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Climate Change, Heavy Rainfall, Drastic Flood and Soil Fertility of Crop Lands of Southern Western Ghats India

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Abstract:
The southern western ghats receive around 360 cm annual rainfall, An increasing trend in heavy or extreme rainfall events can cause events like flood which will have a direct adverse effect on lives and properties on large scale, especially a densely populated state like Kerala. Francis and Gadgil, (2006) reported that there is an increase in the intensity and frequency of heavy rainfall events over the Indian Monsoon region, recently. The meteorological and climate communities have recently focused their attention primarily on the effects of climate change on extreme weather events. Significant repercussions result from an increase in heavy rainfall events on managing disasters like floods, food security, soil characteristics, the availability of fresh water and ground water, as well as India's agricultural planning. Soil nutrient loss is a universal phenomenon worldwide (Kenta, 2019), and how to control and prevent nutrient loss is also a focal point of international research (Jiang 2018) and Ros2020). The main factors affecting soil nutrient loss are rainfall intensity (Yang et al 2020). Nutrient loss is possible as While less soluble nutrients like phosphorus are more likely to be lost with sediments moving in eroding soil and run-off water, soluble nutrients like nitrate and potassium can be lost in run-off and drainage water. The study focused on to determine the rate of nutrient loss during frequent flooding.

Keywords: Heavy rainfall, frequent flood, soil fertility, Climate Change

Introduction

Extreme rainfall events (ERE) and related floods are one of the major natural hazards many parts of the world including India (Ahern et al., 2005). Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people. Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected (IPCC, 2023)..
Climate change can be defined as the change in the weather patterns in a particular region or global

scale, for a significantly long period say decades to millions of years. The changes may be noticeable, like change in average weather conditions or change in the statistical distribution of weather events. The weather conditions refer to ambient temperature and pollutant concentration; weather events refer to rainfall, snowfall, water vapor etc (Susann 2015).

Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has further strengthened. Human influence has likely increased the chance of compound extreme events since the 1950s, including increases in the frequency of concurrent heatwaves and droughts. Climate change has reduced food security and affected water security, hindering efforts to meet Sustainable Development Goals. Climate change has caused widespread adverse impacts and related losses and damages13 to nature and people that are unequally distributed across systems, regions and sectors. Economic damages from climate change have been detected in climate-exposed sectors, such as agriculture, forestry, fishery, energy, and tourism. Individual livelihoods have been affected through, for example, destruction of homes and infrastructure, and loss of property and income, human health and food security, with adverse effects on gender and social equity (IPCC, 2023).

Severe precipitation events have occurred over the last few years in India, there have been a number of damaging floods reported in the last decade. The flash floods and severe rainfall events in India caused heavy damages in economy and loss of life (Goswami et al 2006; Rajeevan et al 2008). Wet extremes are projected to become more severe in many areas where mean precipitation is expected to increase, and dry extremes are projected to become more severe in areas where mean precipitation is projected to decrease. In the Asian monsoon region and other tropical areas there will be more flooding. t the frequency and intensity of extreme rainfall increases more strongly with global mean surface temperature than does mean rainfall (Berg et al., 2013; Myhre et al., 2019). Climate change has been one of the most significant impacts. variation in the rainfall pattern which is directly or indirectly Indirect effect on regional water sources which are rain fed/recharged (Udayashankara, 2016).

