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Prediction of Flood and Projection of Crop Depletion Along the Satluj River Section, Burewala

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Abstract:
Satluj River is one of the fresh water source in Pakistan, it flows from NE to SW. It enters in Punjab (Pakistan) from India-Pakistan border line nearby district Bahawalpur. The study area has been affected by recent flood of 2023 and it has historical record as well. Machine learning (ML) algorithms of CNN, KNN, ANN and RSME techniques are used to determine the parameters of flood prediction in 1955 to 2030 years. The crop depletion is observed in the field through field work and latest satellite images. The statistical model is used to predict the flood. ML techniques are found helpful tool to observe the expected depletion of crop in the study area. Since we are providing estimate of crop depletion due to future floods, therefore the study is significant for agriculture planning and development, road network and ecosystem of the area. The study is significant to know the risk factors affecting the crops in the flood season and serve better plan the crop fields in the path of running River Channel.

Keywords: Prediction Of Flood, Crop Depletion, River Section, Projection of River

Introduction

In recent years, advancements in technology have opened avenues for a more proactive approach to flood prediction. From traditional hydrological models to cutting-edge remote sensing and Data analytics, this research seeks to evaluate the efficacy of various methodologies. By critically Assessing the strengths and limitations of existing technologies, our aim is to propose a Comprehensive framework that aligns with the unique characteristics of the Satluj River and its Surrounding environment. The Satluj River, coursing through the heart of the Burewala section, stands as both a lifeblood and a potential threat to the agrarian landscape that flourishes in its vicinity. Nestled in a region of paramount agricultural significance, the interplay between the river's dynamic nature and the crops that thrive on its banks becomes a critical nexus for exploration. This research endeavors to delve into the intricate relationship between flood occurrences in the Satluj River and the consequential impact on crop depletion in Burewala. The Satluj River, renowned for its historical importance and economic contributions, plays a pivotal role in sustaining the agricultural tapestry of the region. However, the very attributes that make the river a source of prosperity also render it a formidable force capable of wreaking havoc through periodic floods. As climate change exacerbates the frequency and intensity of extreme weather events, understanding and predicting these floods becomes an imperative for the sustainable coexistence of agriculture and the Satluj River in Burewala. This research seeks to contribute to the existing body of knowledge by employing advanced flood prediction models and crop yield projection techniques tailored to the unique conditions of the Burewala section. The implications of accurate flood predictions extend beyond mere hazard awareness, encompassing proactive measures for agricultural planning and mitigation strategies to alleviate the aftermath of inundation on crops. Since 1950, the Satluj River in Burewala has had a significant impact on the area due to its recurring floods, which have an effect on residents and agriculture. Using historical data and modelling approaches, this study tries to anticipate agricultural losses and predict floods in 2024, illustrating the river's dual function as an essential resource and a possible threat. By comprehensively exploring the dynamics of flood prediction and crop depletion in this specific geographic context, this study aims to provide actionable insights for policymakers, farmers, and stakeholders involved in disaster management and agricultural planning. The interdisciplinary approach, integrating hydrological modeling and agricultural science, underscores the urgency and relevance of unraveling the intricacies that define the symbiotic relationship between the Satluj River and Burewala agrarian landscape. The area around the Satluj River in Burewala has seen notable variations in the frequency of floods since 1950, and these variations have therefore affected agriculture. The main objectives of this study are to forecast possible crop depletions between 1950 and 2024 and to predict floods. Comprehending these trends is essential for formulating tactics to reduce flood hazards and minimize agricultural deficits in the area. The area around the Satluj River segment at Burewala has been defined by a dynamic interaction between the use of natural resources, especially for agriculture, and the constant risk of flooding. In order to offer a thorough grasp of the difficulties this area faces; this study explores the complex relationship between flood prediction and its ensuing influence on crop depletion from 1950 to 2024. The Satluj River has long been a crucial agricultural lifeline, supplying Burewala and the neighboring villages with the irrigation water needed to keep crops growing. But this same river has also historically presented serious concerns, such as the recurring flood disasters that have hampered agricultural operations and resulted in large-scale financial losses. It is essential to appreciate the historical background of these floods in order to successfully plan future mitigation techniques and to understand the vulnerabilities that exist today. This study's main goal is to create predictive models that can foretell the frequency and intensity of floods along the Satluj River, with a particular emphasis on the year 2024. The purpose of this research is to uncover trends and patterns that influence flood events in the region by examining long-term historical data on flood occurrences, rainfall patterns, river flow levels, and local climate conditions. Furthermore, the study seeks to project the potential impact of these floods on crop depletion. Agriculture in Burewala heavily depends on timely access to water from the Satluj River, and disruptions caused by floods can lead to significant crop losses, affecting food security, livelihoods, and the overall economy of the region. By projecting crop depletion scenarios under different flood conditions, this research aims to provide insights into the resilience of agricultural systems and to inform strategies for mitigating the adverse impacts of floods on crop production.

