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GLOBAL CHANGE RESEARCH

FINAL REPORT

Improving assessment of drought and its impact on food and water resources in South Asia

CRRP2018-07MY-Kafle

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NAGOYA UNIVERSITY

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1. Summary

Recent declining agricultural production has depressed rural economies and increased widespread hunger and urban migration in many South Asian countries like Nepal, India, Pakistan and Bangladesh. Moreover, due to the changing climatic condition, extreme precipitation events like drought have emerged as a source of vulnerability, particularly in rainfed agriculture. Drought monitoring and assessing tools could be used to predict drought and delimit the drought-prone areas so that mitigating measures of drought could be applied to minimise drought's impact on food production and water resources. However, most of these countries do not have a regional scientific drought monitoring tool that can detect and predict drought using available climatic data. This project aims to develop a suitable drought monitoring method on a regional scale using freely available satellite data sets and products in Nepal, India, Pakistan and Bangladesh. Furthermore, in this study, we will investigate the impact of drought on crop production for the last thirty years. We also propose our outcomes and results for the capacity building of local communities, stakeholders, students and policymakers.

2. Objectives

Specific Objectives of this proposed work are to:

1. Develop a suitable model for assessing and monitoring drought on a regional scale;
2. Assessment of the occurrence of drought in the last 30 years (1987-2017) in South Asia;
3. Evaluate the impacts of drought on food and water resources in drought-prone areas;
4. Create a baseline database of the drought events and their impact on food and water resources, and investigate traditional coping practices;
5. Capacity building of local communities, stakeholders and policymakers.

These objectives will help to tackle the following research questions:

1. What is the spatial extent of drought in South Asia?
2. Which country and which region is more vulnerable to drought among Nepal, India, Bangladesh and
Pakistan?
3. What is the frequency of drought in the past 30 years?
4. What are the trends of drought among the studied countries? Are there any similar patterns?
5. What is the longest duration of drought in the last 30 years?
6. Is there any changes in drought severity or frequency of occurrence due to land cover change?
7. What are the impacts on Nepal, India, Pakistan and Bangladesh? Is there any similarity?

3. Outputs, Outcomes and Impacts

Outputs	Outcomes	Impacts
-Suitable drought assessing and monitoring tools for South Asia -Hardcopy of drought status in South Asia for the last 30 years -Record of the impacts of drought on food and water resources -Record of traditional practices of coping mechanism in drought situations -Trained personnel.	-Drought Severity Index was verified to be a suitable drought monitoring tool in South Asia -Drought Atlas of Nepal, Sikkim, Pakistan and Bangladesh has been published from 2000 to 2020 -Record of crop production in Nepal for the last 50 years has been documented -Traditional practices of fish farmers group of Chitwan district during drought period has been documented -Minimum of 15 trained manpower on using satellite remote sensing and DSI index has been produced.	In this project work, we were successful in demonstrating the picture of drought in Nepal, Sikkim, Pakistan and Bangladesh and also its impact on crop production. Moreover, we are also aware that the irrigation facilities in most of the crop production area is ground water, which is slowly declining. We have also done small-scale research on the impact of fish production in Chitwan district from this project fellowship. Therefore, the immediate action should be increasing ground water table and also expanding food growth opportunity in South Asian countries. Both of these problems will be tackled by developing fish ponds in different parts of the country. This will help us to recharge ground water and also provide us healthy food, that is fish. This will also increase jobs for the farmers and make society independent in food. This will be our immediate next goal in Nepal. Besides, we are also planning to work on drought forecasting using freely available datasets.

4. Key facts/figures

- Twenty years of monthly drought, i.e. 240 maps of drought of each country have been produced
- One manual for using the DSI index for calculating drought has been developed
- Four Drought Atlas of Nepal, Sikkim, Pakistan and Bangladesh has been launched for the first time in Nepal
- One awareness booklet on drought in the Nepali language has been developed
- Fifteen researchers have been trained to monitor drought using DSI index
- Three workshops on drought have been held
- Seven presentations at conferences have been done
- Six stakeholder engagements in different parts of Nepal and Bangladesh have been done
- Four collaborations were established
- Three media coverage on our drought work

5. Publications

- Drought Atlas of Nepal, Sikkim, Pakistan and Bangladesh
- Drought awareness booklet in the Nepali language
- Neupane, P., Rai, S., Kafle, H., & Ranjan, R. (2022). Growth performance of different fish species during dry period in Chitwan, Nepal. Journal of Agriculture and Forestry University, 177–185. https://doi.org/10.3126/jafu.v5i1.48462

6. Media reports, videos and other digital content

1. Featured by Nepal Khabar (Online Magazine)/ June 18th 2021 on the onslaught of natural disasters triggered by the monsoon in Nepal. Read the original article in Nepali here. https://nepalkhabar.com/magazine/60644-2021-6-18-14-42-21

2. Featured by AP1- "Prayas" programme (Television Network) /June 22nd 2021 as a guest of "Prayas", a weekly television programme where the host Rupa Khadka Interviews individuals who have made outstanding contributions nationally, in any field. Watch the Interview in Nepali

3. Featured by Kantipur- "Good Morning Nepal" programme (Television Network) /Jun 22nd 2021; On their daily morning show "good morning, Nepal", host Bikas Thapaliya interviewed to discuss my work on the weather and climate and importance of meteorological stations in Nepal. Watch the full interview in Nepali here

4. Features on Kantipur National Daily on the occasion of the International Day of Women scientist on March 8, 2022 on my work as a women scientist I Nepal: https://ekantipur.com/technology/2022/03/08/164673291595069002.html?fbclid=IwAR2_1D7LQbDE3duB53l7HZjGENhbOq-HX3-xLMgY6WVOUzSZZA4B_h0hFns

