Proceedings of 2022 Asian Conference on Crisisonomy
(20 ~ 23 July, 2022; Jeju National University; Asian Association for Crisisonomy)

Decision support system for Flood Alarming

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A B S T R A C T

Floods and droughts are natural disasters that inflict billions of dollars in damage and significant people suffering throughout the globe. It is important to manage flood and drought hazards in an educated and effective manner to limit damages and minimize long-term effects on developments. In recent years, there has been significant improvement in disaster risk planning, as well as the implementation of monitoring and warning systems. However, when it comes to drought hazards, governments frequently take a reactive rather than a proactive risk management strategy. The various properties of droughts can explain this. Several lessons may be drawn from flood early warning systems for the development of drought monitoring. The major assumption is that the systems must be linked to the decisions that decision-makers face. This implies that, in addition to the regular monitoring of physical characteristics such as water levels, socioeconomic data must be included: drought or flood is primarily a disaster because people are affected.

Key words: DSS; AI; MCDM; GIS; floods; alarming system; droughts

1. Introduction

Between 1995 and 2015, floods and droughts are predicted to have affected 2.3 billion and 1.1 billion people globally, respectively. Furthermore, because of climate change, population expansion, and economic growth, their negative effects have risen over the last century and are expected to increase in the future. There is a pressing need to mitigate the harmful effects of floods and droughts by implementing Disaster Risk Reduction (DRR) methods and policies that address both present and future risks. The United Nations Sendai Framework for Disaster Risk Reduction recognizes this, and the last decade has witnessed a move away from controlling flood and drought risks and toward risk management.

It is therefore critical to study interconnections between these closely related phenomena that are all part of the same hydrological cycle to properly construct DRR measurements and tactics. In practice, however, DRR metrics and policies are often focused on either floods or droughts. As a result, activities done to reduce the danger of one hydrological extreme (for example, flooding) may unintentionally enhance the probability of another hydrological extreme (e.g. drought). (Loon et al. 2021) Just published a study on this topic, focusing on reservoir operations. However, there is still a general dearth of knowledge about this topic.

Despite this advancement, most hydrological risk research focuses either on the flood or drought vulnerability, even though floods and droughts are two extremes of the same hydrological cycle. Many major river basins have had to deal with both recent flood and drought episodes, according to (Krysanova et al. 2010). There are several examples of big flood and drought events interacting. For example, California got a lot of rain following a five-year drought that lasted from 2012 to 2017, causing serious damage to the Oroville Dam's spillway. Authorities evacuated over 200,000 people in the event of its collapse. The notorious Millennium Drought in Australia (1997–2009), which badly impacted the ecology and economy of a huge region, concluded with devastating floods that caused levee breakdown along the Murray Riverbank. Following this catastrophic disaster, the continent experienced severe drought.

Flooding is an issue that has existed since the beginning of time. While natural flooding of massive swaths in the primitive world did not create situations that were more dangerous than others, the expansion of urban activity and cities has made preventing flood damage or leveraging over-bank flows for one's purposes, as in ancient Egypt, a requirement that remains crucial to this day (Anon n.d.), (Anon n.d.).

2. Materials and Methods

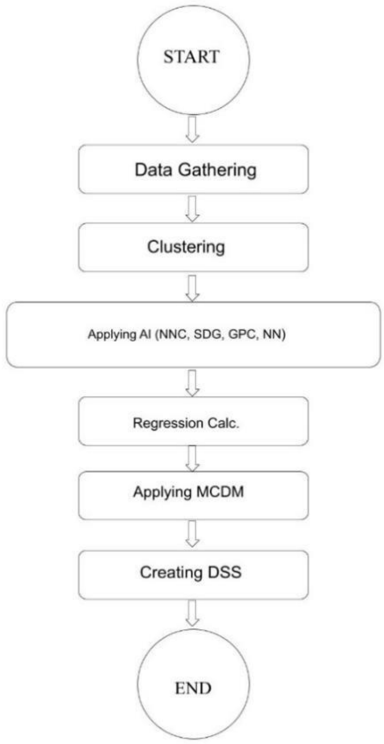
Urban flood management is receiving more and more attention in the scientific community as a result of increased urbanization and climate change. It's worth noting that between 1998 and 2017, urban floods were the most dangerous climate-related threat to humans. The truth is that tremendous efforts are being made throughout the world to make DSS a reality, whether via the use of various AI technologies or other instruments. For example, some recent studies have employed Neural networks (NN) as an AI tool to identify flood disasters, while others have concentrated on real-time flood early warning and web-based water hazards management systems using sensors. Table 1 was generated from research on 10 publications released in 2021 to offer a clearer picture of various strategies used in this subject. Other analyses have been employed in addition to AI and MCDM, as shown. Furthermore, even when AI and MCDM are combined, distinct roles and methodologies such as prediction, analysis, and identification are used.