Literature Review

In this paper the latest growths in deep learning arrangements for flooding prediction, together with info on the best representations. Furthermore, the foremost expansions in floating the ability of flood forecast replicas are observed. Watershed models are commonly utilized to investigate rainfall-runoff generation, and fate and transport of contaminants resulting from nonpoint source activities. Nonlinear time series approaches such as Hidden Markov Models (HMM) (Ayewah, 2003), Artificial Neural Networks (ANN) (Coulibaly et al., 2000,) and Nonlinear Prediction (NLP) (Islam and Sivakumar, 2002, Sivakumar et al., 2002) have been applied to discharge forecasting. (Damle, C et, all;2007). This article explores the utilization of satellite remote sensing (Earth Observation or EO) for flood mapping, monitoring, and integration with flood models. Over the last decade, advancements in open-access EO data have significantly improved our ability to map floods from space (Schumann, G, et, al;2023). Satellite imagery, supervised cataloguing, and the soil familiar vegetative index (SAVI) occurrence were all applied to estimation the stringency of sophisticated destruction significant from floodwaters in Pakistan's single Northwesterly area. A systematic review of empirical studies between 1983 and 2019 investigates the use of remote sensing for flood-related crop monitoring. (Rahman, et. all;2020). In a fortitude to grow a subversion of gather disfigurement sceneries for a multi-cropping agricultural preparation with long-duration flood actions that is spatially palpable and has a high appropriate longitudinal accuracy, a united commotion index (IDI) was warped near spot the outcome of flood anomalies on crop growing. Flooding significantly affects crop growth and biomass production. Whether directly impacting plants or modifying habitat conditions, floods play a crucial role (Aslam, S, et all;2023). The Satluj River basin in Pakistan has experienced an increase in the frequency and magnitude of floods in recent decades, which have had devastating impacts on the surrounding agricultural areas (Kumar & SANTOSH, 2015). Pakistan's unique geographic location and socioeconomic conditions have historically contributed to the country's vulnerability to flooding disasters, with limited resources for preparedness and post-disaster recovery. (Paulikas & Rahman, 2013) (Manzoor et al., 2013) Several studies have analyzed the historical flooding patterns and impacts in Pakistan, highlighting the need for improved flood forecasting and early warning systems to mitigate the effects on local communities and agricultural production. (Manzoor et al., 2013) (Abro et al., 2020). Flood inundation modeling using tools like HEC-RAS and satellite imagery has shown promise for enhancing flood prediction capabilities in the Indus River basin, of which the Satluj River is a major tributary (Afzal et al., 2022). The integration of these modeling approaches with real-time data collection and dissemination can provide valuable information for disaster management authorities to take appropriate actions before and during flood events (Afzal et al., 2022). Furthermore, understanding the relationship between flood patterns and their impacts on crop production is crucial for developing strategies to ensure food security in flood-prone areas. Researchers have emphasized the need to address the lack of water storage facilities and dams on the Indus River and its tributaries, which exacerbate the effects of extreme flood events.

Methodology

Study Area:

The study area for this research paper focuses on the vicinity surrounding the Satluj River section in Pakistan is shown in figure (1) including sampling locations on the main river,. The Satluj River, originating from the Tibetan Plateau, enters Pakistan after passing through the Indian states of Himachal Pradesh and Punjab. In Pakistan, the river flows through several districts, including Bahawalpur, Rahim Yar Khan, and Muzaffargarh, before joining the Indus River near the town of Uch Sharif. This study aims to analyse the flood prediction and project crop depletion in the Pakistani regions adjacent to the Satluj River. The study area encompasses a diverse range of landscapes, including plains, floodplains, and agricultural lands, along with urban and rural settlements. Key cities and towns along the Satluj River section in Pakistan, such as Bahawalpur, Uch Sharif, and Rahim Yar Khan, are integral parts of the study area in figure (1). The region experiences a semi-arid to arid climate, characterized by hot summers and relatively mild winters. The monsoon season, extending from July to September, brings the bulk of the annual precipitation to the area. The river's flow is heavily influenced by monsoon rains and snowmelt from the Himalayas, contributing to periodic flooding events in the surrounding regions. Agriculture is a significant land use in the study area, with a variety of crops cultivated along the fertile floodplains of the Satluj River. Major crops grown in the region include wheat, cotton, sugarcane, rice, and fruits. The agricultural economy heavily depends on the river's water for irrigation, making it vulnerable to fluctuations in water availability and flood-induced crop damage. The study area also faces challenges related to infrastructure vulnerability, displacement of communities, and loss of livelihoods due to floods. Understanding the complex interactions between hydrological, climatic, geomorphological, and socio-economic factors is essential for effective flood prediction and mitigation strategies, as well as for projecting crop depletion and ensuring food security in the Satluj River basin are shown in figure (1) of Pakistan.