The study was carried out in three sites that belong to three physiographic zones such as highland, midland and lowland. Kerala is a small strip of land located on the Malabar coast of Southwest India. To the west of Kerala lies the Arabian sea and to the east lies the Western Ghat. Kerala consists of three physiographic zones namely - Eastern highland, Central midland and Western lowland. About 48% of the total area of Kerala is occupied by highlands. Western Ghats form the highland zone of Kerala. The average height of this region is about 900 m above MSL, in which several peaks reach upto 1800 m. Tea, coffee, and spices are some of the plantations of this region with latitude of N8°58'5.87'' and longitude of E77°2'57.29''. Midland is sandwiched between the highland and lowland. It occupies about 41% of the total area of Kerala with latitude of N 8°48'19.95'' and longitude of E 76°52'14.90''. It consists of undulating hills and valleys. Cashew, coconut, rubber, arecanut and banana are some of the important cultivations in midland. Lowlands or coastal plains form the remaining portion of Kerala. It consists of an interconnected network of lakes, rivers, estuaries and brackish water region with latitude of N 8°41'6.03'' and longitude E 76°45'47.07'' and the major crops are coconut and paddy.

Materials and methods

Soil samples were collected from three study areas. From each area, six samples were collected from randomly selected sites, in which three were for control. The surface litter of the soil was scraped away.

Then the soil samples were collected in blocks using a garden spade from the surface to a depth of about 10 cm and transferred into a plastic tray of dimension 45×30×14 cm.

A total of 18 plastic trays of dimension 45×30×14 cm, three wooden stands, PVC pipes, PVC elbows, etc were used to make the experimental apparatus. A small hole was made on one side of the bottom of the tray for the passage of water. In order to prevent the passage of soil through it, the hole was covered using a net. Sample trays collected from each study area were placed in each wooden stand. Each stand consists of six trays containing samples from the same study area. A set of three sample trays were placed one by one on each row of the stand. Another set of three sample trays (control) were placed in a similar manner on the next side of the same stand. Water was supplied to the samples in the first row using PVC pipes. The water from the samples in the first row falls onto the samples on the second row, and from it the water falls onto the samples on the third row. From the samples on the third row, the water passes out through an outlet connected to it. Soil samples were collected after every one week interval and air-dried. The samples were analyzed for pH, Organic carbon, Total nitrogen, Total phosphorus and Total potassium. The statistical analysis of the data was done using standard statistical software IBM SPSS Statistics 28. Statistical tool ANOVA was used for the statistical analysis. Tukey's multiple comparison tables help to find out the difference between specific pairs of groups. It tests all pairwise differences, it is also robust with respect to unequal group sample sizes (McHugh, 2011).

Results and Discussion

The study has been carried out in order to determine the impact of flooding on the nutrient status of lowland, midland and highland soil of Southern Western Ghats. Flood occurs when the surface water covers the land that is normally dry or when water overflows normal confinements (Kwari *et. al*., 2015). Flooding influences the physical, chemical and biological properties of the soil, which in turn influences its fertility and productivity. pH affects the plant growth because it influences the availability of both essential elements (phosphorus, zinc, iron, copper, etc.) and non-essential elements (aluminium), which can be toxic to plants at elevated concentrations (Slattery *et. al*., 1999). pH scale ranges from 0 to 14 with 7 being neutral. Even though plants can tolerate the pH between 5.2 and 7.8, most of the plants grow best in soil pH between 6 and 7 (Bierman and Rosen, 2005). Both natural and anthropogenic processes can affect the pH of the soil. The mean pH value of the samples from the lowland, midland and highland areas during initial observations are 5.0, 4.1 and 4.06 respectively. The mean pH value of the samples from the lowland, midland and highland after experienced flooding are 6.7, 5.42 and 5.4 respectively. The result indicates that frequent flooding leads to increase the soil pH. It is also observed that pH of lowland soils was most affected by flooding compared to that of midland and highland soils. The results obtained correspond to the study of Ding *et. al* (2019) that flooding of soils with an initial pH < 6.5 increased the pH of the soil to approximately 7.0. But in the case of soils with pH > 6.5, flooding initially decreased and then increased the pH to approximately 7.0. The main factors that controlled the pH change after flooding were initial pH of soil, organic matter content, cation exchange capacity and extent of flooding. Pointing *et. al* (2021) also observed that the soil pH increases with flooding conditions. This is due to the reducing conditions of the soil created by flooding. Under reducing conditions more H^+ ions are consumed and thus the pH increases.

