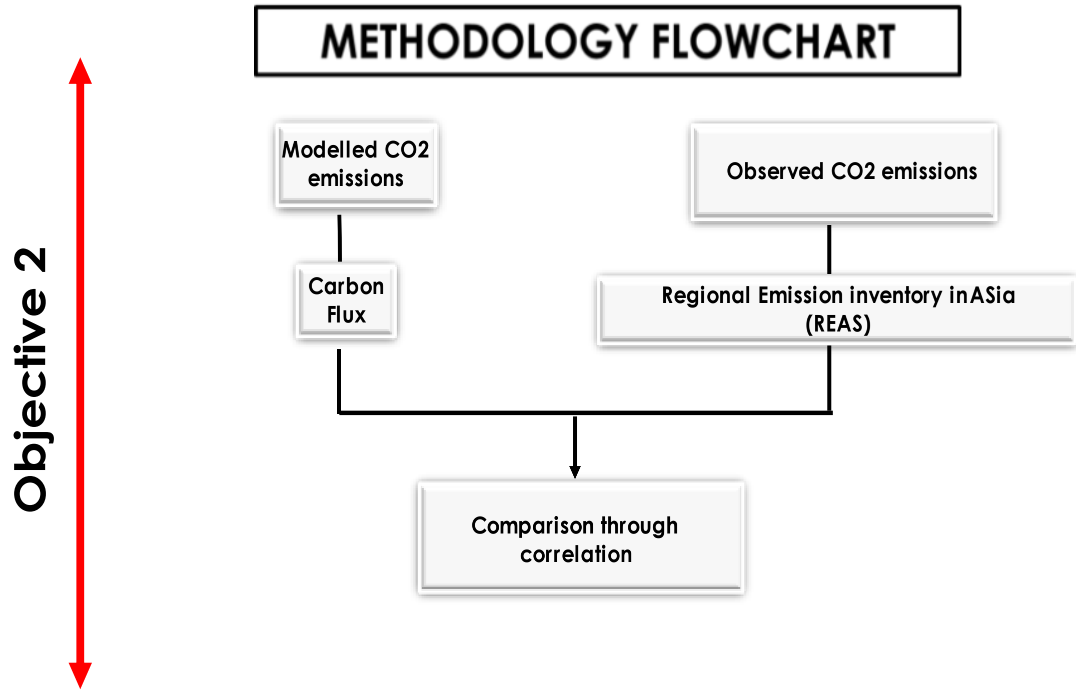


Figure7: Methodology Flowchart for Objective 2

In this study output simulations were reanalyzed with a focus on the Pakistan region. The output simulations of LPJ-GUESS under RCP 2.6 and RCP 8.5 were utilized. The ESM include MPI-ESM-LR. The data of LPJ-GUESS was read and extracted in R programming. Output files containing carbon flux and carbon pool were utilized. Factors include in carbon flux are NEE, fire, soil, litter and harvest. While in cpool vegetation carbon, soil carbon and total carbon were used. After that, aggregation of NEE, Vegetation carbon and total carbon data was carried out at a spatial and temporal scale. Spatial and temporal plots were generated in accordance with time periods for the study region.

The second objective was to examine the difference between modelled and calculated data for Pakistan region. The variable compared is carbon flux. CO2 data was downloaded from REAS inventory (Regional Emission inventory in Asia) in order to compare it with the modeled simulation.

3.2 LPJ-GUESS settings

Study simulations were reanalyzed from (Pugh et al., 2015) with a focus on the Pakistan region. Only an overview of the salient features of the set-up were given for this study. For more set-up details, please see (Pugh et al., 2012). Spatial patterns of Net Ecosystem Exchange, Vegetation Carbon, Soil Carbon and Total Carbon were investigated in Pakistan region by using the output simulations of LPJ-GUESS resolution of 0.5° × 0.5° with climate forcing from climate models participating under RCP 2.6 (Van Vuuren et al., 2007) and RCP8.5 representative concentration pathway (Riahi et al., 2011). RCP2.6 emission pathway is representative of scenarios indicating to extremely reduced GHG concentration levels. It is a defined as a "peak-and-decline" scenario, in which the radiative forcing level first reaches around 3.1 W/m^2 by mid-century, and return to a value of 2.6 W/m^2 by 2100. In contrast, RCP8.5 is characterized by increasing GHG emissions over time, culminating in a radiative forcing of 8.5 W/m^2 in 2100. The radiative forcing in RCP 8.5 corresponds approximately to the A2 scenario used in the earlier Special Report on Emission Scenarios (SRES) (Stocker et al., 2013). LPJ-GUESS represents plant vegetation as Plant Functional Types that establish dynamically in response to climate and CO_2 forcing.

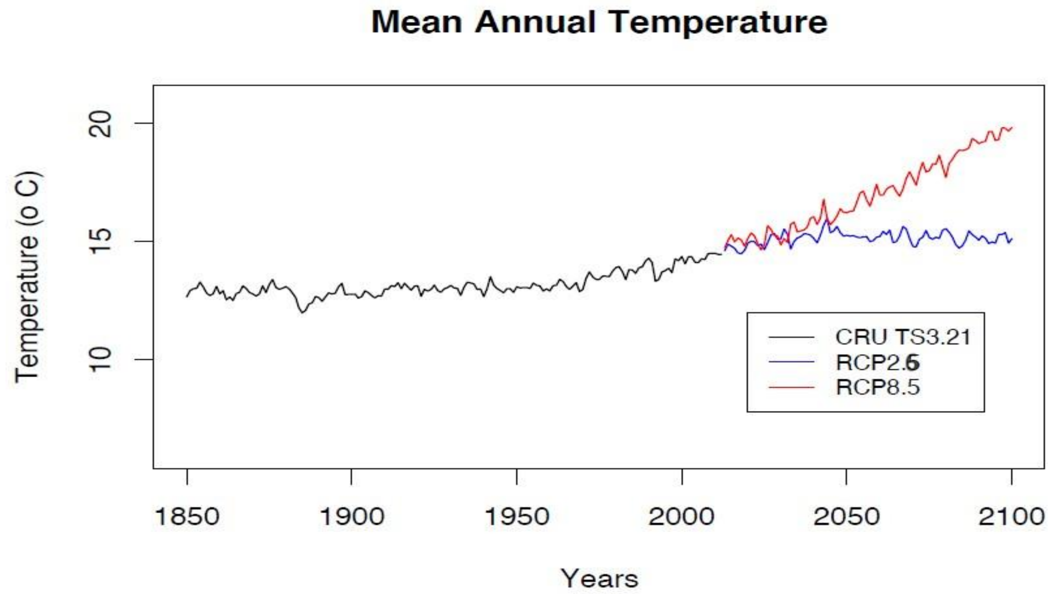


Figure 8: Mean Annual Temperature from 1850 to 2100.