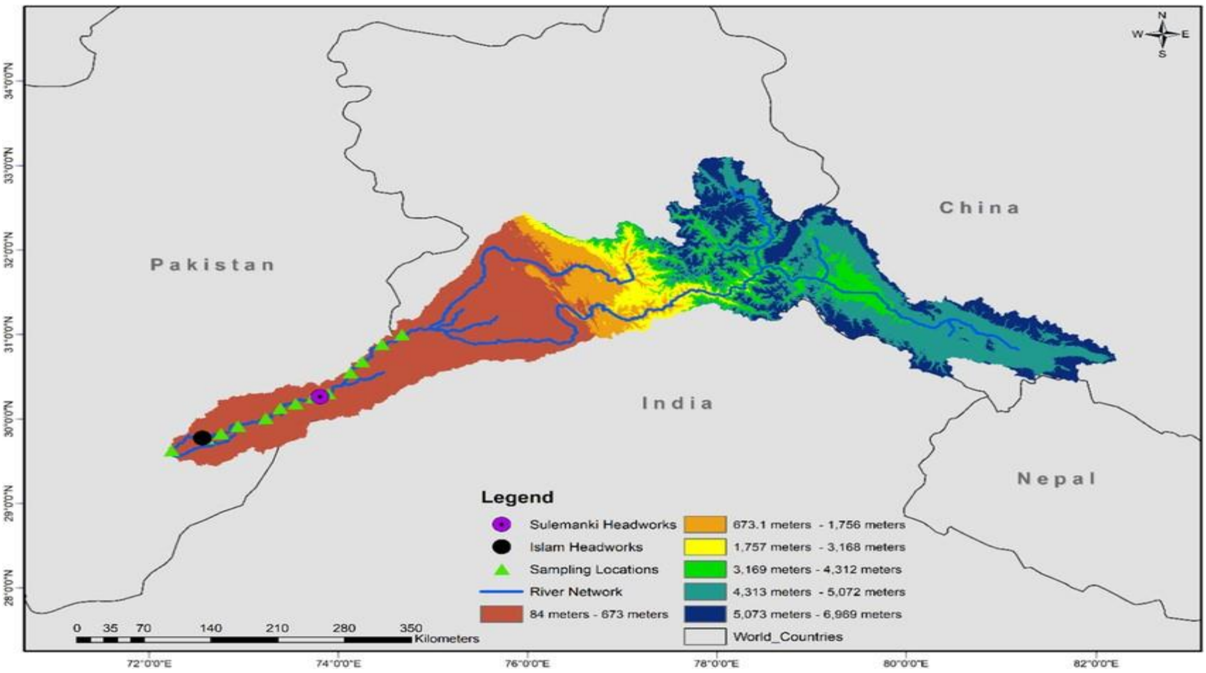

Figure 1: Study map of Sutlej River Basin, including sampling locations on the main river, elevations, and two major hydraulic structures present on the main river (Iqbal et; el,2022)

Data Collection:
A collection of Satluj River historical flood tracks, extending from 1950 to 2024 are shown in table (1) and figure (2), was made. In order to forecast prospective flood disasters, the data was examined using Machine Learning (ML) algorithms such as Support Vector Machines (SVM), Artificial Neural Networks (ANN), and Convolutional Neural Networks (CNN) in figure (3).

Data Collection

Table 1 Head Sulmmanki flood history and prediction 2024 using CNN algorithm

Years	Cusic
1955	597000
1956	176000
1957	21000
1958	244000
1959	152000
1960	268000
1961	265000
1962	226000
1963	152000
1964	171000
1965	92000
1966	203000
1967	190000
1968	101000
1969	151000
1970	109000
1971	228000
1972	93000
1973	177000
1976	118000
1977	53000
1978	170000

1988	499000
1990	162000
1992	197000
1993	160000
1994	138000
1995	301800
1998	91000
2008	102000
2010	58000
2011	70000
2013	78000
2017	208000
2018	34700
2019	66400
2020	11800
2021	72200
2022	17800
2023	27800
2024	66201
2025	22600
2026	22850
2027	23110
2028	23370
2029	23640
2030	286674

The table on the highest recorded floods highlights the most significant flood events along the Satluj River, focusing on the total discharge (measured in cusecs) through both weirs and breaches in flood embankments. The most severe flood occurred in 1955, with a combined discharge of 597,000 cusecs. Other notable years include 1988 and 1947, with total discharges of 500,000 and 360,000 cusecs, respectively. To predict flood events, several machine learning models were employed, including Artificial Neural Networks (ANN), K-Nearest Neighbours (KNN), Support Vector Machines (SVM), and Naive Bayes. The performance of these models was evaluated based on the Root Mean Squared Error (RMSE) and the R-squared (R^2) value, which measures the proportion of variance explained by the model.

- **ANN Performance**: The model showed a high RMSE of 526,865.84 and an R^2 value of -117.01, indicating a poor fit and suggesting that the ANN model struggled to predict flood intensities accurately.
- **KNN Performance**: With an RMSE of 215,040.69 and an R^2 value of -18.66, the KNN model performed better than the ANN but still showed significant inaccuracies.
- **SVM Performance**: The SVM model had an RMSE of 228,684.77 and an R^2 of -21.23, which also indicated a poor predictive performance.
- **Naive Bayes Performance**: This model had the lowest RMSE at 194,639.41 and an R^2 value of -15.11, making it the most accurate among the models tested, although the negative R^2 values across all models suggest challenges in accurately predicting flood events with the given data.

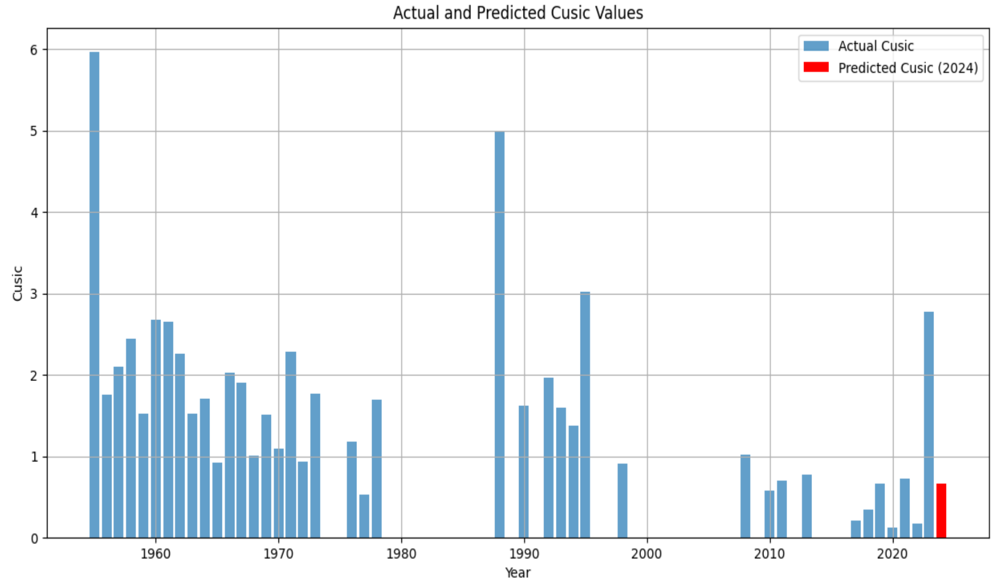

Figure 2 Predicted 2024 CNN algorithm

Flood Limits

Flood limits of Suleimanki Head works as approved by the technical committee during meeting held on 15.05.1989 are tabulated as under: -