5. Featured on Himal Khabar Patrika; February 12, 2022 for our work on drought and weather stations in Nepal: https://www.himalkhabar.com/news/128268?fbclid=IwAR1s3PUtUrU04Sb27izRF3aTfDUMCv2WTPPgIJX-LsOQ1AMzOBWYlQ0o5q4

6. Featured in Nepali Times Newspaper on 11th February 2022: https://www.nepalitimes.com/here-now/sky-is-the-limit-for-nepals-women-scientists/?fbclid=IwAR2_1D7LQbDE3duB53l7HZjGENhbOq-HX3-xLMgY6WVOUzSZZA4B_h0hFns

7. Featured in nature: Where I work on 12th July 2022: *doi: https://doi.org/10.1038/d41586-022-01902-w*

7. Pull quotes

A much-needed and appreciated work done by Dr Kafle and her team. I will be using the Drought Atlas of Nepal while teaching climate change in my university and also recommend my students to use it -Dr. Ramji Bogati, Program Coordinator, Nepal Open University

I am very proud to be part of this project. This is very important work done by Dr Kafle and her team. Thankful to APN and KIAS for allowing us to research the impact of drought on fish production for the first time in Nepal -Prof. Dr Sunila Rai, Agriculture and Forestry University

This is essential for South Asian countries, especially in disaster management and food production. I am also surprised to see the high quality of research work done in Nepal by Dr Kafle and her team. This is the first time I am seeing this quality of work by any Nepali researcher.

Thank you, Dr Kafle, for inviting me to this workshop -Prof. Dr Md. Giashuddin Miah, Vice Chancellor, Bangabandhu Sheikh Mujibur Rahman Agriculture University, Dhaka, Bangladesh

This APN-funded project changed my perception of drought. I knew from this project that drought in South Asia (India, Pakistan, Nepal, Bangladesh) is real, already happening and making a detrimental impact on agriculture production. I realised that it might jeopardise the lives of billions of people, mainly those underprivileged and living with subsistence agriculture. I hope the project provided the first scientific evidence of the extent and intensity of drought at the regional level and provided a wake-up call for policymakers in Nepal -Dr Prakash Kumar Paudel, Executive Director, Kathmandu Institute of Applied Sciences

8. Acknowledgments

We are very grateful to Asia Pacific Network for Climate change research (APN) for allowing us to work on this project. I would like to thank all my collaborators for their support and kind understanding while doing this research work also in the COVID time. I am very much thankful to all the team of this project work, the research assistant, program manager, field data collectors, technical supervisors and also the advisor whom we approached. I felt very lucky to have such a team; without them this work quality would not have been the same.

9. Appendices

Appendix 1: APN Planning Meeting:

Date: 2018-10-09 and 2018-10-10

Place: Radisson Hotel, Kathmandu, Nepal

APN planning meeting report

A successful APN (Asia-Pacific Network for Global Change Research) meeting occurred on 9th and 10th of October 2018 at Radisson Hotel. Among the participants were distinguished guests - Prof. Yasushi Yamaguchi from Nagoya University, Japan. Mr Devesh Koirala from the Nepal Academy of Science and Technology, Nepal and Dipak Gyawali from the Nepal Water Conservation Foundation, Nepal. The meeting was hosted by Dr Hemu Kharel Kafle, a scientist from the Centre for Water and Atmospheric Research (CenWAR), Kathmandu Institute of Applied Sciences (KIAS). Researchers, Research students and Thesis students from CenWAR, Bijaya Luitel, Stuti Shakya, Prakash Sharma, Santosh Khanal and Sashank Karki, were present in the meeting. Our distinguished collaborators from India, Pakistan and Bangladesh could attend this meeting due to the short period. This meeting was organised in a very short period of time due to the unavailability of research funds on time. The meeting was the first planning meeting of the project "Improving assessment of drought and its impact on food and water resources in South Asia."

The meeting was inaugurated by a presentation from Dr. Kafle, who gave a brief overview and insight into the necessities of the meeting. In her presentation, she described how Nepal doesn't have a metric for determining drought and how it is absolutely essential for crop monitoring and

assessment to have a system in place to detect and monitor droughts. She established the scope of the project and its duration – the project aims to create a drought index to monitor the entire South Asia region comprising Nepal, India, Pakistan and Bangladesh within the next two years.
Thereafter, there was a presentation by Prof. Yasushi Yamaguchi, who detailed the participant's various drought indices using satellite datasets. He offered insights into which indices might be suitable for the region by citing his own research that he had conducted with his students.
After discussing which drought index should be used in case of Nepal topography and the availability of datasets, Mr. Devesh Koirala gave a presentation on data sets and the challenges for data standardisation. Problems that might come up while looking at data accuracy and timings were discussed during the meeting. His sentiments were further elaborated on by Dipak Gyawali, who talked about the challenges facing data collection due to the national interests of nations in the program. Since Mr Gyawali expertise was in policy, his sharing of experiences dealing with officials was much appreciated.
Finally, the first day of the meeting was concluded. On the second day, we discussed the plan for beginning the project. Testing of a few drought indices following the availability of datasets was finalised. In the first phase, we concluded to test the Drought Severity Index, Vegetation Condition Index and Vegetation Water Temperature Condition Index in Nepal and check the results. After finalising the drought index, we plan to move further to other countries using the same index. The meeting could not have been successful without the presence of the various dignitaries who offered key insights into the problems that might be faced throughout the project and potential solutions to these problems. After finishing the meeting, Prof. Yasushi Yamaguchi and Dr Kafle attended meetings with people from Hydro-meteorological and remote sensing backgrounds at Kathmandu University and Tribhuvan University to have more ideas for similar ongoing kinds of works in these institutes.