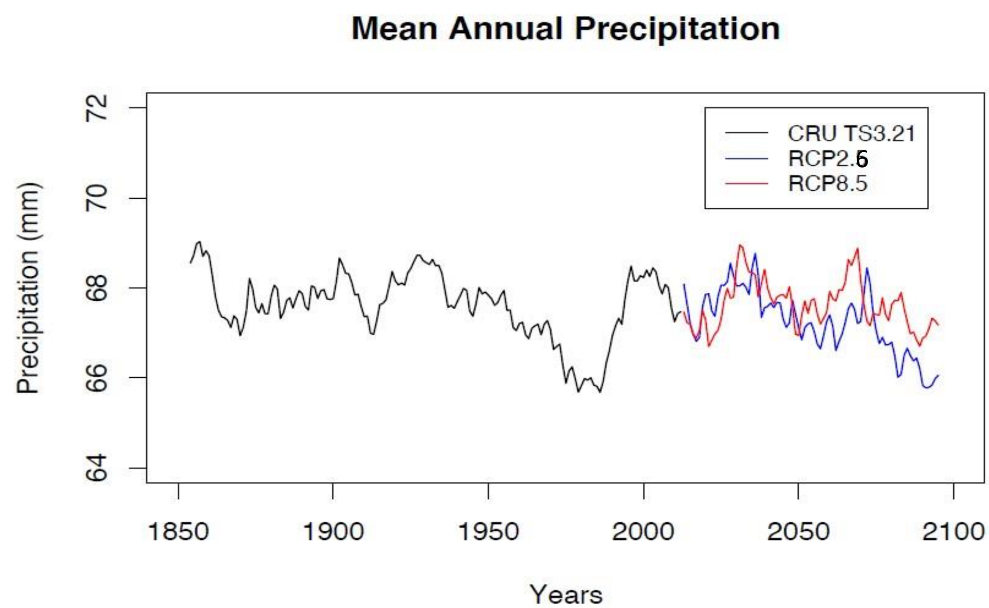


Figure 9: Mean Annual Precipitation from 1850 to 2100.

Croplands and pastures were correspondingly treated as natural grasslands in the vegetation model (Ahlström et al., 2012). The fractional cover of the land use for the historical and scenario period employed by Ahlström et al., (2012) was obtained from the data set of Hurtt et al., (2011). The simulations start from 1850 and end at 2100.

The model output was driven by gridded monthly data for air temperature and precipitation from Climate Research Unit (CRU) Time Series version 3. The climatic data was bias corrected by using CRU TS 3.0 1961-90 on annual and monthly basis (seasonal bias correction), the monthly fields of precipitation, downward shortwave radiation and air temperature were bi-linearly interpolated to the CRU grid at a resolution of 0.5°x0.5°. The correction in the climatology field (1961-90) adjusts for biasness and annual averages and seasonal distribution.

3.3 List of Outputs

Abbreviation	Full name	Description
NEE	Net Ecosystem Exchange	Net Ecosystem Exchange is a measure of the net exchange of C between an ecosystem and the atmosphere (Kramer et al.,2002)
VegC	Vegetation Carbon	Total Carbon stored in plants and in soil is the vegetation carbon (IPCC, 2000)
Soil Carbon	Soil Carbon	Soil organic matter is composed of soil microbes including bacteria and fungi, decaying material from once-living organisms such as plant and animal tissues, fecal material, and products formed from their decomposition (Todd A. Ontl et al,. 2012)
Total Carbon	Total Carbon	All carbon present in any particle and compound (Isabella Bisutti et al,. 2004)

Table 1: List of Outputs

3.4 Data Analysis

Data acquired from (Pugh et al., 2015) was further reanalyzed in R- programming language in RStudio (RStudio) The shapefile for Pakistan region was downloaded. Extraction of LPJ-GUESS output was analyzed within the R- software by the package DGVM Tools (Matthew Forrest et al. 2019). DGVM Tools provides a high-level framework for assessing DGVM data output. The package has the ability to read the model data and aggregate in spatial and temporal time scale and results in plots that are comparable to the standard observed data sets. The framework provides a comprehensive DGVM analysis workflow, taking raw model output through comprehensive analysis and evaluation to publication-quality figures. It also easily interfaces with both the raster package and base R functionality. Various R packages were also utilized such as raster package (Hijmans, 2020).

3.5 Data Years:

Simulations were split in number of years as follows:

i. 1850-1950 (referred to as Past)

ii. 1951-2012 (referred to as Present)

iii. 2013-2100 (referred to as Future)

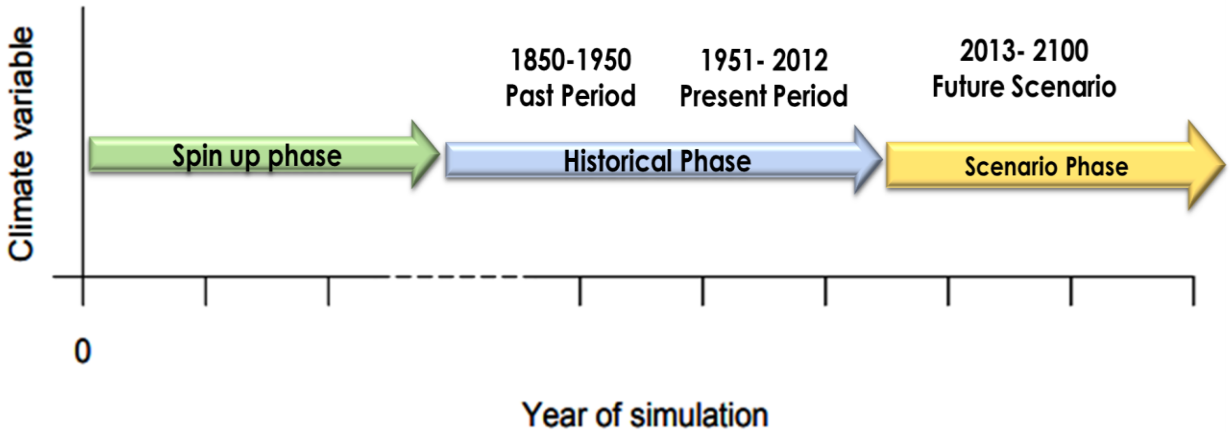


Figure 10: The division of time scale taken for this study.

The simulation for a particular area or grid cell normally follows three phases, separated in simulation time. The first phase of the simulation is known as the spin up phase. The simulation begins with “bare ground”, which means that the modelled area is empty with no vegetation present. After the spin up phase from 1850 the “historical phase” begins and runs through till 2012. In this phase historical climatic data and atmospheric CO2 from the respective GCM historical simulation was applied. For this research the historical years are divided into periods from 1850-1950 represents the past period and from 1951-2012 represents the present period. The future scenario begins from 2013 and runs through till 2100.

3.6 Comparison with Calculated Data

3.6.1 Comparison with Regional Emissions Inventory ASIA (REAS)

This website provides data sets and related information of the series of Regional Emission inventory in ASia (REAS). First version of REAS (REASv1.1) were developed by Ohara et al. (2007), which accounted for actual emissions during 1980-2003 and projected ones in 2010 and 2020. The inventory was updated by Kurokawa et al. (2013) as REASv2.1 for the period between 2000-2008 and datasets of Regional Emission inventory in Asia for Persistent Organic Pollutants (REAS-POP) 1.0 focusing on polycyclic aromatic hydrocarbons (PAHs) in Northeast Asia were also developed (Inomata et al., 2012). The current latest version REASv3.2 provides a long historical emission inventory during 1950-2015 in Asian region (Kurokawa and Ohara, 2020).

The gridded data set of carbon dioxide was downloaded from the REAS global dataset. The Carbon flux of Net Ecosystem Exchange was converted into data frames. Once the Carbon dioxide was calculated from Net Ecosystem Exchange, we calculated the correlation between the two variables.

3.6.2 Comparison with Vegetation carbon estimates

The data from Statistical Beauru of Pakistan was used for comparison with the vegetation carbon modelled carbon pool. In this study we incorporated vegetation carbon that contains annual sums of carbon pool with spatial resolution for the period 1980–2015. In order to compare LPJ-GUESS Carbon Pool estimates, total crop production of Pakistan datasets was downloaded from "The Statistical Beauru of Pakistan" website. The data points for each year were divided by the total area of Pakistan in order to convert it into tonnes per hector.