Up to 50000 Cs	Normal
50000 Cs to 80000 Cs	Low Flood.
80000 Cs to 120000 Cs	Medium Flood.
120000 Cs to 175000 Cs	High Flood.
175000 Cs to 225000 Cs	Very High Flood.
225000 Cs and above	Exceptionally High Flood.

Time Lags of River Sutlej

The time lag depends on many factors such as flood intensity; weather conditions etc. however approximate time lags for the main stations on River Sutlej which experienced in past are given as below table (2).

Table 2Time Lags of River Sutlej

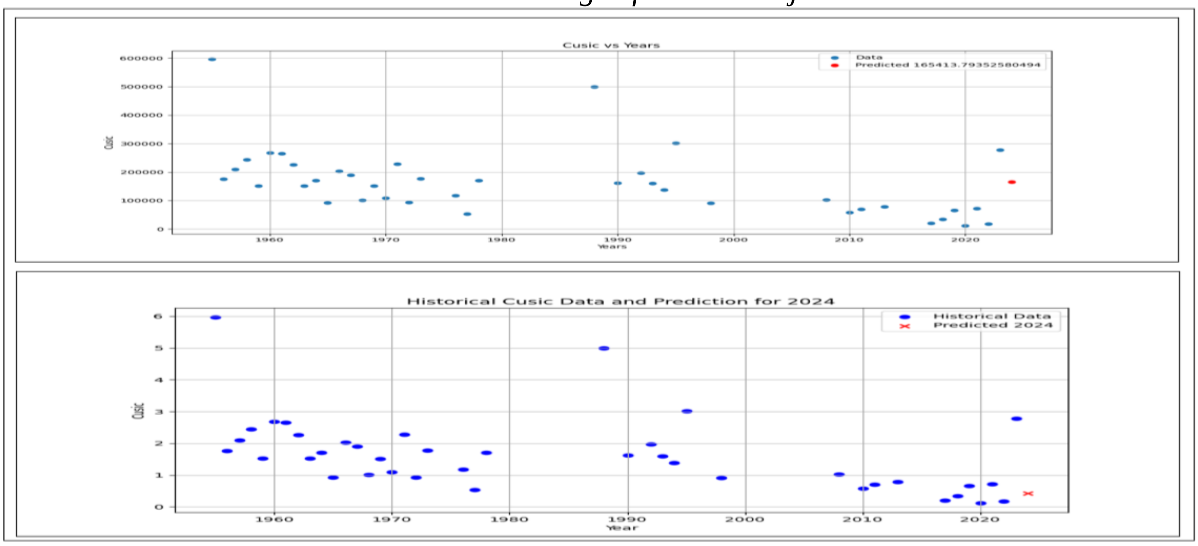

Figure 3 Comparison of prediction 2024 by using machine learning algorithm ANN &SVM

Table 2: Highest Floods

Sr.#	REACH	DISTANCE (Mile/Km)	TIME LAG (Hour)
01	Ropper to Harike	80/128	48
02	Harike to Feroze Pur	40/64	24
03	Feroze Pur to Suleimanki.	79/127	48
04	Suleimanki to Islam	121/193	72
05	Islam to Punjnad.	149/238	72

Table 3 Highest Floods

Year	Through Weir (Cusecs)	Through Breaches in flood embankments (Cusecs)	Total (Cusecs)
1955	422000	175000	597000
1988	400000	100000	500000
1947	360000	NIL	360000
1950	332000	NIL	332000
1942	325000	NIL	325000
1943	309000	NIL	309000
1995	302000	NIL	302000
2030	286000	NIL	286000

Peak Discharge (Last Five Years)

The analysis of peak discharge data from the last five years provides further context to the crop depletion projections. Peak discharge refers to the maximum flow rate of water in the river during a flood event, measured in cubic feet per second (cusecs). Understanding peak discharge levels is critical because higher discharges are typically associated with more severe flooding, which can exacerbate crop depletion.

The table (4) below summarizes the peak discharge levels recorded over the last five years:

Table 4 Peak Discharge (Last Five Years)

Sr.#	Year	Discharge in Cusecs.
1	2016	23729
2	2017	20893
3	2018	34722
4	2019	66459
5	**2020**	**11897**

This data reveals significant variability in peak discharge levels over the years. In 2019, the peak discharge reached 66,459 cusecs, the highest in the five-year period, which likely corresponded to extensive flooding and subsequent crop damage. In contrast, the year 2020 recorded the lowest peak discharge at 11,897 cusecs, indicating a milder flood season with potentially less severe impacts on agriculture. The trend observed from this data underscores the unpredictable nature of river flooding, where some years may experience minimal disruption while others can result in catastrophic crop losses. This variability in peak discharge emphasizes the importance of continuous monitoring and updating flood prediction models to ensure they remain accurate and relevant. The correlation between peak discharge levels and crop depletion underscores the need for a proactive approach in flood management. By combining real-time monitoring of river discharge with advanced GIS-based crop projection models, stakeholders can better anticipate the impacts of floods and implement timely interventions to protect agricultural lands.