Appendix 2:APN year-end meeting report:

Date: August 22 and 23, 2019

Venue: SKY CITY Hotel, Dhaka

Research Coordination Meeting on "Improving assessment of drought and its impact on food and water resources in South Asia".

According to our proposal work division, the research coordination meeting was organised on August 22 and 23, 2019, at SKY CITY Hotel, Dhaka. This meeting aimed to analyse our work, achievements and the challenges we faced during 2018/2019. Besides, we also plan to have a fruitful work plan for 2019/2020 with the suggestions and ideas from all the collaborators and technical supervisors of this project. However, we also wanted suggestions and advice from the community outside the project group. Therefore, on the first day of the meeting, especially in the morning session, we invited a few distinguished personalities from Bangladesh to share our work and discuss the importance of drought studies in South Asia. We were very fortunate to have the ambassador of Nepal to Bangladesh, his excellency Mr Dhan Bahadur Oli, Prof. Dr Md. Giashuddin Mia, Vice-chancellor, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh; Dr Mizan R Khan of the International Centre for Climate Change and Development (ICCCD), Bangladesh; Prof. Fatima Aktar from the University of Dhaka; Prof. Mohan Kumar Das of Bangladesh University of Engineering and Technology; Dr Rudra Bahadur Shrestha, Senior program specialist, policy planning of SAARC Agricultural Centre, Dhaka and Dr A. S. M. Maksud Kamal, Dean, Faculty of Earth and Environmental Sciences, University of Dhaka, among our guests.

The program started with welcoming remarks by the collaborator of Bangladesh, Prof. Md Kamaruzzaman, followed by an introduction of the participants. Executive Director of Kathmandu Institute of Applied Sciences, Dr Prakash Kumar Paudel, gave an opening remark. After that, Project PI Dr Hemu Kharel Kafle briefly introduce the project and its activities to all the present guests and collaborators. His Excellency Mr Dhan Bahadur Oli presented his remarks. He appreciated our work and emphasised the importance of collaboration among the South Asian region for extreme climatic events. He mostly liked our activity of preparing a database of traditional coping mechanisms for drought in all four countries to study the impact analysis of drought on food and water resources. Finally, he thanked us for inviting him to this scientific event and expressed his willingness to help us by any means. Then we have a small tea/coffee break with the photo session. After this, our first session on "Discussion on Extreme Climate, Crop Production, Society and Policy in South Asia" started with a presentation from our collaborator from Nepal, Academician of NAST and Ex-Minister of Water, Mr Dipak Gyawali. He presented on Extreme Climate, Society and Policy in South Asia. Mr Gyawali highlighted how Nepal is a semi-arid region with four months of flood and eight months of drought. He also talked about our policies; they are perfect; however, we are backward in implementing them. He gave an example of improved technology destroying the yearlong sustainable water management process. After that, we had a presentation from Dr Rudra Shrestha from SAARC agriculture, Dhaka, about "Climate Smart Agriculture in South Asia". He presented South Asia's agriculture

production statutes and the policies they have. After the two presentations, we had questions/answers followed by remarks from the session's chairperson, Prof. Dr Md. Giashuddin Miah. Our first session ended here, and our second session on "Technical Workshop on Assessment of Drought and Its Impact on Food production in South Asia" started after the lunch break with Prof. Yasushi Yamaguchi as a chairperson. This session started with a presentation from project PI, Dr Kafle. She briefed the team about the project work, that had been completed in the first year and the remaining work that needed to be done in the second year. Our second presentation was from Prof. Yasushi Yamaguchi on "Drought Monitoring by Remote Sensing". He explained in detail about the drought indices that could be useful in this project and also about the datasets that are used. Results on the Drought Severity Index of Nepal were presented by Dr Kafle, on behalf of Mr Bijaya Luitel after Prof. Yamaguchi's presentation. Ms Stuti Shakya presented the result of field data analysis in Nepal using different indices. We discussed the result we got so far and the way to improve it. Dr Shinchi Sobue presented about GEOGLAM/Asia RICE and APRSAF SAFE Argo-met activity. He also showed us how the impact on food production could be checked by different methodologies and the similar work done in India by APRSAF. After that presentation on the Impact of drought on crop production was done by Dr Kafle, on behalf of Areena Maharjan. The first day ends with a recommendation and discussion. On the second day, we had a close meeting on future work that needed to be done and also the distribution of work among collaborators. This two-day workshop was closed by the remarks from the Executive Director of Kathmandu Institute of Applied Sciences, Dr Prakash Kumar Paudel.


APN Research Co-ordination Meeting
"Improving assessment of drought and its impact on food and water resources in South Asia."
Date: 22-23 August, 2019
Dhaka, Bangladesh

Appendix 3: The South Asian Drought Workshop (APN project closing workshop)

28th - 30th April 2022

The Himalayan Horizon, Dhulikhel

The South Asian Drought Workshop, held from 28th to 30th April 2022, was organised to discuss and summarise the works done on drought severity index assessment in South Asian countries like Nepal, Bangladesh and Pakistan. Additionally, the drought brochure was displayed at this event with a particular emphasis on farmers and school children. This conference's other primary purpose was to introduce the Drought Atlas book of Nepal, Pakistan, and Bangladesh and solicit feedback and recommendations from professionals and academics.