As vegetation carbon is calculated as the sum of above- and belowground estimates and converted the results to live tree carbon content by using a conversion factor of 0.5 by the following equation(Saatchi et al., 2011).

$$\text{Vegetation Carbon} = 0.5(\text{Above Ground Biomass} + \text{Below Ground Biomass})$$

Once the vegetation carbon was added now the data is ready to compare with the modeled observation.

Chapter# 4

4. RESULTS AND DISCUSSION

LPJ-GUESS has the ability to simulate the future vegetation taking account input of CO2 concentration based on set of scenarios known as Representation Concentration Pathway.

The first RCP is RCP2.6. The RCP 2.6 is the optimistic scenario. It is assumed that maximum effort is taken to reduce emissions by use of renewable energy generation and additional carbon capture emissions technologies.

The RCP 4.5 and 6.0 are both moderate scenarios, in which efforts to reduce the emissions are lower than the RCP 2.6.

The fourth scenario is the RCP 8.5, which is the most extreme scenario, where efforts to curb the emissions is minimal and the energy generation is highly dependent on fossil fuels.

For this research, RCP 2.6 and RCP 8.5 have been utilized.

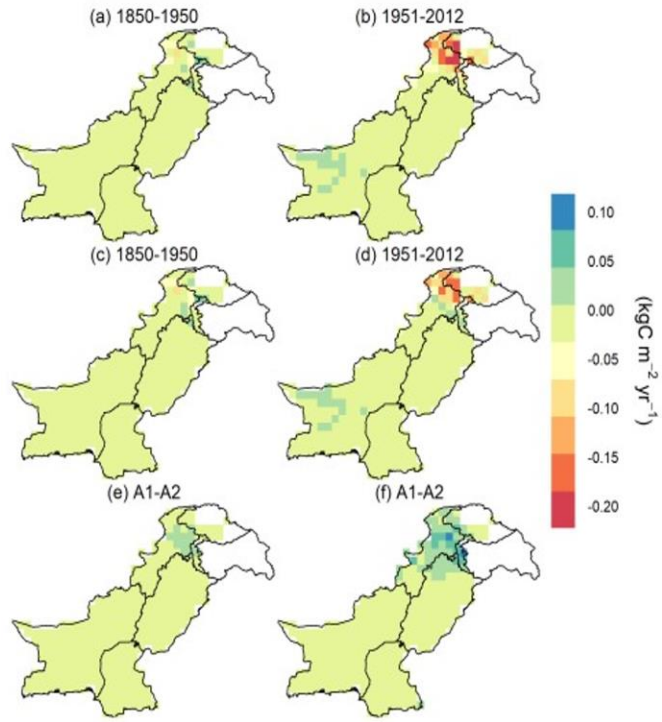


Figure 11: Spatial maps of Net Ecosystem Exchange.

4.1 Estimation of Net Ecosystem from 1850- 2100.

The above figure shows averaged model estimated NEE simulated by the model. It is important to note that the region acts as a carbon source if the NEE values are positive or act as a net carbon sink if the NEE values are negative.

The upper panel shows NEE for the time period of 1850-1950 and 1951-2012 for the fixed land use (fixed land use referred as the land having no agricultural practices).

The middle panel shows the NEE for the time period of 1850-950 and 1951-2012 for the transient land use (transient land use indicate the land with agricultural practices including harvest, grazing and tillage).

The lower panel shows the difference between the fixed land use and the transient land use historical in figure showing on the left bottom side and on the right bottom side the difference of fixed and transient land use present is shown.

Spatial patterns of NEE show that in past the north region of Pakistan act as carbon sink. The representation of the land use change in cumulative historical land use i-e; from the year 1850-1950 shows less CO2 emissions in blue area. However, from 1951-2012 there were lots of agricultural activities made this region sink as well as source of CO2.

And in the difference panel the figure bottom left is showing the difference in fixed and transient land use historical, there is less CO2 emissions in the upper parts of Pakistan and figure bottom right shows more CO2 emissions comparatively.

Using data from 28 flux measurement sites, an analysis of the relationship between annual net ecosystem exchange (NEE) and the length of the carbon uptake period (CUP). The observations suggest a linear correlation between the two quantities (Galian et al,. 2005).

The large net release of carbon in the various parts of north is due to the land use change practices like harvest, tillage and grazing.

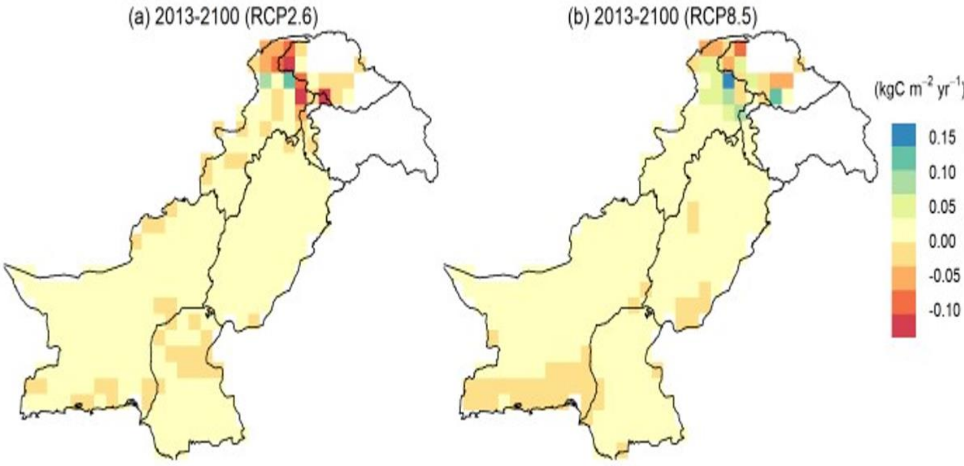


Figure 12: The emissions of NEE as simulated by MPI-ESM-LR from 2013-2100.

For the future scenarios the figure on the left side illustrates RCP 2.6 from 2013-2100, it predicts that the north of Pakistan will act as a carbon sink as compared to the RCP 8.5 scenario, the red pixels indicate the CO2 absorption in this region. While the blue pixels indicate CO2 emissions in the upper parts in 8.5 scenario.