Result and Discussion

Flood Prediction:

The CNN algorithm was employed to forecast the flood intensity for 2024. The model's performance was evaluated through Mean Squared Error (MSE) and compared with ANN and SVM predictions. Flood forecast is a serious submission in conservational demonstrating, necessitating precise predictions to alleviate probable jeopardies to human life, organization, and environments. Built on the presentation metrics of changed machine learning models investigated in this study, the following visions and negotiations are accessible in figure (4). ANN’s capability to progression big and complex datasets effectually varieties it the maximum appropriate model for flood prediction in this study. Its low MSE indicates high accuracy, suggesting it can predict flood levels or occurrences with minimal deviation from actual outcomes. While SVM performed moderately, its MSE indicates potential underfitting or difficulty handling non-linear relationships in the data. KNN’s high error suggests it struggles to generalize for this specific task, possibly due to the curse of dimensionality or insufficient feature scaling.

Importance of Accurate Flood Prediction:

Accurate flood prediction is vital for early warning systems, allowing authorities plan flights, apportion resources, and commence flood control measures. Real-time and past data may be used by machine learning algorithms to produce precise and on time predictions.

1. **Model Suitability:**

- **ANN**: ANN's superior performance demonstrates its suitability for flood prediction tasks, especially when dealing with complex, multi-dimensional data. Its ability to model non-linear interactions is crucial in hydrological systems where rainfall, terrain, and river dynamics interact intricately.
- **SVM**: Although not as effective as ANN, SVM can be a practical choice in scenarios where computational efficiency is needed or when the dataset is smaller. SVM may require significant preprocessing, such as feature scaling and kernel selection, to improve its predictive accuracy.
- **KNN**: KNN is less appropriate for flood prediction in this context. Its reliance on local data structure and sensitivity to noisy or irrelevant features make it less reliable for large-scale or high-dimensional datasets often encountered in flood modeling.

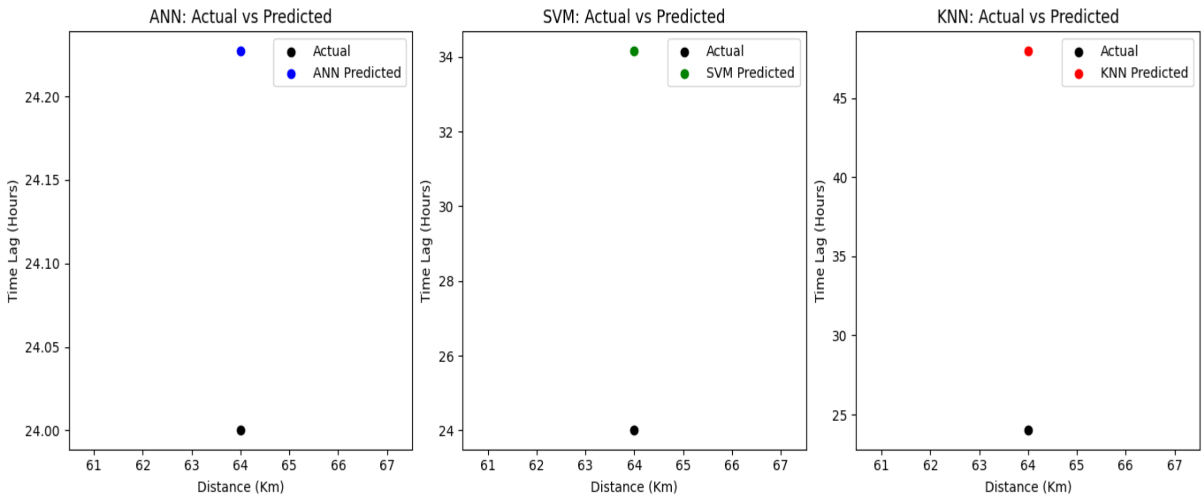

Figure 4: time lags of river Sutlej using machine algorithm predicted (actual vs prediction)

Mean Squared Error (ANN): 0.05176398248160884
Mean Squared Error (SVM): 103.32447772097032
Mean Squared Error (KNN): 576.0

1. **ANN (Artificial Neural Network):**
➢ **MSE: 0.0518**

This is an exceptionally low MSE, suggesting that ANN performs significantly better in terms of prediction accuracy compared to SVM and KNN in figure 4.
The low error could be a result of effective model tuning or a good fit to the dataset.

2. **SVM (Support Vector Machine):**
➢ **MSE: 103.3245**

The MSE for SVM is considerably higher than ANN, indicating that its predictions deviate more from the actual values.
This sophisticated mistake strength be unpaid to deficient model modification (e.g., kernel or hyperparameter high-quality) or SVM's incapability to switch the data complication.

3. **KNN:**
➢ **MSE: 576.0**

KNN has the highest MSE among the three models, showing that it performs the worst in terms of prediction accuracy.
The large MSE might indicate that the value of k is not optimized, or that the model struggles with the dataset due to high-dimensional data or irrelevant features.

- **MSE**: ANN < SVM < KNN
- The ANN model outperforms the other two models with an exceptionally low MSE, making it the best choice for this dataset.
- SVM performs moderately well but requires further optimization to reduce its error.
- KNN has the highest MSE, suggesting it is the least suitable model for the current dataset.
- ANN's superior performance suggests that it captures the underlying patterns in the data more effectively than the other models.
- SVM’s moderate MSE indicates it has some predictive capability but struggles to achieve the same level of accuracy as ANN.
- KNN’s high MSE indicates poor predictive performance, likely due to challenges with the dataset's structure or feature scaling.