Soil organic matter is the organic part of the soil that includes plants and animals detritus at various stages of decomposition and microorganisms. Soil organic carbon is simultaneously a source and sink for nutrients and plays a vital role in soil fertility maintenance (Bation *et. al*., 2006). Organic carbon enhances soil structure by holding the soil particles together as aggregates. It also improves the physical properties of the soil such as water holding capacity, gaseous exchange, water infiltration, root growth and ease of cultivation (Chan, 2008). SOC is a natural resource for the sustainable development of human society and a key foundation for sustainable forestry development (Lei *et. al.*, 2019). The mean value of organic carbon of the samples from the lowland, midland and highland areas during initial observations are 0.96%, 0.91% and 1.1% respectively. Organic carbon of the soil samples from the lowland, midland and highland areas. The mean organic carbon value of the samples from the lowland, midland and highland after experienced flood are 0.21%, 0.40% and 0.57% respectively. This result indicates that flooding the soil has decreased the soil organic carbon. It is also observed that organic carbon of lowland soils was most affected by flooding compared to that of midland and highland soils. It is due to the sandy texture of the lowland soil. Leaching occurs more rapidly in sandy soils. The results obtained corresponds to the observations of Wang and Bettany (1993) that flooding reduced the concentration of soil organic carbon.

Nitrogen in soil exists in two forms, namely organic and inorganic forms. It cycles between the two forms. Soil inorganic nitrogen, which is derived from soil organic nitrogen mineralization and fertilizers is the main form of plant available nitrogen (Chen *et. al.*, 2014). The interconversion of organic and inorganic forms of nitrogen in the soil is carried out by soil microorganisms. This conversion is influenced by several factors such as soil moisture, temperature, soil aeration, soil pH, nature of organic material, etc. Nitrogen is an essential plant nutrient. It stimulates root growth and crop development as well as uptake of other nutrients (Hoffman and van Cleemput, 2004). The removal of nitrogen from the soil can be influenced by factors such as volatilization, leaching, denitrification, runoff, crop removal and soil erosion. Temperature, rainfall, moisture, organic matter, vegetation and terrain features also influence the total nitrogen content in the soil (Miller and Donahue, 2001). The mean value of nitrogen of the samples from the lowland, midland and highland areas during the initial observations are 0.095%, 0.091% and 0.11% respectively. The mean nitrogen value of the samples from the lowland, midland and highland areas after experienced flooding are 0.021%, 0.04% and 0.057% respectively. This result indicates that flooding the soil has decreased the soil nitrogen content. It is also observed that nitrogen content of lowland soils was most affected by flooding compared to that of midland and highland soils. It is because the rate of leaching is greater in soils with sandy texture. The results obtained correspond to the study of Reddy *et. al* (1984) that nitrogen transformations taking place in flooded soils have an influence on nitrogen loss from the system. It was found that nitrification - denitrification process was mainly involved in the nitrogen loss from flooded soils. Furthermore, slow nitrification activity was found to be limited in controlling nitrogen loss from flooded soils, whereas rapid denitrification was found to be unrestricted in controlling nitrogen loss. Alaoui-Sosse *et. al* (2005) also observed that flooding had a negative impact on the growth and available nitrogen in the soil. Further analysis showed that flooding reduced the nitrate level in the soil, rhizosphere and roots of the seedlings, but increased the concentration of ammonium.