Summary of Discussion

Discussion topics	Synopsis
Keynote Presentation by Prof. Dr Yasushi Yamaguchi, "Drought Monitoring by Remote Sensing"	➢ Remote sensing and its importance in the drought monitoring process. ➢ Various drought monitoring systems and its applications
Guest lecture by Dr Shincihi Sobue, "Climate Change and Agricultural Production: Global Systems for Crop Alerts to Help Producers Choose Improved Varieties"	➢ Introduction to Climate Change and its global issues. ➢ Linkage between Climate change and Agricultural Production. ➢ Various researches on Climate change impact on various crops globally. ➢ Recommendations to help farmers match the best variety with their field contexts
Presentation by Dr Hemu Kafle, "Historical agricultural drought in South Asia 2000-2020"	➢ Elaboration of Drought Severity map of South Asia ➢ Movement of drought in studied South Asia countries
Presentation by Ms Pratishya Neupane, "Growth performance of different fish species during dry period in Chitwan, Nepal".	➢ Used stock fishes like Silver carp, Bighead carp, Grass carp, Rohu, Naini, *Nile tilapia*. ➢ Growth and yield of fish species. ➢ Gross margin analysis ➢ *Nile tilapia* culture was found to be appropriate for dry period because yield, survival rate and gross margin were better in low water depth, high water temperature and low Dissolved oxygen.
Presentation by Ms Soni Khaitu, "Impact of drought on cropland of South Asia"	➢ Drought severity frequency of Bangladesh and Pakistan from 2000-2020. ➢ Cropland drought frequency in Bangladesh and Pakistan from 2000-2020.
Guest Presentation by Dr Anjum Rasheed, "Importance of Drought	➢ Drought and food security in Pakistan. ➢ Types of drought monitoring systems and its application.

Monitoring System for Food Security".	➢ Role of drought monitoring system in food security.
Presentation by Ms Anjala Khanal, "Impact of drought on aquaculture and mitigation strategies adopted by farmers in Chitwan district of Nepal".	➢ Socio-economic and demographic characterisation of the farmers. ➢ Farm characteristics of fish farmer in Chitwan district. ➢ Farmer perception on definition of drought. ➢ Farmer faced drought problems on aquaculture. ➢ Success of farmers and source of knowledge to cope drought impact. ➢ Training, Subsidy and Insurance in aquaculture. ➢ Subsidy and facilities requirement from government.
Launching of Drought Literacy Booklet	➢ Drought literacy booklet comprises of introduction, causes, effect, mitigation and adaptation regarding drought which is prepared to focus on children and farmers. ➢ This booklet is simple and easy to understand.
Guest lecture by Er. Dipak Gyawali	➢ Relation between scientific research and social science and its importance. ➢ Application of our scientific research in social sciences and community.
Launching of Drought Atlas of Nepal, Bangladesh and Pakistan	➢ Drought atlas comprises summarised information about DSI index of different countries with values and maps from 2000 to 2020.


मसलाबाली विकास केन्द्र

Stakeholders' meetings:

Appendix 4: Presentations in Conferences:

1. Agricultural Drought assessment in Nepal using MODIS-based Drought Severity Index (DSI)

Bijaya Luitel, Hemu Kafle

Abstract

Droughts are one of Nepal's greatest threats to agricultural crop production, a country whose economy relies heavily on agriculture. The croplands of Nepal are found primarily along the fertile Terai belt, characterised by low-lying fields interspersed with settlements, and both seasonal and permanent rivers. Due to the dearth of artificial irrigation methods, farmers rely heavily on adequate and timely rainfall to provide the necessary crop outputs. Consequently, dips in agricultural production coincide heavily with sparse rainfall. In order to analyse recent precipitation and drought trends in Nepal, we use MODIS-derived monthly NDVI, Evapotranspiration (ET) and Potential Evapotranspiration (PET) data at 1km spatial resolution from February 2000 to December 2014 to calculate monthly DSI for Nepal. For the validation, we then use APHRODITE-derived precipitation data, at a spatial resolution of 0.25 degrees, from 1951 - 2014 to calculate SPI-1 and SPI-3 pixel-wise for Nepal. After that, Pearson correlation coefficients are calculated on a pixel-wise basis separately for SPI-1 with DSI and SPI-3 with DSI. Preliminary results indicate a superior correlation between SPI-3 with DSI compared to SPI-1 with DSI, with temporal trends indicating the better performance of the Pearson correlation coefficient during comparatively low precipitation periods (nationwide) from January to May. These results indicate DSI can capture drought trends in Nepal, especially for crops planted after the onset of the winter season.

Keywords: *Agriculture drought, Nepal, MODIS, DSI*

2. Agriculture Production Scenario in Nepal: Historical Analysis

Areena Maharjan, Hemu Kafle

Abstract

Agriculture is the mainstay of the Nepalese economy and about two-thirds of people depend on agriculture for their livelihood. Nepal has diversified climatic conditions which are suitable for growing a large number of cereal crops. Cereal crops, including rice, maise and wheat, dominate the agricultural sector. Rice is a major source of dietary energy for the Nepalese people and has a huge contribution to enhancing food and nutrition security in Nepal. Agriculture is a mostly rainfed and prolonged water scarcity is the main cause of the drought. Drought adversely affects crop production by reducing crop yield and leaving the land barren. Although Nepal was considered a food exporting country till mid-1980s, it started importing grains in 1991. The domestic production of cereal crops is not enough to meet growing demand and tremendously increasing population, thereby decreasing cultivated area; the country heavily relies on imports. However, production data from various sources, including the ministry of agriculture, shows the growing trend in grain production and productive land in Nepal. Documented data shows the

actual crop production within Nepal and the number of imports from other countries are still lacking, which hampers the making policies and planning for the food security of the Nepalese population. In this study, we have analysed crop production data from different sources and crop import data from different countries for over thirty years (1980-2018). This study is significant for food security in Nepal.