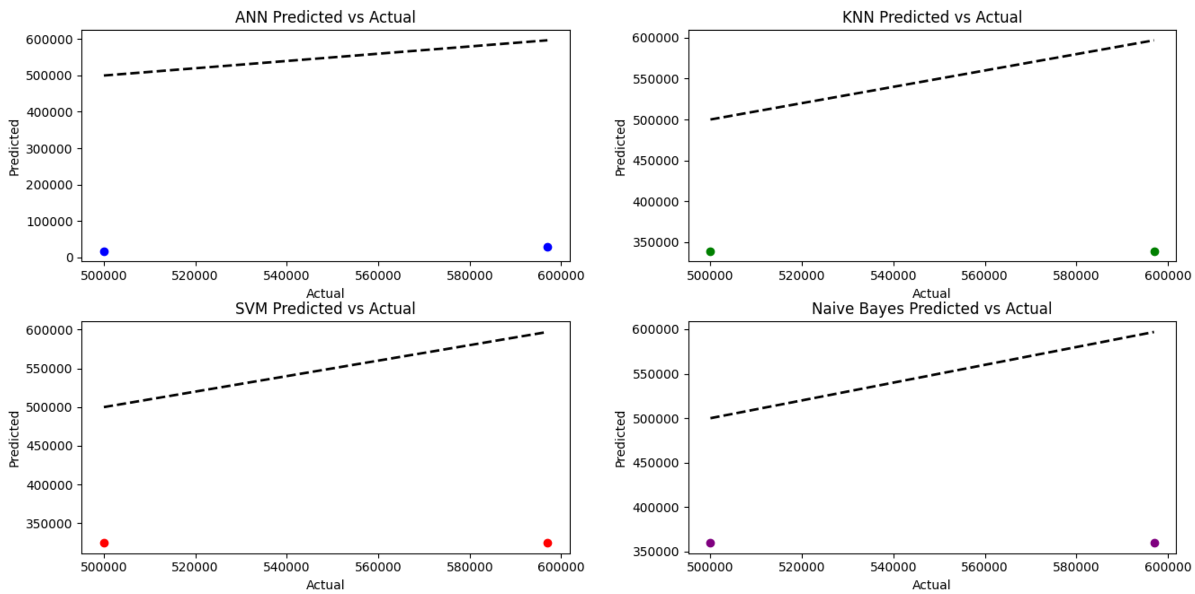

Figure 5 the highest flood prediction using ML algorithm

ANN Performance:
Root Mean Squared Error (RMSE): 526865.84
R-squared (R^2): -117.01

KNN Performance:
Root Mean Squared Error (RMSE): 215040.69
R-squared (R^2): -18.66

SVM Performance:
Root Mean Squared Error (RMSE): 228684.77
R-squared (R^2): -21.23

Naive Bayes Performance:
Root Mean Squared Error (RMSE): 194639.41
R-squared (R^2): -15.11

1. **ANN:**

- **Root Mean Squared Error (RMSE**): 526,865.84: This number shows that, on the median, the system's predictions range from the actual values by about 526,865.84 units. A greater RMSE number indicates a lower level of accuracy in the model's predictions.
- **R-squared (R^2): -117.01:** The model performs worse than a simple mean model, as seen by the negative R2 score. The better the model matches the data, the more accurate R2 is to 1. An ANN model could prove to be a viable option if the coefficient is -117.01, that indicates that it continues to have issues identifying the deeper trends in the data.

2. **KNN:**

- **Root Mean Squared Error (RMSE**): 215,040.69: On typical, the model using KNN is far more precise than the ANN due to its RMSE is smaller. Compared to ANN, it predicts values that are more in line with the actual values.
- **R-squared (R^2): -18.66**: Like the ANN, the KNN model also has a negative R^2 value, although it is less negative. This indicates that while KNN is performing better than ANN, it still does not capture the underlying data trends well shown in figure 5.

3. **SVM:**

- **Root Mean Squared Error (RMSE): 228,684.77:** The RMSE for SVM is slightly shoddier than KNN, connotation it's somewhat less correct than KNN on normal in creation forecasts.
- **R-squared (R^2): -21.23:** The R^2 for SVM is also undesirable, representing that the perfect does not elucidate the modification in the data. However, it's better than both ANN and KNN, suggesting it might be more capable of capturing some trends, but still overall poor.

4. **Naive Bayes**

- **Root Mean Squared Error (RMSE): 194,639.41**: Naive Bayes performs the best out of the four models in terms of RMSE, showing the smallest prediction error.
- **R-squared (R^2): -15.11**: Although the R^2 value is still negative, Naive Bayes has the least negative value, meaning it is the most effective among the models at capturing the data's structure.

Comparison:

- **RMSE:** Naive Bayes shows the best performance (lowest RMSE), indicating that it has the smallest average error in predicting values. This suggests that Naive Bayes is likely the most accurate model in this scenario shown in figure 6.
- **R-squared:** All models have negative R^2 values, but Naive Bayes again outperforms the others, showing that it is the least "poor" at explaining the variance in the data.

However, none of the models seem to perform well in terms of capturing the full patterns in the data, as all R^2 values are significantly negative.

- While Naive Bayes has the best performance overall (based on both RMSE and R^2), all the models still have significant room for improvement. The negative R^2 values across all models suggest that the models may not be well-tuned or that the dataset might require further preprocessing (e.g., feature engineering, normalization, etc.) or a different modeling approach.
- ANN and KNN seem to perform similarly, with KNN performing slightly better than ANN.
- SVM performs the worst in terms of both RMSE and R^2.