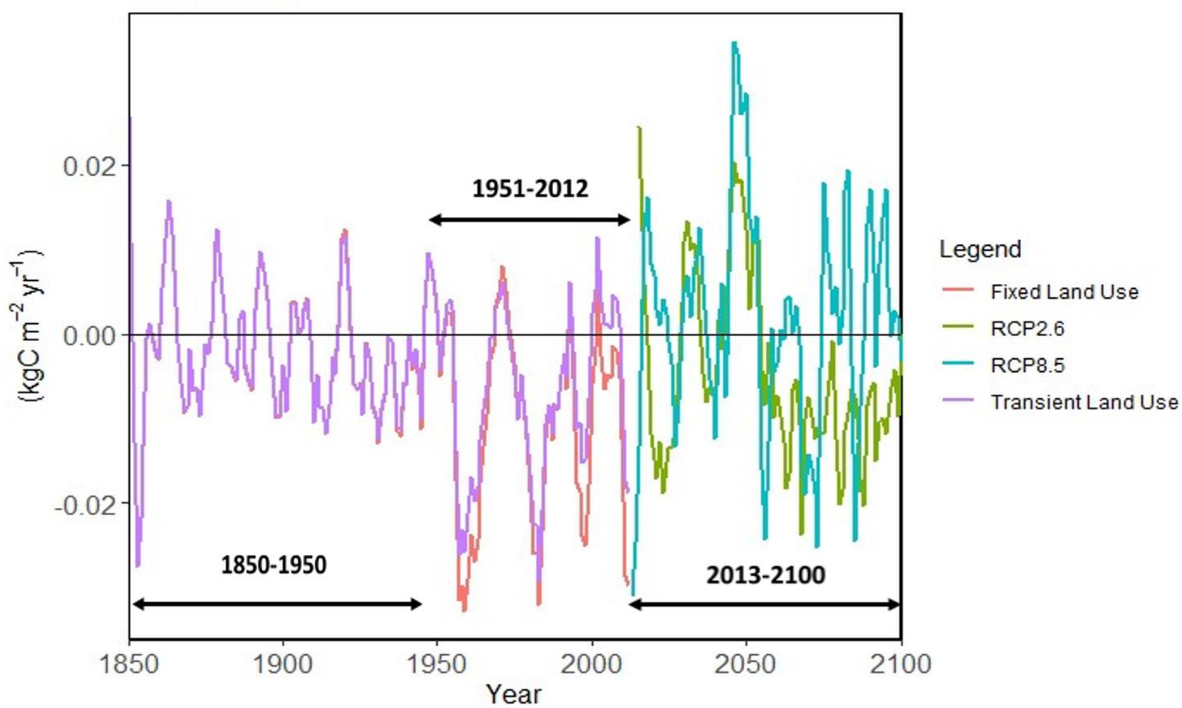


Figure 13: Temporal trend of Net Ecosystem Exchange.

For the temporal time series graph of NEE red line shows fixed land use while the purple shows the transient land use, from 1850-1950 both the fixed and transient land use are not showing any difference, but from 1951-2012 there is a slight difference of CO2 absorption and emissions can be seen. For the future predicted scenarios, the green line RCP 2.6 and the blue line RCP 8.5 shows much fluctuations from 2013-2100.

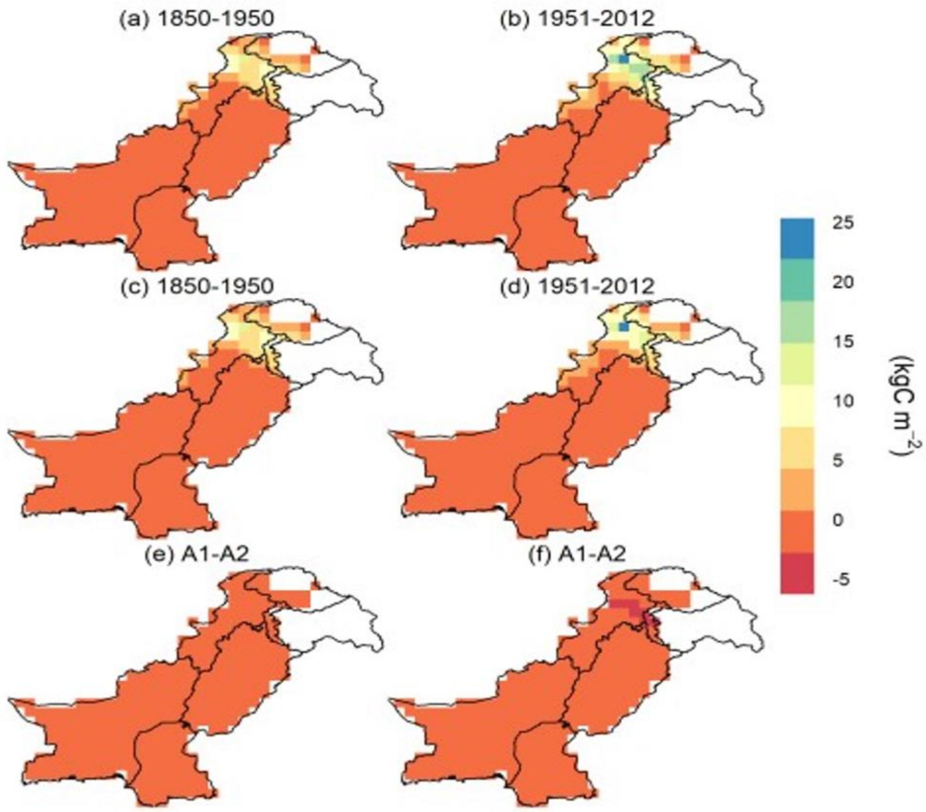


Figure 14: Spatial patterns of Vegetation Carbon

4.2 Estimation of Vegetation Carbon from 1850-2100

This figure illustrates the spatial trends of mean Vegetation carbon by the model. Similarly, the top panel shows the vegetation carbon for the time period of 1850-1950 and 1951-2012 respectively.

The middle panel shows the vegetation carbon from 1580-1950 and 1951-2012 respectively. For the past period most of the vegetation carbon is located in the northern parts of Pakistan, where the vegetation carbon is allocated in agricultural lands both in fixed and transient land use. Whereas because of the recent land use changes in the present period from 1951-2012 in fixed and transient land use the increase in vegetation carbon is seen in upper parts of Pakistan.

The bottom panel shows the difference between the fixed and transient land use. There is very minimum or zero vegetation carbon is present. However, due to the agricultural practices in transient land use the values of vegetation carbon are slightly higher than in fixed land use and because of that the result in the difference panel is around zero.

Further to compare vegetation carbon with the past study Fang Jing Yun in 2007 estimates the terrestrial vegetation carbon sinks in China from 1981-2000 and suggest considerable uncertainties exist in the study, especially in the estimation of soil carbon sinks, and need further intensive investigation in the future.

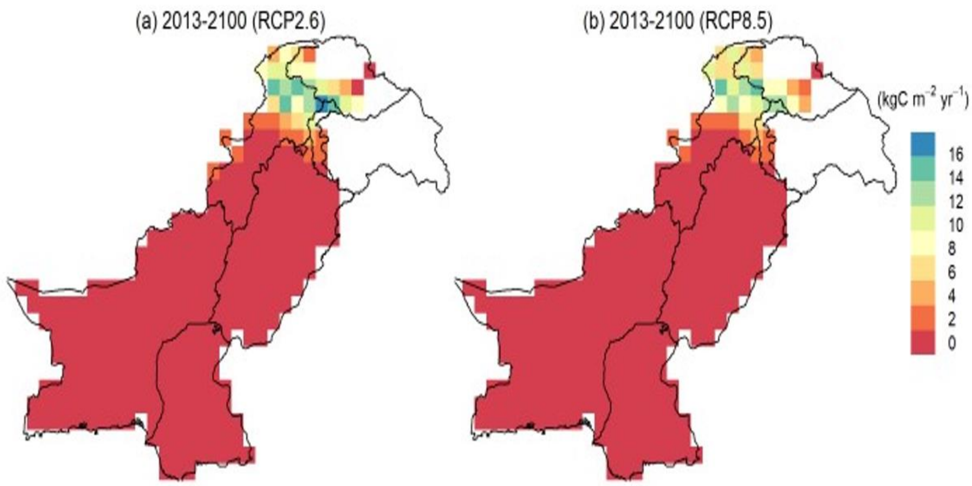


Figure 15: Pakistan showing mean Vegetation Carbon from the LPJ-GUESS model (average for the period 2013–2100)

In RCP 2.6, being the optimistic scenario, it is predicted that the status of vegetation carbon is higher than in the historical and present period. And in RCP 8.5 scenario from 2013-2100 there will be not much change in vegetation carbon as compared to RCP 2.6 scenario.