<Table 1> Shows that the strategies utilized to create flood DSS are not restricted. Nonetheless, AI, MCDM, GIS, and real-time sensors might be considered popular technologies.

Method	Approach	Reference
AI	Identifying the most effective algorithm that can be used in flood DSS, Flood intensity prediction using multiple methods at various times, For post-flood administration, a mix of AI and the Internet of Things is being used	Conceptual framework of an intelligent decision support system for smart city disaster management. Applied Sciences, 10(2), 666 [5]
Hazard Mapping	Recognizing flood-prone or damaged areas and proposing appropriate remedies both before and after a flood	Flood hazard mapping methods: A review. Journal of Hydrology, 603, 126846 [6]
MCDM	Identifying disaster mitigation infrastructure development priorities at the local levels	[7] An MCDM approach [7]
GIS	Collecting data to build flood vulnerability maps and recommending urban design succession direction	[8]. Development of flood alert application in Mushim stream watershed Korea. International journal of disaster risk reduction, 21, 11-26.

How the methodology works

This DSS is designed to cluster locations, estimate the likelihood of flooding, and provide flood management options. To prove it, the present study began with data collection, which included historical rainfall, flood insurance, and geographic and topographical variables. The recognized groups also conducted flood predictions based on historical data. Finally, regression coefficients are used to evaluate the performance of each AI approach. The next phase is to give correct proposals suitable for various flood circumstances in various climates using a decision-making approach. Finally, the DSS is created by combining the phases discussed above, and it would be able to identify locations, estimate flood danger, and provide quick remedies. The methodology of the current investigation is depicted below.



- NNC: Nearest Neighbors Classification
- SDG: Stochastic Gradient Descent
- GPC: Gaussian Process Classifier
- NN: Neural Network

1) ARC-GIS Approach:

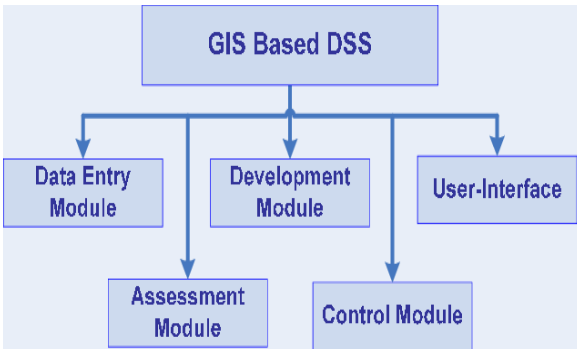


Figure 1 (a): ARC GIS methodology for DSS (Sultani et al. 2009(Jenkins et al. 2017))

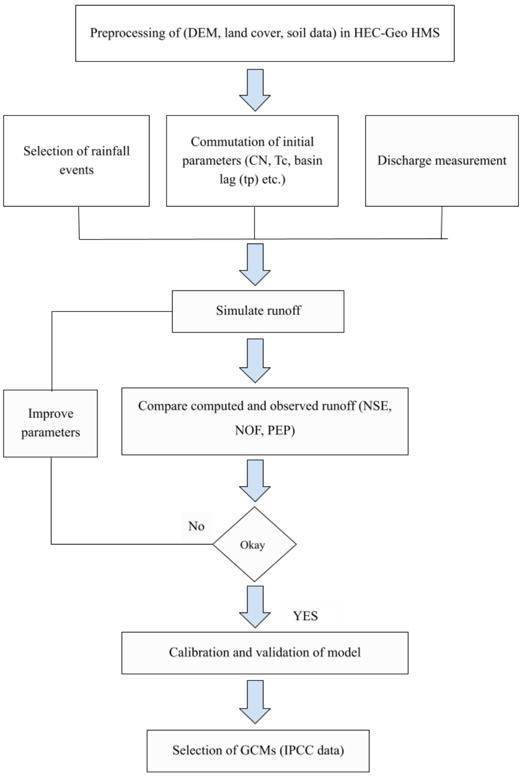


Figure 1 (b): ARC GIS methodology for DSS (Azam et al. 2009(Azam, Kim, and Maeng 2017))

2) MCDM Approach:

To construct a decision-making matrix, first identify alternatives and criteria; next, interpret the weights of criteria and alternative ratings about each choice criterion. Experts have developed a grading scale to assess the performance of production systems in the face of flood risk factors, and MOORA will evaluate and score the systems. Climate change (C1), catchment runoff (C2), groundwater systems (C3), fluvial systems (C4), urban systems (C5), coastal processes (C6), human behavior (C7), and socioeconomic factors (C8) are defined as drivers (decision criteria) for evaluating flood risk affection (Jung et al. 2020a), and six main agronomic systems should be considered (alternatives) as shown in Figure. The MOORA approach is then used to address the decision-making problem. The MOORA is said to have three primary characteristics: simultaneous consideration of interrelationships between objectives and options, a cardinal approach, and non-subjective dimensionless metrics. MOORA is divided into two parts: a reference point method and a radio system, and it may assess both non-benefit and benefit factors in a selection process. Its procedure begins with the identification of alternatives, followed by the identification of the most relevant criteria and the determination of criteria importance weights.