3. Meteorological Drought in Nepal: Spatial and Temporal Analysis

Stuti Shakya and Hemu Kafle

Abstract

Drought is a natural phenomenon which occurs due to the lack of precipitation over a while. However, the constant rise in global temperature has accelerated the hydrological processes that are onset them. Nepal is an agricultural country where still traditional methods are being applied and are primarily dependent on rainfall, and drought is a serious matter. This study has scrutinised Nepal's spatial and temporal changes in drought occurrences. Standardised Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) were used to quantify the severity and frequency of drought events at multiple time steps. Altogether 79 meteorological stations for SPI and 74 stations for RDI were analysed for drought occurrences from 1982 to 2017 based on their data availability. The SPI study revealed that the summer season of 1983, 1992, 2005, 2006, 2012, 2014, and 2015 and the winter seasons of 1998-1999, 2005-2006, 2007-2008, 2008-2009, 2015-2016 and 2016-2017 were the widespread droughts. Similar results were obtained from the RDI analysis. At the regional scale, western and eastern Nepal is characterised by frequent summer droughts, while southeast and western Nepal observe frequent winter droughts. Most stations have observed all three categories of drought (moderate, severe and extreme).

Keywords: *Drought, Nepal, Station-data, RDI, SPI*

4. Current scenario of crop yield and national food security in Nepal

Ms Yurisha Upadhyaya and Dr Hemu Kafle

Kathmandu Institute of Applied Sciences

Abstract

This study reviewed the general overview of Nepal's crop yield and food security status. The increasing rate of population growth, their increasing demand for food requirements and the decreasing limited productive agricultural lands have raised a concern towards national food security status, even though the interim constitution of Nepal has mentioned "food sovereignty as a fundamental right in its constituents". Although agriculture contributes to 25.29% of the nation's GDP and 65.6% of national employment by the domination of small and marginal holders, the impact of food scarcity is most severe on the rural population and particular livelihoods of the far west (62%) and mid-west (72%). Hence, the issue of food security lies in priority. Since cereal crops are major staple food crops in terms of their productivity, they play

significant roles in addressing food security issues in Nepal. There have been fluctuations in production and demand situations in recent years due to various reasons. Thus, this research aims to analyse the dynamics of cereal crops production, i.e. production status and causes of low production and discusses the strategies to mitigate the food insecurity situation in Nepal by reviewing various literature as well as actual data from the Ministry of Agriculture and Livestock Development (MoALD), Government of Nepal, Food and Agricultural Organization (FAO), World Food Programme (WFP) and statistical reports.

Master Thesis Abstracts:

1. Impact of Drought on Aquaculture and Mitigation Strategies Adopted by Farmers in Chitwan District of Nepal

Abstract

A study was conducted to assess the impact of drought on aquaculture and mitigation strategies adopted by farmers in different areas of Chitwan districts, viz. east Chitwan, west Chitwan and south Chitwan. Altogether, 150 fish farmers were selected by random cluster sampling in the Chitwan districts. 75 Farmer from east Chitwan, 25 farmers from west Chitwan and 50 farmers from south Chitwan depends on fish farmer abundance with the consultation of the District Livestock Office (DLSO). Out of 150 farmers, 55% strongly agree, 28% agree, 13% somewhat agree, and 5% have no problem with drought's impact on aquaculture. 94% of farmers faced water quality problems in drought, like 96% water level decreases, 90% Oxygen deficiency,77% hot water temperature, 43% algal bloom occurrence, 39% macrophytes growth and 37% predation increase. 67% of farmers experienced disease occurrence, particularly in drought periods, mainly Argulus(86%); some fish had a wound-like appearance and fungus. Post-monsoon had more impact on fish production than monsoon and premonsoon because the fish growth rate increased in both the summer and the premonsoon seasons. , 46% of farmers said that fish mortality is less than monsoon and more than post-monsoon, 35% of farmers said that more than monsoon and post-monsoon, and 17% said there is no mortality. The farmers tried to mitigate some of the problems encountered due to climate change. Overall, 85% of farmers are pumping freshwater, followed by 33% splashes by bamboo, 22% swimming by children/men, 17% use submersible pumps, 21% use aerators and other methods etc., to increase the oxygen level of fish culture ponds. 7% of farmers in South Chitwan applied oxygen tablets during higher summer. With low rainfall, 44% of farmers maintain the water level by pumping water from their bore well. In drought, 9% of the farmers reported that they had made early harvest, irrespective of the fish growth, others never stocked the ponds and 49% of farming had done final harvesting before winter to escape the winter period after winter stock fish seed for better growth in the summer season.

2. Effect of drought on growth and yield of different fish species in Chitwan, Nepal

Abstract

Climate is an important factor for aquaculture production. Important climate-related risks include extreme temperatures (hot and cold), excessive rainfall, prolonged cloud cover, flood