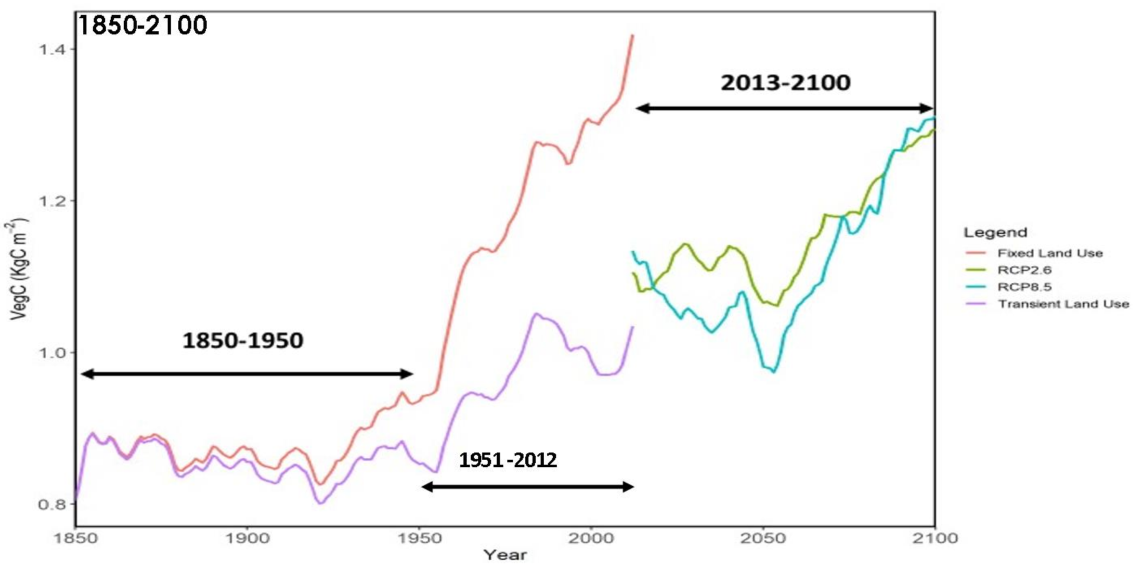


Figure 16: Temporal Trend of Vegetation carbon

The visualization displayed illustrates the mean temporal trend of vegetation carbon for the past, present and future time periods. Model estimates of Pakistan region vegetation carbon storage show a decreasing trend from 1850-2012 in transient land use with purple line. Whereas fixed land use shows increasing trend. For future scenarios RCP 2.6 and RCP 8.5 there is less difference in the trend. There can be seen a decrease in vegetation carbon after 2050 but by 2100 it will be higher than 2.6 scenario.

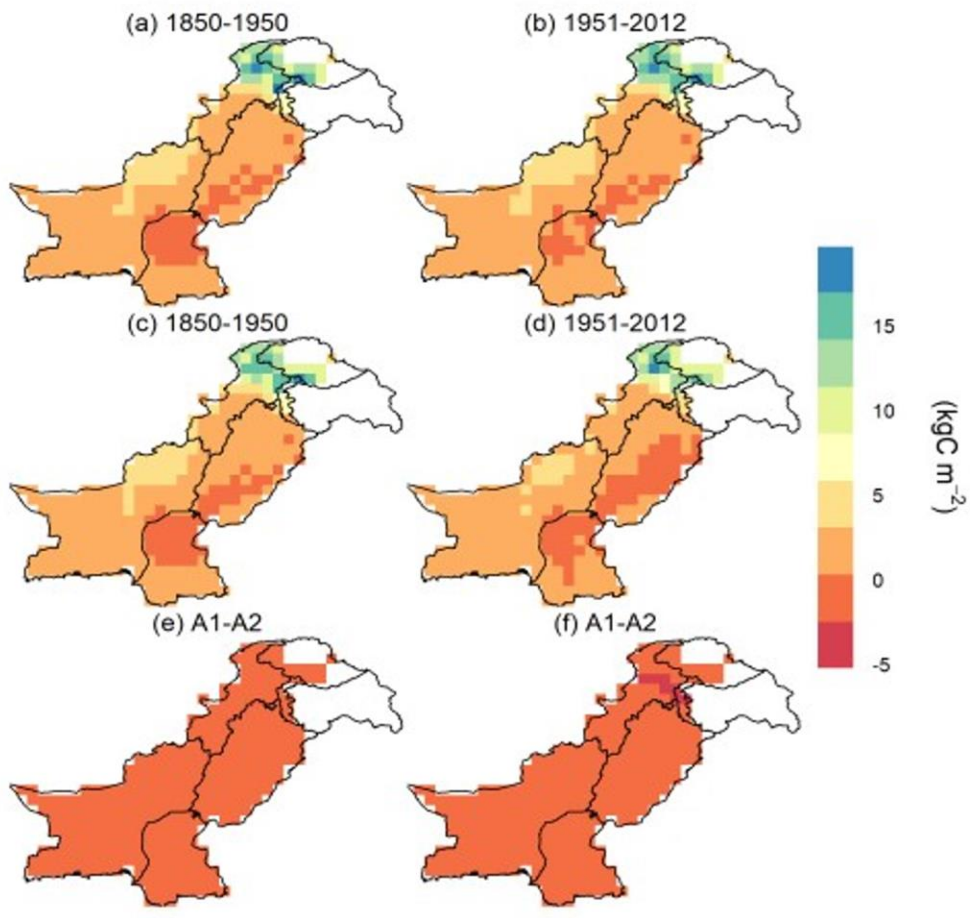


Figure 17: Spatial Patterns show Soil Carbon

4. 3 Estimation of Soil Carbon

This figure shows the spatial trends of mean soil carbon by the model. Top panel shows the soil carbon for the time period of 1850-2012. Middle panel also shows the soil carbon for the same year but for the transient land use. The bottom panel shows the difference of both fixed and transient land use. As a result of increased soil legacy flux from harvest and grazing and increased heterotrophic respiration rates in tilled soils, which respectively reduce soil carbon inputs in transient land use in the lower part of Pakistan.

Due to the land use change practices the north of Pakistan shows more soil carbon. When ignoring the agricultural processes fixed land use almost accumulates slightly more soil carbon under the same climatic conditions. Because the values are very close to each other that's why the difference panel not show much changes it is almost close to zero.

Current farming practices deplete soil carbon, which degrades soil quality, reduces productivity, and results in the need for more fertilization, irrigation, and pesticides. No-till farming with residue mulching would reverse these effects by slowing soil erosion and pollution runoff, benefiting aquatic ecosystems, improving agronomic productivity, and achieving food security (Michael et sl,. 2004).

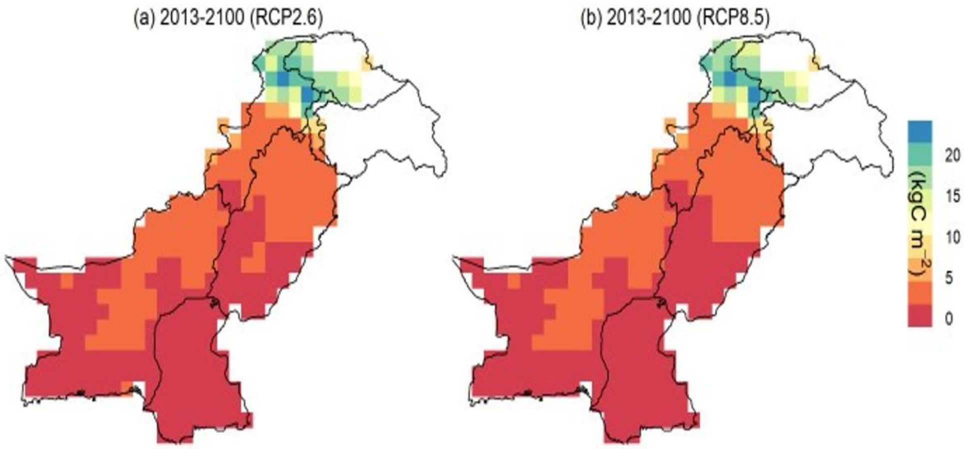


Figure 18: Pakistan region showing mean Soil Carbon stocks from the LPJ-GUESS model (average for the period 2013–2100)

In the future scenarios of RCP 2.6 and RCP 8.5 due to the high temperatures and higher levels of CO2 microbial activities increases and as a result of land use change practices the soil carbon is more in North of Pakistan.