Phosphorus is typically highest in the youngest actively growing tissues of most plants, and gradually shifts to the seeds and fruits as the plants mature (Ashworth and Mrazek, 1995). Phosphorus exists in both organic and inorganic forms. Organic forms include phosphates, phospholipids, phosphoglycerides, phosphate sugars, nucleic acid and phosphonates. Inorganic forms include appetite, complexes of iron and aluminum phosphates, and phosphorus absorbed on dry particles (Albert *et. al.*, 1981). Phosphorus is generally bound to soil particles or incorporated into organic matter. The release and export of phosphorus from the soil is controlled by factors such as geology, soil composition, precipitation, air temperature, pH, hydrological conditions, etc. Plants absorb phosphorus from the soil mainly in orthophosphate forms. The level of orthophosphate in soil with large amounts of iron and aluminium hydrous oxides is largely determined by sorption-desorption reactions (Holtan *et. al*., 1988). The mean phosphorus value of the samples from the lowland, midland and highland areas during initial observations are 129.33 Kg/ha, 15.33 Kg/ha and 23 Kg/ha respectively. The mean phosphorus value of the samples from the lowland, midland and highland after experienced flood are 56.16 Kg/ha, 9.66 Kg/ha and 13.83 Kg/ha respectively. This result indicates that flooding the soil has decreased the phosphorus content. It is also observed that phosphorus content of lowland soils was most affected by flooding compared to that of midland and highland soils. Since leaching is greater in soils with sandy texture, the rate of decrease of phosphorus is greater in the lowland soil.

Potassium improves the nitrogen use efficiency of plants (Prajapati and Modi, 2012). Potassium exists in soil in four forms - solution, exchangeable, non-exchangeable or fixed and structural or mineral form. Majority of the total potassium is in mineral form, that is, about 98%. Potassium in solution form is directly absorbed by plants and microbes, and this form is more prone to leaching. Forms of potassium in the order of their availability are solution > exchangeable > fixed (non-exchangeable) > mineral (Mouhamad, 2016). The mean potassium value of the samples from the lowland, midland and highland areas during initial observations are 402 Kg/ha, 177 Kg/ha and 210.66 Kg/ha respectively. The mean potassium value of the samples from the lowland, midland and highland after three weeks of experienced flooding are 253.83 Kg/ha, 109 Kg/ha and 162.33 Kg/ha respectively. This result indicates that flooding the soil has decreased the soil potassium content. Since the rate of leaching is greater in soils with sandy texture, it is observed that potassium of lowland soils was most affected by flooding compared to that of midland and highland soils.

Conclusions

The observations obtained in the present study support the hypothesis of the work, which states that flooding has a significant impact on the nutrient status of the soil. Prolonged flooding can cause leaching of nutrients in the soil, which in turn may affect the productivity of the soil. This can ultimately lead to the desertification of the land. According to Narteh and Sahrawat (1999) flooding changed the chemical and electrochemical properties of the soil; varying changes were observed in the concentration of different nutrients such as pH, redox potential and nutrient content of the soil. Ethan (2015) also observed changes in electrochemical and chemical properties of paddy soils due to flooding. Anaerobic conditions of the flooded soil reduced the decomposition rate of organic matter and also induced various reduction processes along with emission of various gases. Natarajan *et. al* (2010) reported that floods had a negative impact on the soil and plant nutrients. Flood caused severe loss of soils, soil organic matter, soil nutrients and crops which in turn contributed to a decrease in crop productivity thus affecting the rural economy of the area. According to Kalshetty *et. al* (2012) flood had a negative impact on the overall quality of the soil which in turn can affect the vegetation.

References

1. Ahern M., Kovats R.S., Wilkinson P., Few R., Matthies F. (2005): Global health impacts of floods: epidemiologic evidence. Epidemiol. Rev., 27 (1), 36–46.