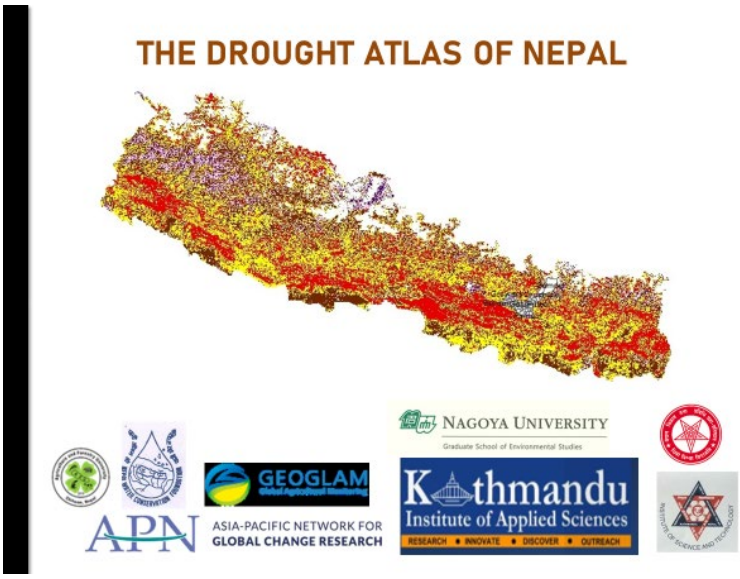
and drought. The selection of appropriate fish species is important to address the problem of increased temperature and reduced culture period in ponds under drought-prone areas. The main objective of this study is to know the effect of drought on aquaculture in the Chitwan district. This study was conducted under three treatments (T1: Carp polyculture including Silver carp, Bighead carp, Grass carp, Rohu, Mrigal and Common carp; T2: Common carp monoculture and T3: Tilapia, each with three replications). Mean stocking weight (g) of carps in T1, namely Silver carp (7.43 ± 0.45 g), Bighead carp (8.68 ± 0.31 g), Grass carp (7.25 ± 0.54) g, Rohu (6.88 ± 0.33 g), Mrigal (5.81 ± 0.35 g) and Common carp (9.34 ± 0.47 g), at densities of 1400, 4000, 2600, 6000, 2000 and 4000, fingerlings per hectare respectively. Similarly, Common carp monoculture (T2) was stocked with fingerlings of (8.17 ± 0.45 g) and Tilapia (T3) with (6.23 ± 0.37 g) at a density of 20,000 fish per hectare. The stocking density (20,000/ha) of fishes were the same for all the treatments. Ponds under different treatments were applied with bleaching powder at the same level (275kg/ha) to remove weed and predatory fish species. Fertilisation was done with (Urea@ 47) kg/ha and DAP @ 35 kg/ha, respectively. Feeding was carried out with pelleted sinking feed @ 3% of body weight and adjusting feed rations monthly based on the sampled weight of fish species. In situ water quality parameters were monitored twice a day, transparency weekly, and total ammonium nitrogen (TAN), Soluble reactive phosphorous (SRP), Nitrite, Total alkalinity and chlorophyll biweekly. Water quality parameters were found within the suitable range. Average dissolved oxygen, temperature, pH, transparency, total alkalinity, soluble reactive phosphorous, nitrite, total ammonia-nitrogen and chlorophyll a of water were 3.5±0.7, 28.2±1.7, 7.8, 28.2±4.0 cm, 84.07±7.29, 0.039±0.01, 0.007±0.00, 0.033±0.01 and 27.88±5.81 mg/L respectively. Water quality did not vary significantly between the treatments. Treatment T3 (with Tilapia monoculture) varied more significantly ($P < 0.05$) than other treatments for the mean values of growth (survival rate, AFCR, Extrapolated Gross Fish Yield and Extrapolated Net Fish Yield). Feed cost, total variable cost gross return and gross margin were significantly higher ($p<0.05$) in treatment T3.

Keywords: *aquaculture, carp polyculture, Chitwan, drought, tilapia*

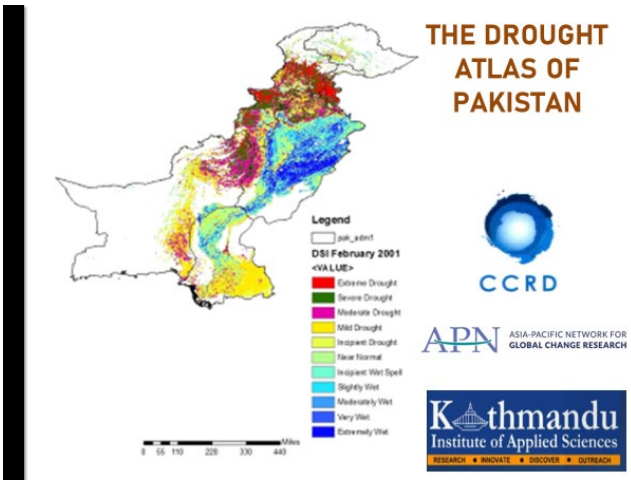
Appendix 5: Other Publications:

1. Drought Booklet in the Nepali Language

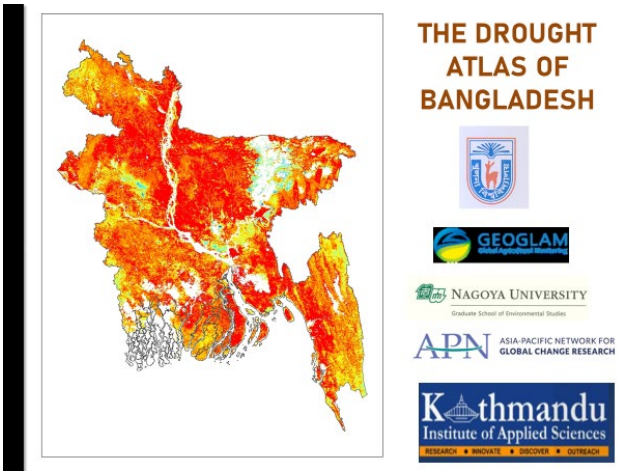
2. Drought Atlas of Nepal



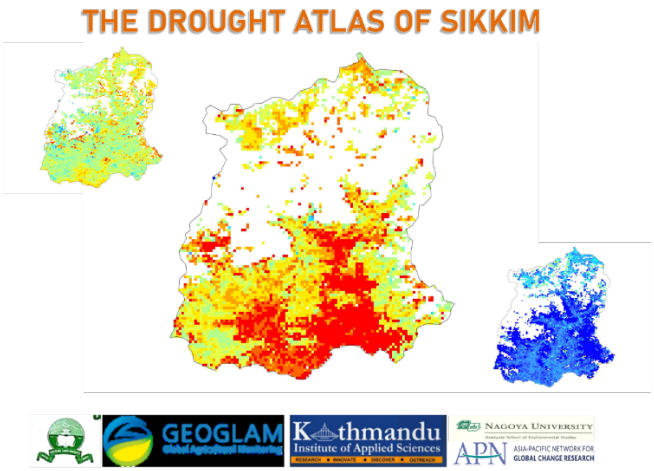
3. Drought Atlas of Pakistan



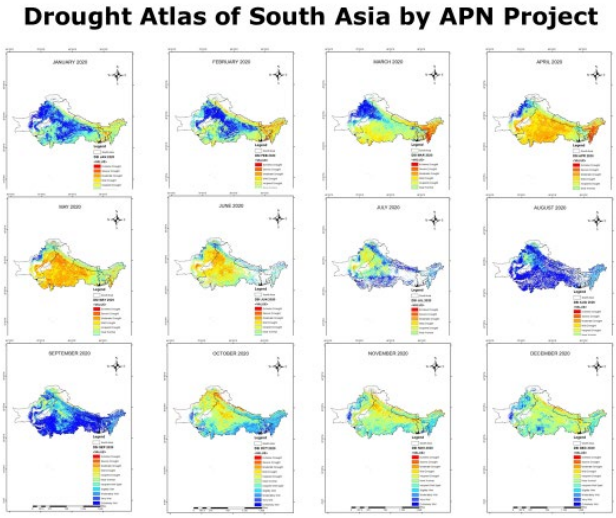
4. Drought Atlas of Bangladesh



5. Drought Atlas of Sikkim



6. Drought Atlas of South Asia



7. Manual of Drought assessment tool:

MANUAL TO CALCULATE DROUGHT SEVERITY INDEX (DSI) AND OBTAIN DSI MAPS

Application needs to download/install calculating Drought Severity Index

- Arc Gis
- Python
- Wget
- Cygwin
- Microsoft packages

***** Before downloading the MODIS data, one should login to Earthdata Login (https://urs.earthdata.nasa.gov/users/new) to get access for downloading NDVI and ETPET datas.

❖ **How to Download NDVI datasets??**

- Required dataset= MOD13A1 - MODIS/Terra Vegetation Indices 16-Day L3 Global 500m SIN Grid
- NDVI datasets are obtained from and the NASA Land Processes Distributed Active Archive Center (LP DAAC, https://lpdaac.usgs.gov/).

Steps to download NDVI datsets

1. Go to Google
2. Search LAADS DAAC (https://ladsweb.modaps.eosdis.nasa.gov/search/)
3. Click Data
4. Select Find Data
5. Click Search by Product
6. Type keyword (MOD13A1)
7. Select MODIS/ Terra Vegetation Indices 16-Day L3 Global 500m SIN Grid
8. Go to Time
9. Fill the Date From (YYYY/MM/DD) To (YYYY/MM/DD), then click Add Date
10. Goto Location
11. Select the Countries from the area of Interest

Drought characteristics in the specific countries:

Nepal

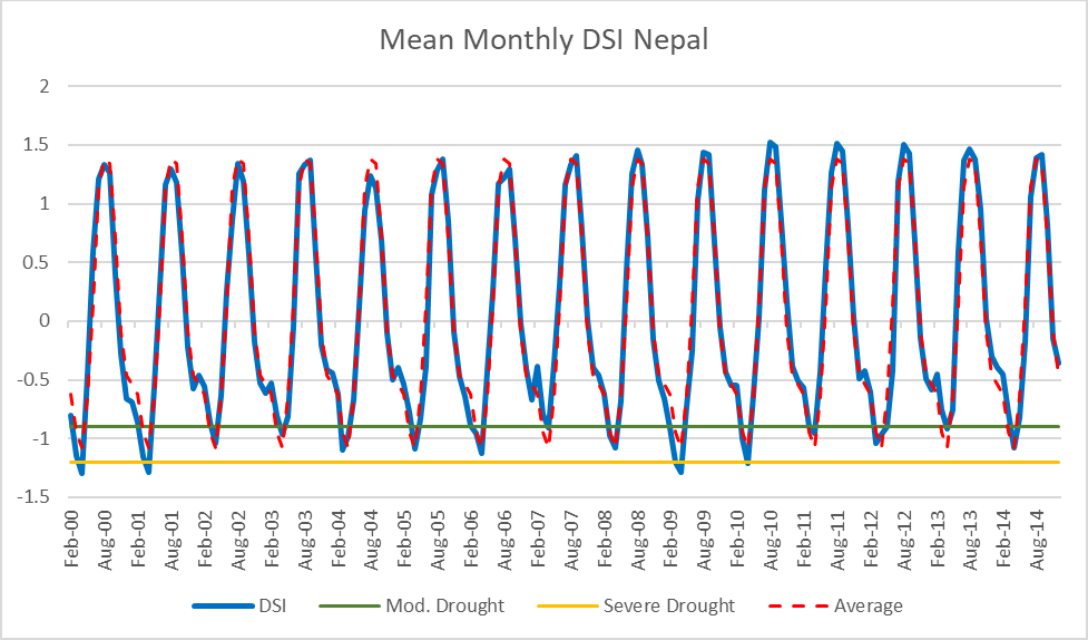


Figure 9. The mean monthly DSI time-series graph of Nepal for the period 2000-2014