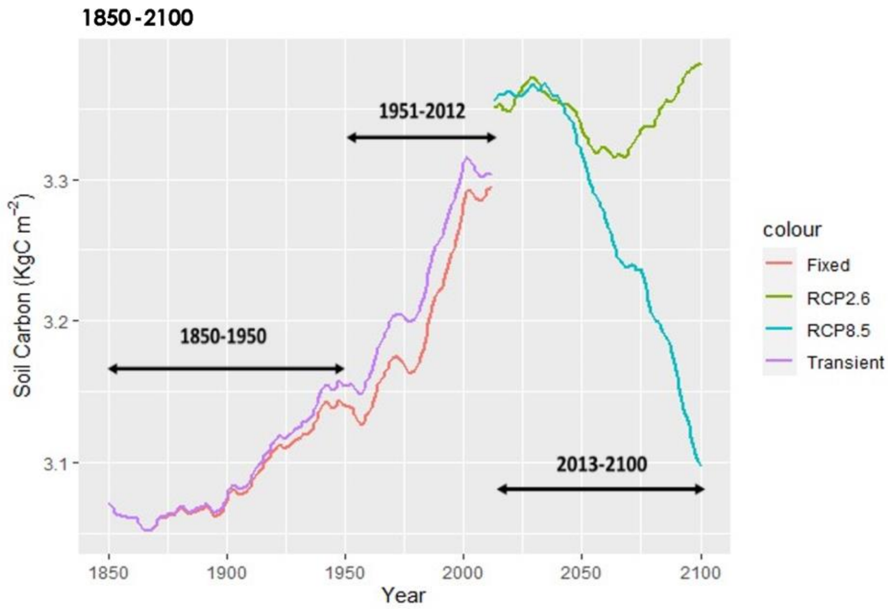


Figure 19: Temporal Trend of Soil Carbon

The soil carbon temporal trend can be seen in this figure shows that the future scenarios the blue and the green line shows much difference in their trends. As I have mentioned earlier that due to increase temperatures and higher levels of CO2 the soil organic carbon disturbs and moving towards the lower organic content present in the soil.

4.4 Estimation of Total Carbon

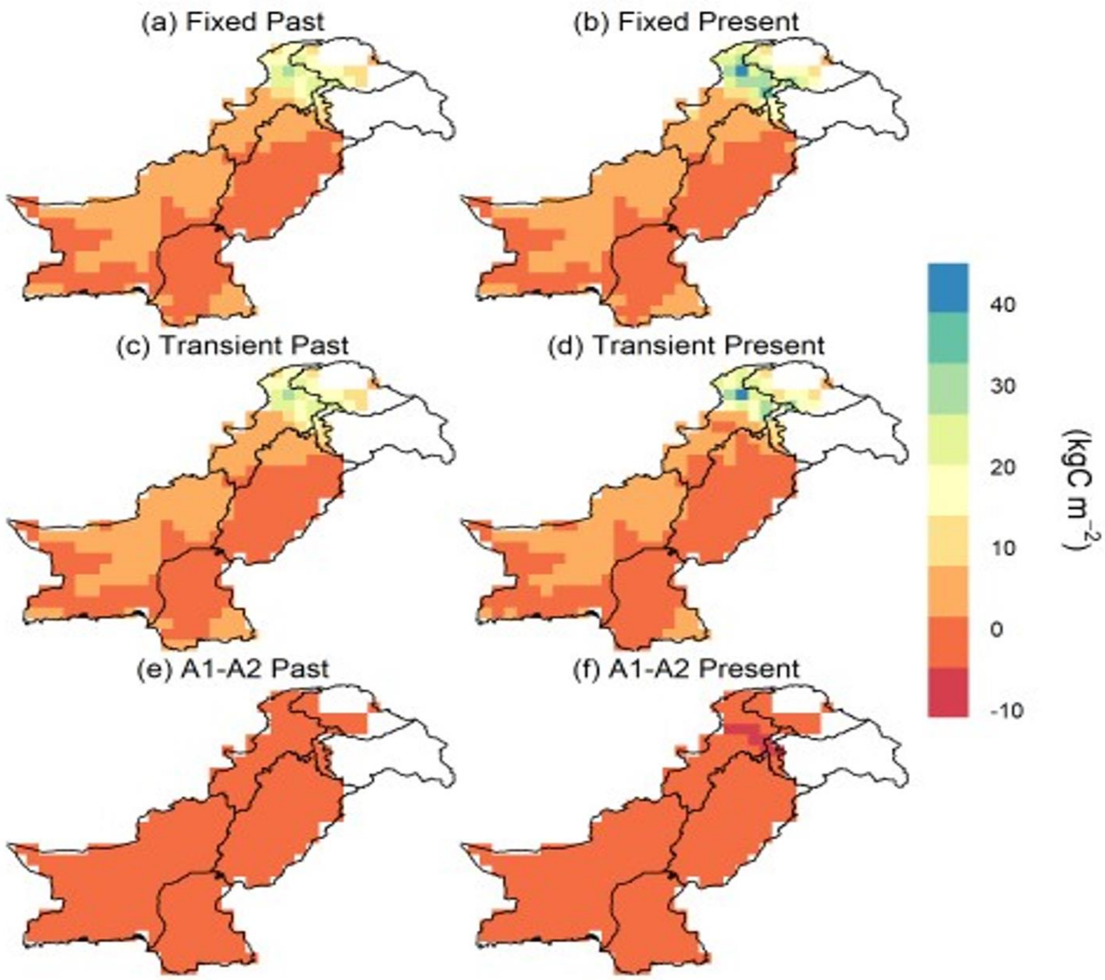


Figure 10: Pakistan region showing mean Total Carbon stocks from the LPJ-GUESS model

This figure shows the spatial trends of mean total carbon by the model.

Top panel shows the total carbon for the fixed land use and the middle panel shows the total carbon for the transient land use. Whereas the bottom panel shows the difference between the fixed and transient land use.

As it is shown in the figure, the light orange shaded parts of Pakistan showing less amount of total carbon present in the soil organic matter in both fixed and transient land use. However, it can be seen that in the upper parts of Pakistan in the top panel of fixed land use the blue or slight yellow pixels showing more total carbon present. Where as in the middle panel of transient land use there is less carbon present in the upper part compare to the fixed land use.

The bottom difference panel of fixed and transient land use show more orange shading which indicates less total organic carbon content present. It is due to the plant residue removal and constraints to crop growth reduce organic inputs into the soil. It is also due to the erosion events that remove topsoil which contains the bulk of soil organic matter.

Past study concluded that estimates of aboveground biomass largely under estimate total carbon stock in ecosystem. Additionally, it is suggested that heterogeneous landscapes impose additional challenges for their study such as sampling intensity (Carlos A. Sierra et al,. 2007).