2. Alaoui-Sossé, B., Gérard, B., Binet, P., Toussaint, M.L. and Badot, P.M. (2005). Influence of flooding on growth, nitrogen availability in soil, and nitrate reduction of young oak seedlings (*Quercus robur L.*). Annals of Forest Science, 62(6), 593-600.
3. Albert, E.E., Neibling, W.H. and Moldenhauer, W.C. (1981). Transport of sediment nitrogen and phosphorus in runoff through corn stalk residue strips. Soil Science Society of America Journal, 45(6), 1177-1184.
4. Bation, O.A., Kihara, J., Vanlauwe, B., Waswa, B. and Kimetu, J. (2006). Soil organic dynamics, functions and management in West African agroecosystems. Agricultural systems, 94(1), 13-25.
5. Bierman, P.M. and Rosen, C.J. (2005). Nutrient cycling and maintaining soil fertility in fruit and vegetable crop systems. University of Minnesota.
6. Chan, Y. (2008). Increasing soil organic carbon of agricultural land. Primefact, 735, 1-5.
7. Chen, B., Liu, E., Tian, Q., Yan, C. and Zhang, Y. (2014). Soil nitrogen dynamics and crop residues: A review. Agronomy for sustainable development, 34(2), 429-442.
8. Ding, C., Du, S., Ma, Y., Li, X., Zhang, T. and Wang, X. (2019). Changes in the pH of paddy soils after flooding and drainage: modeling and validation. Geoderma, 337, 511-513.
9. Ethan, S. (2015). Effect of flooding on chemistry of paddy soils: a review. International Journal of Innovative Science, Engineering and Technology, 2(4), 414-420.
10. Ethan, S. (2015). Effect of flooding on chemistry of paddy soils: a review. International Journal of Innovative Science, Engineering and Technology, 2(4), 414-420.
11. Francis P.A. and S. Gadgil (2006): Intense rainfall events over the west coast of India. Meteorol. Atmos. Phys., 94, 27-42.
12. Goswami B N, Venugopal V, Sengupta D, Madhusoodanan M S and Xavier P K 2006 Increasing trend of extreme rain events over India in a warming environment; Science 314 1442–1445.
13. Holtan, H., Kamp-Nielsen, L. and Stuanes, A.O. (1988). Phosphorus in soil, water and sediment: an overview. Phosphorus in freshwater ecosystem, 19-34.
14. Holtan, H., Kamp-Nielsen, L. and Stuanes, A.O. (1988). Phosphorus in soil, water and sediment: an overview. Phosphorus in freshwater ecosystem, 19-34.
15. IPCC 2007 Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change.
16. IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 36 pages. (in press).
17. Jiang JY, Fan H, Pang BK, Zhang JS, Li ZL, Jiang SS, et al. Assessment of reactive nitrogen mitigation potential of different nitrogen treatments under direct-seeded rice and wheat cropping system. *Environmental science and pollution research international*. 2018;25(20):20241–20254. 10.1007/s11356-018-2104-1
18. Kalshetty, B.M., Giraddi, T.P., Sheth, R.C. and Kalashetti, M.B. (2012). River Krishna flood effects on soil properties of cultivated areas in Bagalkot District, Karnataka state. Global Journal of Science Frontier Research Chemistry, 12(6), 23-28
19. Kalshetty, B.M., Giraddi, T.P., Sheth, R.C. and Kalashetti, M.B. (2012). River Krishna flood effects on soil properties of cultivated areas in Bagalkot District, Karnataka state. Global Journal of Science Frontier Research Chemistry, 12(6), 23-28