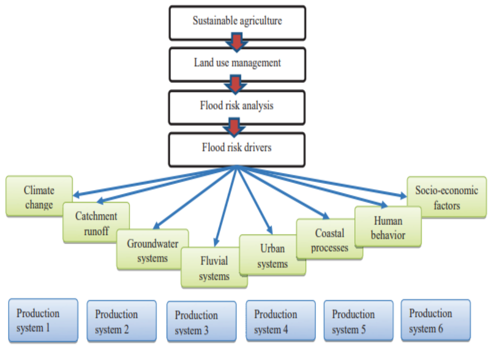


Figure 2: MCDM Approach for Flood DSS (Yazdani et al. 2017(Anon n.d.))

3) Flood Hazard Mapping Approach:

FHM is an important component of flood risk assessment because it allows for accurate geographic estimation of flood parameters such as velocity, depth, and frequency. Flood hazard maps are useful in flood management because they efficiently depict the spatial extent and distribution of flood threats. Experimentation is required for the physical modeling approach to validate the model's forecasting accuracy. Numerical models, on the other hand, are important as long as they imitate or depict the physical/real processes of a flow/flood occurrence.

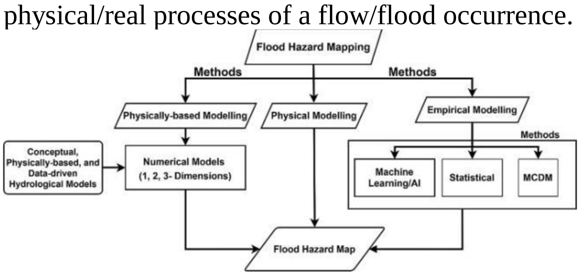


Figure 3: Flood Hazard Mapping Approach for Flood DSS (Mudashiru et al. 2021(Mudashiru et al. 2021))

4) AI Approach:

Artificial intelligence (AI) can foresee the advent of natural disasters, potentially saving thousands of lives and averting financial damages. Earthquakes, floods, hurricanes, forest fires, and volcanic eruptions are examples of natural calamities that AI can forecast. Different models (hydrodynamic, forecasting, and economic) that are part of the DSS share data and provide feedback to each other in the field of flood prediction. The DSS may help with selecting appropriate flood damage reduction alternatives (using an expert system method), forecasting floods (using artificial neural networks), modeling flood control structure functioning, and characterizing flood consequences (area flooded and damage).

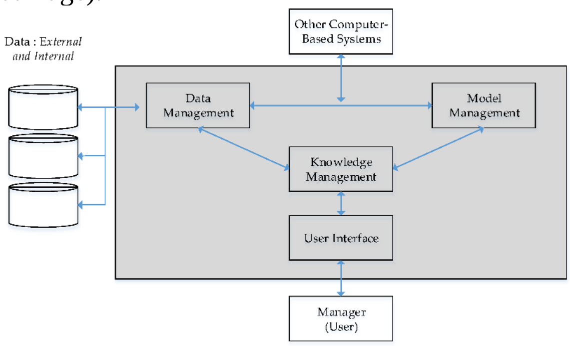


Figure 4 (a): AI for Flood DSS (Jung et al. 2020(Jung et al. 2020b))

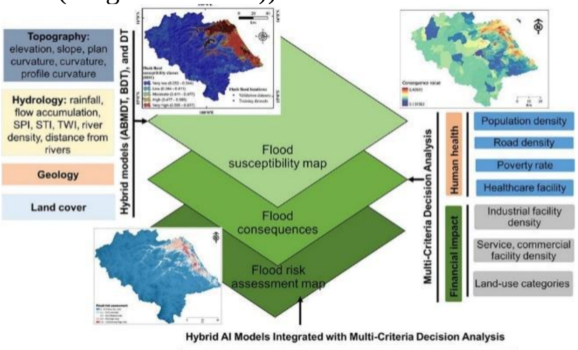


Figure 5 (b): AI for Flood DSS (Pham et al. 2021(Mudashiru et al. 2021))

5. Limitations

Despite the sheer number of high-risk scenarios and the extremely high costs in terms of casualties and damage associated with flooding, implementing all structural and non-structural policies aim at its decline becomes critical in this holistic view of the dilemma. While structural interventions may be executed with a sufficient degree of dependability in places with minimal anthropic pressure, the requirement for non-structural measures becomes exceedingly high when dealing with strongly entropized areas, particularly in metropolitan areas. For flood control, four separate non-structural methods must be used.