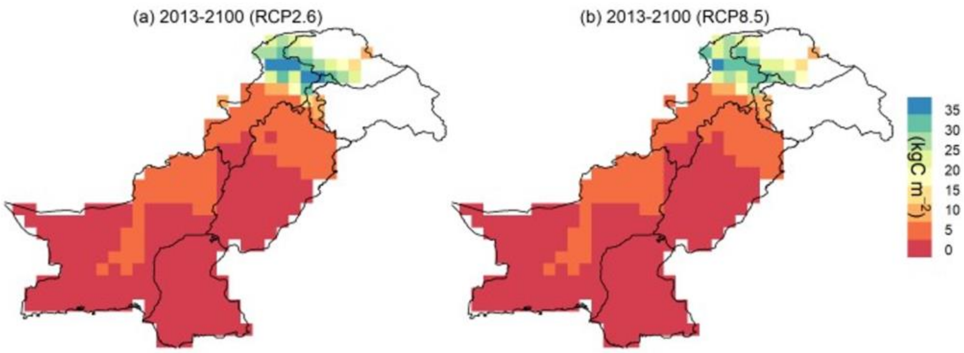


Figure 21: Pakistan region showing mean Total Carbon stocks from the LPJ-GUESS model

The left figure shows the RCP 2.6 scenario for the year 2013 till 2100. This optimistic scenario shows more carbon content in the agricultural soil in the upper parts of Pakistan as compared to the RCP 8.5 scenario, which is due to higher levels of CO2 in the extreme scenario.

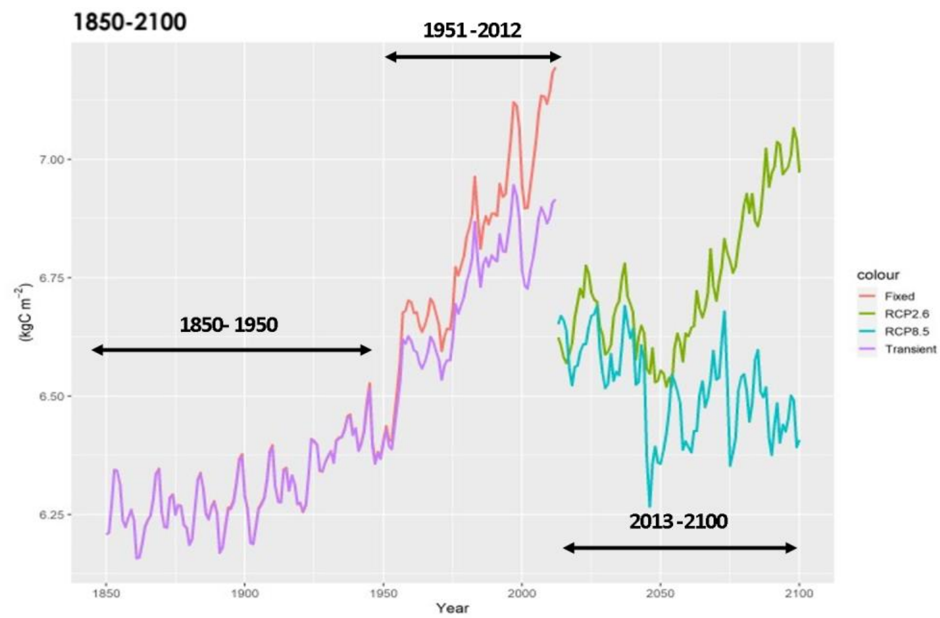
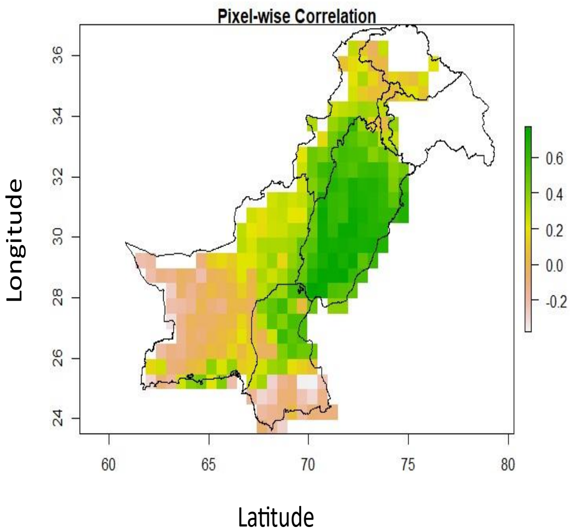


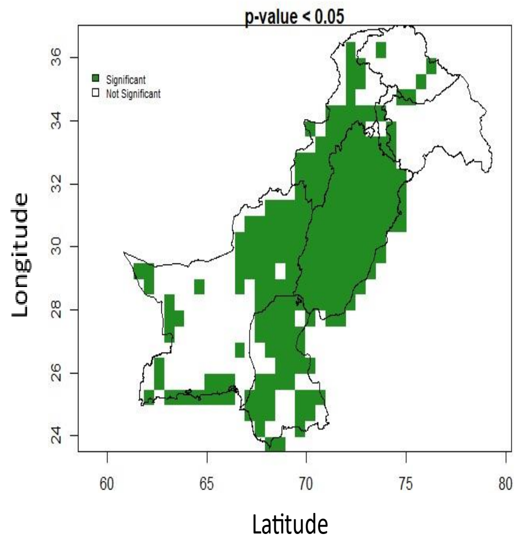
Figure 3: Temporal Trend of total carbon

The temporal trends illustrate that from 1850-1950 the total carbon content in the agricultural soil of transient land use which represent with the purple line and fixed land use which represent with the red color line show not much difference but till 2012 the trend is moving upward showing more carbon content in the agricultural soil. Red color line shows more carbon as compared to the purple line means that in fixed land use as there is no agricultural practices indicates that if the soil is not disturbed it can have more organic carbon is present in it.

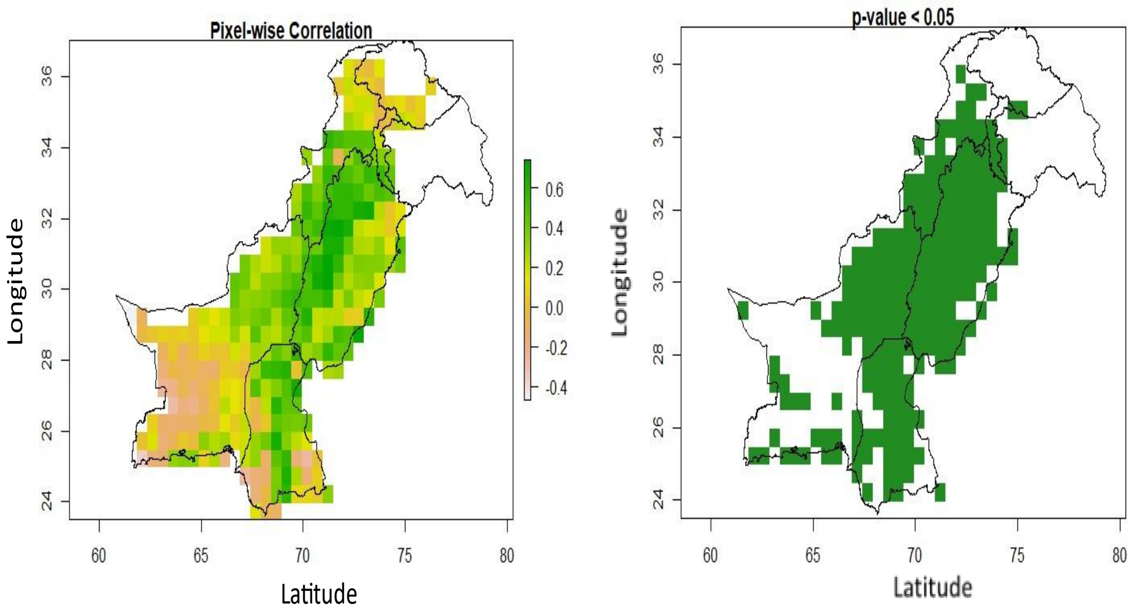
And in future scenarios RCP 2.6 the green line indicates more organic carbon stays in the soil due to the less high temperatures. Whereas the blue line RCP 8.5 indicates less carbon content in soil and vegetation due to extreme temperatures in future.