20. Kenta I, Hitoshi S, Ueru T. Soil and Nutrient Loss from a Cultivated Field During Wind Erosion Events in the Sahel, West Africa. *Japanese Society of Pedology*. 2019;55(3):355–363. 10.18920/pedologist.55.3_355.
21. Kwari, J.W., Paul, M.K. and Shekarau, L.B. (2015). The impacts of flooding on socio-economic development and agriculture in Northern Nigeria: A case study of 2012 flooding in Yola and Numan areas of Adamawa state of Nigeria. International Journal of Scientific and Engineering Research, 6(7), 1433-1442.
22. Lei, Z., Yu, D., Zhou, F., Zhang, Y., Yu, D., Zhou, Y. and Han, Y. (2019). Changes in soil organic carbon and its influencing factors in the growth of *Pinus sylvestris varmongolica* plantation in Horqin Sandy Land, Northeast China. Scientific reports, 9(1), 1-12.
23. Miller, R.W. and Donahue, R.L. (2001). Soils in Our Environment. Seventh edition. Prudence Hall, Englewood, Cliffs, N.J, pp :323.
24. Mouhamad, R., Atiyah, A. and Iqbal, M. (2016). Behaviour of potassium in soil: a mini review. Chemistry International, 2(1), 58-69.
25. Narteh, L.T. and Sahrawat, K.L. (1999). Influence of flooding on electrochemical and chemical properties of West African soils. Geoderma, 87(3-4), 179-207.
26. Narteh, L.T. and Sahrawat, K.L. (1999). Influence of flooding on electrochemical and chemical properties of West African soils. Geoderma, 87(3-4), 179-207.
27. Natarajan, A., Hegde, R., Naidu, L.G.K., Raizada, A., Adhikari, R.N., Patil, S.L., Rajan, K. and Sarkar, D. (2010). Soil and plant nutrient loss during the recent floods in North Karnataka: Implications and ameliorative measures. Current Science, 99(10), 1333-1340.
28. Natarajan, A., Hegde, R., Naidu, L.G.K., Raizada, A., Adhikari, R.N., Patil, S.L., Rajan, K. and Sarkar, D. (2010). Soil and plant nutrient loss during the recent floods in North Karnataka: Implications and ameliorative measures. Current Science, 99(10), 1333-1340.
29. Ponting, J., Kelly, T.J., Verhoef, A., Watts, M.J. and Sizmur, T. (2021). The impact of increased flooding occurrence on the mobility of potentially toxic elements in floodplain soil - A review. Science of the Total Environment, 754, 142040.
30. Prajapati, K. and Modi, H.A. (2012). The importance of potassium in plant growth-a review. Indian Journal of Plant Sciences, 1(02-03), 177-186.
31. Prajapati, K. and Modi, H.A. (2012). The importance of potassium in plant growth-a review. Indian Journal of Plant Sciences, 1(02-03), 177-186
32. Rajeevan M, Bhate J and Jaswal A K 2008 Analysis of variability and trends of extreme rainfall events over India using 104 years of gridded daily rainfall data; Geophys. Res. Lett. 35 L18707, doi: 10.1029/2008GL035143.
33. Reddy, K.R., Patrick, W.H. and Broadbent, F.E. (1984). Nitrogen transformations and loss in flooded soils and sediments. Critical Reviews in Environmental Science and Technology, 13(4), 273-309.
34. Ros MBH, Czymmek KJ, Ketterings QM. Combining field phosphorus runoff risk assessments with whole- farm phosphorus balances to guide manure management decisions. *Journal of Environmental Quality*. 2020;49(2). 10.1002/jeq2.20043 [PubMed]
35. Slattery, W.J., Conyers, M.K. and Aitken, R.L. (1999). Soil pH, aluminium, manganese and lime requirement. Soil analysis: an interpretation manual, 103-128.

36. Susann S. Climate Change Adaptation in South Korea: Environmental Politics in the Agricultural Sector. Germany: the Deutsche National Bibilografie; 2015; 110–111p.
37. Udayashankara TH, Sadashiva Murthy BM, Madhukar M. Impact of Climate Change on Rainfall Pattern and Reservoir Level. Journal of Water Resource Engineering and Management. 2016; 3(1): 10–14p.
38. Wang, F.L. and Bettany, J.R. (1993). Influence of freeze-thaw and flooding on the loss of soluble organic carbon and carbon dioxide from soil. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, 22(4), 709-714.
39. Yang LX, Yang GS, Li HP, Yuan SF. Effects of rainfall intensities on sediment loss and phosphorus enrichment ratio from typical land use type in Taihu Basin, China. *Environmental science and pollution research international*. 2020;27(12):12866–12873. 10.1007/s11356-018-04067-0