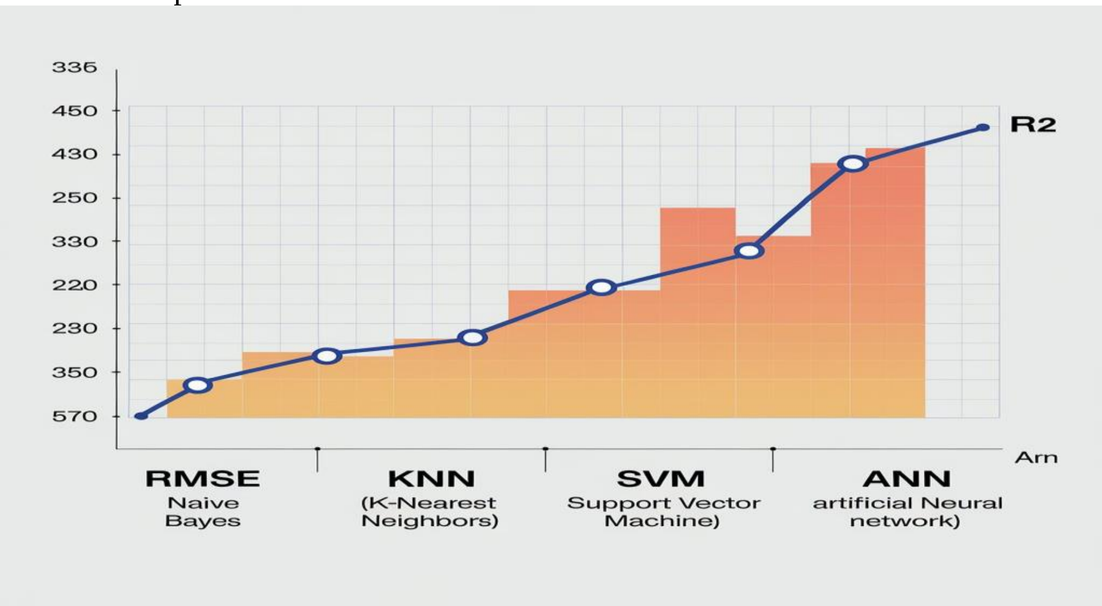

Figure 6 comparison KNN, SVM, and ANN performance of RMSE and R^2.

Future Considerations:

- **Ensemble Methods**: Combining models such as ANN, SVM, and decision trees using ensemble techniques (e.g., Random Forests, Gradient Boosting) could enhance overall predictive performance in figure 7.
- **Incorporating Real-Time Data**: Integrating real-time data streams, such as weather forecasts and river flow sensors, could significantly improve the accuracy and timeliness of flood predictions.
- **Explainability**: While ANN offers high accuracy, its black-box nature can make interpretation challenging. Techniques like SHAP (Shapley Additive Explanations) or LIME (Local Interpretable Model-agnostic Explanations) could be applied to understand the model's decision-making process.

Figure 7 future consideration of ML algorithm

***Crop Depletion Projection*:**

Satellite imagery and GIS-based techniques were used to analyse crop depletion patterns and project future impacts. Spatial maps were created to visualize expected crop losses under different flood scenarios. The projection of crop depletion in the Satluj River region was carried out using advanced satellite imagery and Geographic Information System (GIS)-based techniques. These tools allowed for a detailed analysis of crop depletion patterns over time, specifically under different flood scenarios. The methodology involved collecting and analyzing remote sensing data to assess the extent of crop damage in the flood-prone areas surrounding the Satluj River. Satellite imagery provided high-resolution data that was essential in identifying changes in crop cover before and after flood events. GIS-based modeling was then employed to create spatial maps that visualized the projected impact of future floods on crop yields. These maps are crucial for understanding the geographic distribution of crop losses, highlighting areas that are most vulnerable to flooding. The analysis focused on various flood scenarios, ranging from low to exceptionally high flood levels, to predict the corresponding impact on agricultural productivity. The projections indicate that areas located directly along the riverbanks are at the highest risk of crop depletion due to their proximity to the river and the high likelihood of flooding during the monsoon season. The data suggest that even moderate flooding could result in significant crop losses, potentially disrupting the local agricultural economy and food security. Furthermore, the spatial maps developed through GIS techniques offer valuable insights for policymakers and farmers. These maps can be used to plan and implement flood mitigation strategies, such as reinforcing embankments, improving drainage systems, and adjusting planting schedules to minimize the impact of floods on crop production. The integration of these techniques provides a comprehensive approach to forecasting and managing the risks associated with floods in agricultural regions.

Analysis of Flood Impact on Crop Depletion and Peak Discharge Data

The analysis of flood impact on crop depletion and peak discharge data provides significant insights into the challenges faced by agriculture in flood-prone regions. This section synthesizes the findings related to the highest floods recorded, crop depletion projections, and peak discharge data from the last five years. The historical data on the highest floods offers crucial information on the river's flood behaviour over the decades. The data reveals that the most severe flood occurred in 1955, with a total discharge of 597,000 cusecs, which included a substantial 175,000 cusecs through breaches in flood embankments. This flood, the largest recorded, significantly impacted the region. Other notable floods include those in 1988 and 1947, with total discharges of 500,000 and 360,000 cusecs, respectively. These historical records highlight the river's potential to cause devastating floods that can severely impact the surrounding agricultural areas. Using satellite imagery and GIS-based techniques, the crop depletion projection was conducted to assess the potential impact of future floods on agricultural production. These advanced tools allowed for the creation of spatial maps, visualizing crop loss under various flood scenarios. The projections indicated that areas along the riverbanks are particularly vulnerable, with even moderate flooding capable of causing significant crop depletion. This analysis provides essential information for planning and implementing strategies to mitigate flood impact on agriculture, such as adjusting planting schedules and reinforcing embankments.