Correlation Between Modelled CO_2 emissions from NEE (fixed) and Observed CO_2 emissions from REAS (1950 -2015)

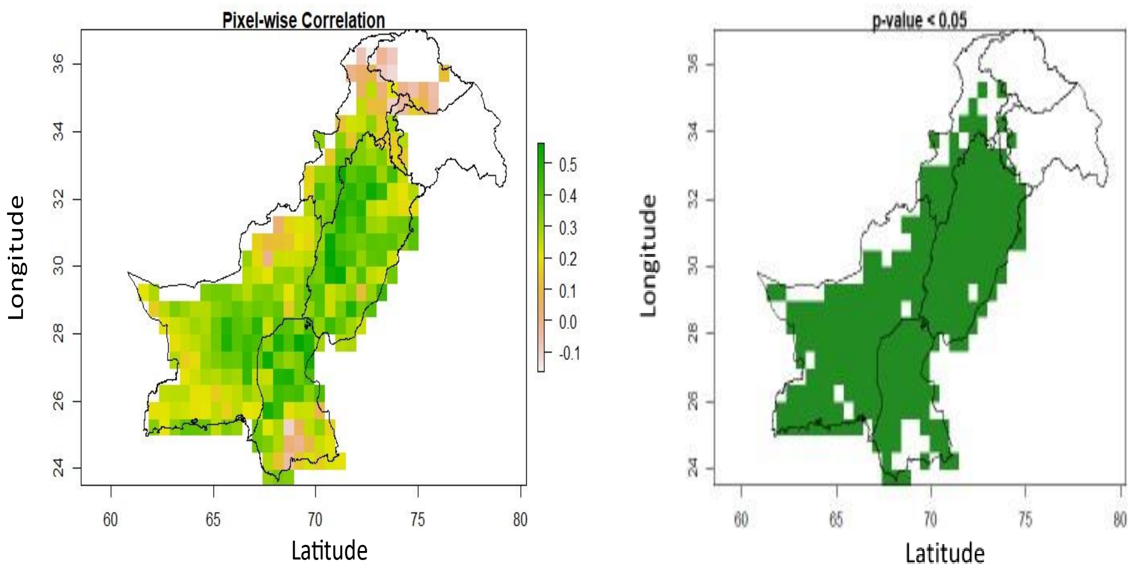




Correlation Between Modelled CO_2 emissions from NEE (transient) and Observed CO_2 emissions from REAS (1950-2015)



Correlation Between Modeled CO_2 Emissions From NEE (Fixed) and Modeled CO_2 Emissions From NEE (Transient)



The second objective is to compare the model and observed CO2 emissions. For this figure modelled CO2 emissions have been taken from the NEE for the fixed land use and the observed CO2 emissions were taken from the REAS inventory. The strong correlation between the two data sets can be seen. The figure shows that the p value the result is statistically significant.

The modeled vegetation carbon from Carbon pool and calculated total crop yield data from Bureau of Statistics of Pakistan starting from 1980 till 2010 were also assessed. The values of total crop yield were converted to the above and below ground biomass factor by multiplying it with 0.5 (Saatchi et al., 2011) in order to compare it with the model calculations.

$$\text{Vegetation Carbon} = 0.5\,(\text{above ground biomass} + \text{below ground biomass})$$

Results have shown that the total crop productivity in terms of carbon for Pakistan was increasing from 0.8 tones C ha^{-1} to around 1.4 tones C ha^{-1} till 2010. And the vegetation carbon by the model was calculated as 1.5 kg C m^{-2} with the slight increase of 1.7 kg C m^{-2} for the fixed land use. Whereas for the transient land use the vegetation carbon is estimated as 1.2 kg C m^{-2} from 1980 and with not much change it remains same till 2010. With the increasing consumption more surface area is converted into agricultural land with the expansion of crop lands and pasture lands leading towards reduction in carbon stored in vegetation from 1998-2000. However, around 2000 the trend took a stable increase which is not much studied in the previous literature. Due to the agricultural activities (like grazing, harvesting and tillage) physical properties of a soil affect resulting in decrease of carbon content present. Inappropriate tillage and poor timing of field operations can cause sub soil compaction which decreases soil productivity and crop yields (Ishaq et al., 2001).

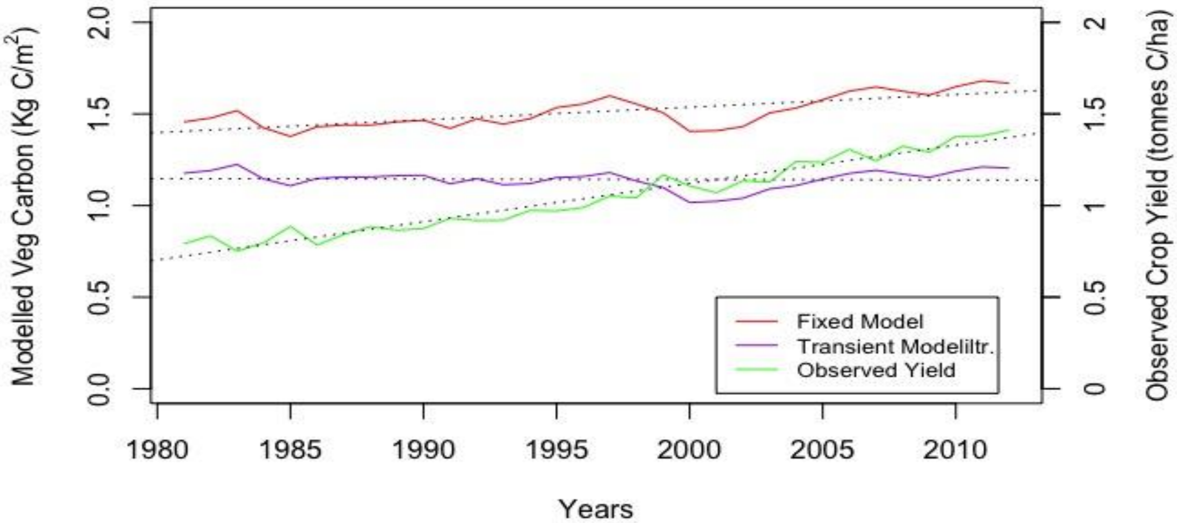


Figure 23: Total Crop Yield as simulated by LPJ-GUESS is represented in green temporal line. The land use change include fixed and transient land use is denoted by red and purple lines respectively.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The LPJ-GUESS simulations revealed that for the past years 1850-1950 agricultural activities emitted less carbon dioxide as compared to 1951-2012. Furthermore, for vegetation carbon, soil carbon and total carbon analyses suggest that for the RCP 8.5 future scenario the model predicts lower carbon values compare to the RCP 2.6 scenario. However, there is a large variation in the net effect on NEE due to uncertainties arising from different climatic forcing. Uncertainties were also found between modeled and calculated data sets. Regional effects are of primary importance and good estimates will be required for the most effective adaptations. Thus, including realistic interactions of carbon dioxide with the environment remains an important area of research, especially in regions with highly diverging trends in land use scenarios.

5.2 RECOMMENDATIONS

The results of the study have indicated that Pakistan will act as both net sink and source of Carbon.

However, the extent to which it will act as both carbon sink and source is uncertain as the LPJ GUESS limits our confidence in inferring which process in the simulated carbon cycle causes the largest share of overall uncertainty. Recommendations based on the outcome from this study are as follows:

- Integration of missing processes to represent realistic processes (such as underlining processes like interplay of land use emissions and bio spheric carbon uptake).
- LPJ GUESS should couple with other GCMs (global climatic models) in order to evaluate dynamic multidirectional fluxes which may cause uncertainties.
- There is a need at policy level for prioritizing crop management practices to develop specific regional models to integrate the results in a more justified scientific way.

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