- The first is the identification of high-risk flood zones and the creation of flood risk maps.
- The second is the establishment of dependable real-time food prediction and warning programs that enable an operational forecasting lead time.
- The third step is to define flood risk emergency plans, which includes preparing and distributing to the authorities in charge a unified manual of procedures that describes, for each area at risk, the delineation of the flood-threatened area, the risk tolerances, the governing bodies in charge, the action to be taken, who to sound the alarm, and so on.
- The final nonstructural measure is the creation of an integrated decision support system (DSS), which aims to centralize relevant data in an operational emergency unit while also tracking and coordinating the operation of all organizations involved using manual processes, given that the main issue during flood events has been identified as a lack of collaboration among the wide variety of authorities and agencies involved.

6. Conclusions

A great amount of effort has gone into developing smart frameworks for managing floods with the least amount of harm. The best technologies used worldwide for flood management entail flood prediction, detection, and relief actions, all of which may be accomplished with the use of current techniques such as Artificial Intelligence (AI) and Multi-Criteria Decision-Making (MCDM) calculations. The combination of AI and MCDM computations has the potential to generate flood Decision Support Systems. AI can anticipate flood risk locations and flood occurrence regimes, while MCDM computations transform expert experiences into quantitative criteria (DSS).

Acknowledgement: This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2020S1A5B8103910).

References

Anon. n.d. “[PDF] Flood Risk Assessment ; A MCDM Approach | Semantic Scholar.” Retrieved May 23, 2022a (https://www.semanticscholar.org/paper/Flood-risk-assessment-%3B-A-MCDM-approach-Yazdani-Zaraté/9729568e943d42ea4f9dd047a2d16f78c48b82e7).

Anon. n.d. “Floods.” Retrieved May 23, 2022b (https://www.who.int/health-topics/floods#tab=tab_1).

Anon. n.d. "The Many Effects of Flooding | National Geographic Society." Retrieved May 23, 2022c (https://www.nationalgeographic.org/article/many-effects-flooding/).

Azam, Muhammad, Hyung San Kim, and Seung Jin Maeng. 2017. "Development of Flood Alert Application in Mushim Stream Watershed Korea." *International Journal of Disaster Risk Reduction* 21(November 2016):11–26. doi: 10.1016/j.ijdrr.2016.11.008.

Jenkins, K., S. Surminski, J. Hall, and F. Crick. 2017. "Assessing Surface Water Flood Risk and Management Strategies under Future Climate Change: Insights from an Agent-Based Model." *Science of the Total Environment* 595:159–68. doi: 10.1016/j.scitotenv.2017.03.242.

Jung, Daekyo, Vu Tran Tuan, Dai Quoc Tran, Minsoo Park, and Seunghee Park. 2020a. "Conceptual Framework of an Intelligent Decision Support System for Smart City Disaster Management." *Applied Sciences (Switzerland)* 10(2).

Jung, Daekyo, Vu Tran Tuan, Dai Quoc Tran, Minsoo Park, and Seunghee Park. 2020b. "Conceptual Framework of an Intelligent Decision Support System for Smart City Disaster Management." *Applied Sciences 2020, Vol. 10, Page 666* 10(2):666. doi: 10.3390/APP10020666.

Krysanova, Valentina, Tobias Vetter, Fred Hattermann, Valentina Krysanova, Tobias Vetter, and Fred Hattermann. 2010. "Detection of Change in Drought Frequency in the Elbe Basin : Comparison of Three Methods Detection of Change in Drought Frequency in the Elbe Basin : Comparison of Three Methods." 6667. doi: 10.1623/hysj.53.3.519.

Loon, Anne Van, Philip J. Ward, Marleen C. De Ruiter, Johanna Mård, Kai Schr, Ted Veldkamp, Nina Von Uexkull, Niko Wanders, Amir Aghakouchak, Karsten Arnbjerg-nielsen, Lucinda Capewell, Maria Carmen, Rosie Day, Benjamin Dewals, Giuliano Di, Laurie S. Huning, Heidi Kreibich, Maurizio Mazzoleni, Elisa Savelli, Claudia Teutschbein, Harmen Van Den Berg, Anne Van Der Heijden, Jelle M. R. Vincken, Maarten J. Waterloo, and Marthe Wens. 2021. "The Need to Integrate Flood and Drought Disaster Risk Reduction Strategies." 11(2020). doi: 10.1016/j.wasec.2020.100070.

Mudashiru, Rofiat Bunmi, Nuridah Sabtu, Ismail Abustan, and Waheed Balogun. 2021. "Flood Hazard Mapping Methods: A Review." *Journal of Hydrology* 603(PA):126846. doi: 10.1016/j.jhydrol.2021.126846.

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