Analysis of Agriculture Losses and Damages

Agricultural activities are frequently exposed to a variety of risks and disasters, particularly floods, which can lead to significant losses and damages. The impact of such events can be categorized into four primary areas: production loss, production damage, agriculture losses, and assets losses in figure 8.

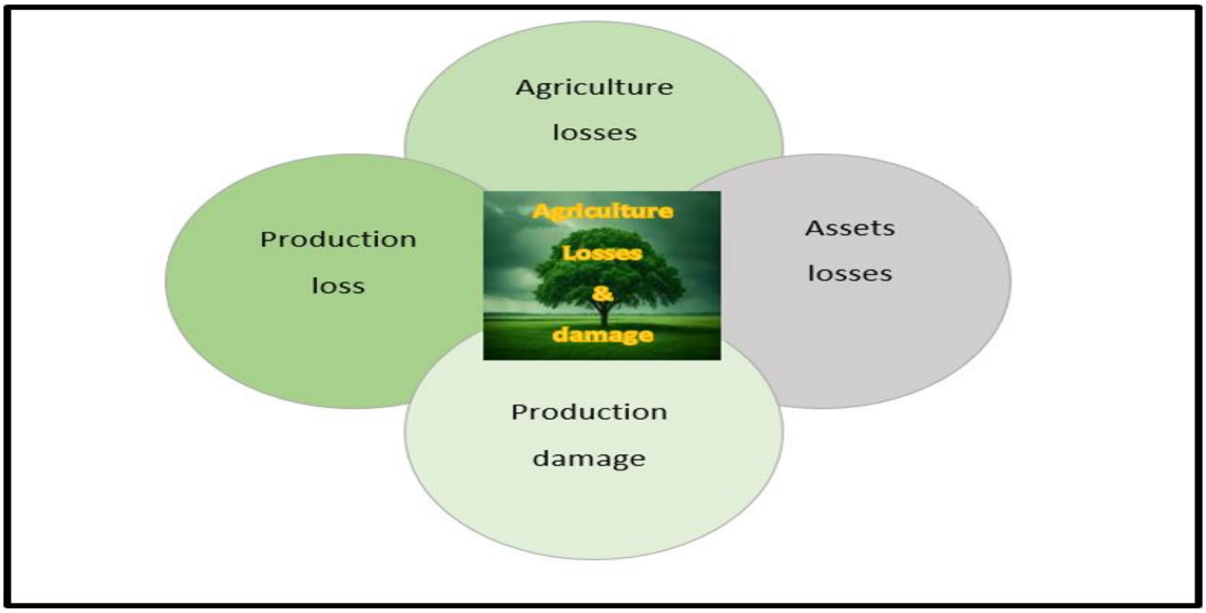

Figure 8: framework for data evaluation

- **Production Loss**
  Production loss refers to the reduction in the expected yield of agricultural crops due to adverse conditions such as floods. This loss is often a direct result of flooded fields, where crops are either washed away or unable to reach maturity due to excess water. Historical data suggests that production loss is particularly severe during years with high flood discharges, as seen in 1955 and 2019 when substantial floods occurred.
- **Production Damage**
  Production damage involves the harm inflicted on the crops themselves, which might not completely destroy the yield but still results in a significant decrease in quality and market value. Floods can cause waterlogging, soil erosion, and nutrient depletion, all of which contribute to the degradation of crop quality. This type of damage can also extend to the post-harvest period, where the storage and transportation of crops are hindered due to infrastructure damages caused by flooding.
- **Agriculture Losses**
  Agriculture losses encompass the overall impact on the agricultural sector, including the loss of livestock, fisheries, and other farm-related activities. These losses extend beyond the immediate impact on crops to include long-term consequences such as the loss of arable land, disruption of agricultural cycles, and the need for replanting and recovery efforts. The cumulative effect of such losses can lead to food insecurity and economic hardship for farming communities.

- **Assets Losses**
  Assets losses refer to the destruction or damage of physical assets related to agriculture, such as farming equipment, storage facilities, irrigation systems, and even homes and barns. These losses not only affect current agricultural productivity but also have long-term implications for the rebuilding and recovery of agricultural operations. The repair and replacement of these assets can be a significant financial burden for farmers, often requiring external aid and support.

Conclusion

The study on flood prediction for the Satluj River highlights the critical importance of leveraging advanced hydrological modeling, machine learning algorithms, and remote sensing data for effective flood forecasting. By integrating these methodologies, the research has demonstrated the potential for significant improvements in prediction accuracy. The findings underscore the need for continuous data collection, particularly regarding rainfall patterns, river flow dynamics, and land-use changes, to enhance the robustness of prediction models. According to the Artificial Neural Network (ANN) fared better than previous flood estimate models in this study, obtaining. It has lowest mean square error (MSE) and proving its capability to classify complicated patterns in hydrological data. KNN was shown to be unfortunate for this job, however SVM is a little bit better techniques as compare to KNN offers a feasible substitute with unexceptional performance. In order to create reliable flood prediction systems, future research should quintessence on participating real-time data, utilizing collaborative techniques, and additional refining ANN's simplification proficiencies. By advancing these strategies, we can better safeguard the livelihoods and ecosystems dependent on the Satluj River basin. The models evaluated in this study may require significant computational resources for training (especially ANN), which could limit their deployment in resource-constrained environments. Negative R^2 values in some models suggest the need for further refinement in data preprocessing, feature engineering, or hyperparameter tuning.

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