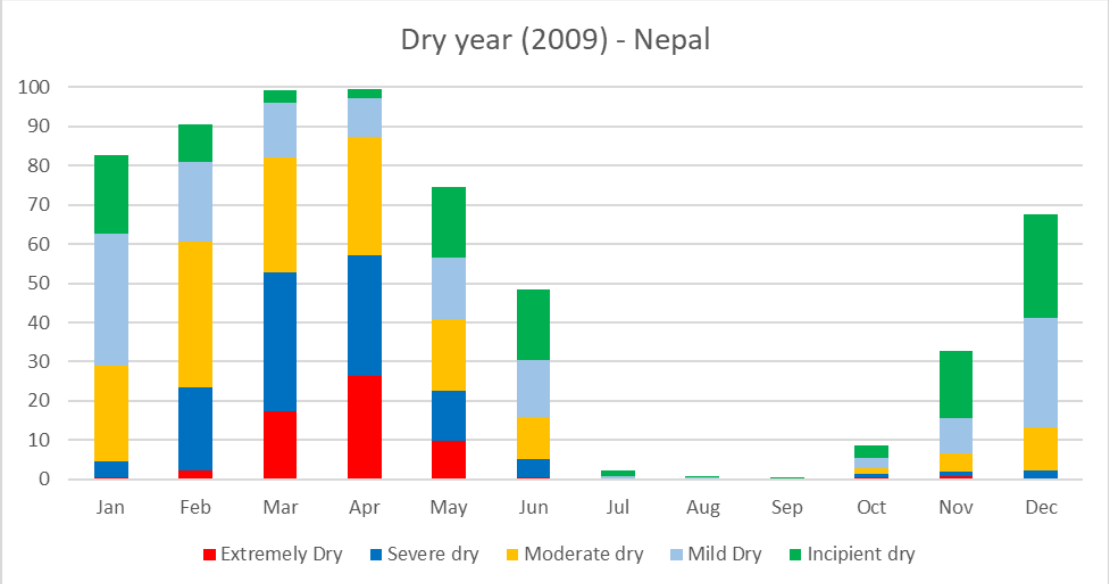


Figure 10. The drought coverage-intensity graph of Nepal in the dry year (2009)

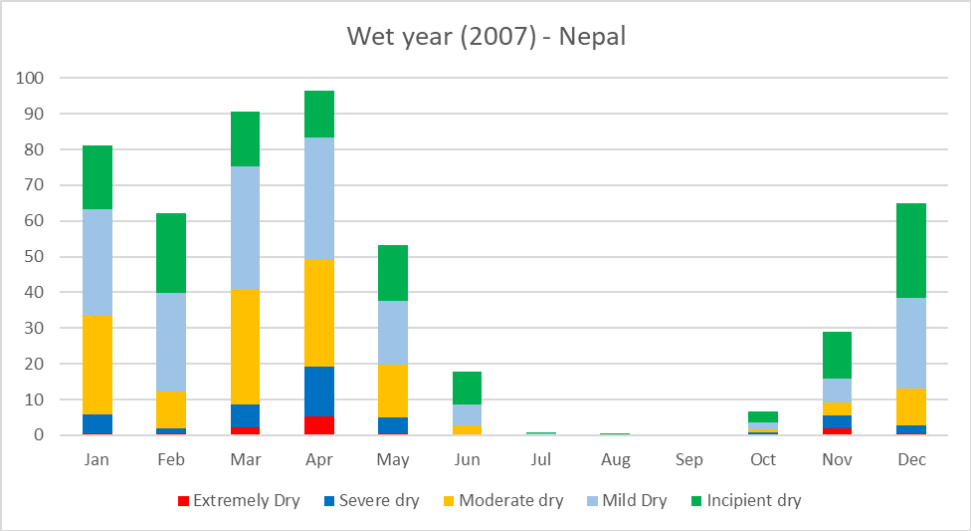


Figure 11. The drought coverage-intensity graph of Nepal in the wet year (2007)

Bangladesh:

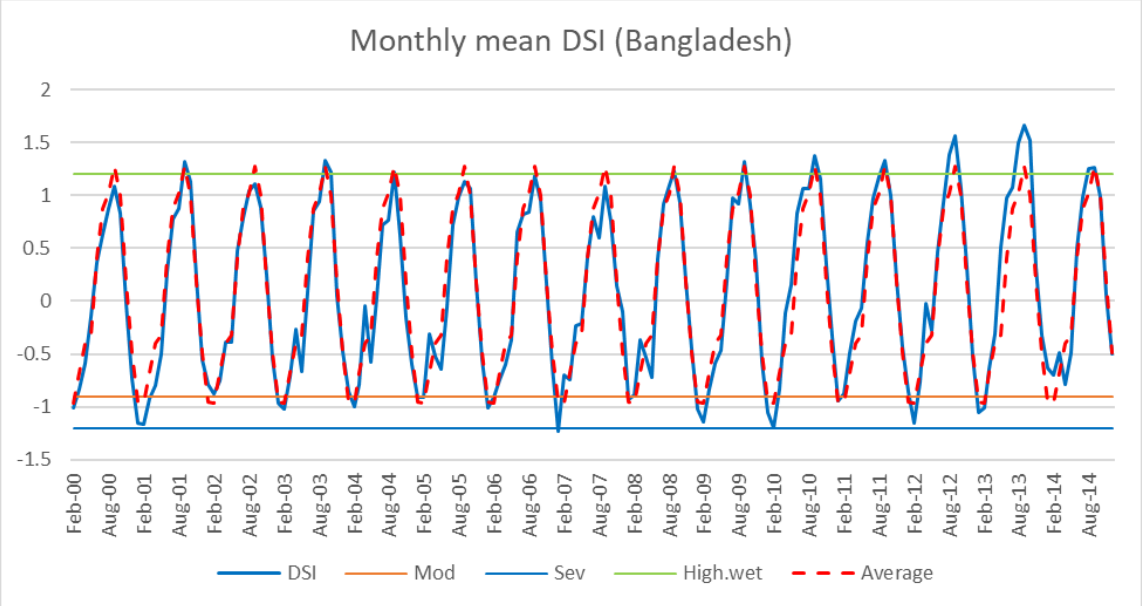


Figure 12. The mean monthly DSI time-series graph of Bangladesh for the period 2000-2014

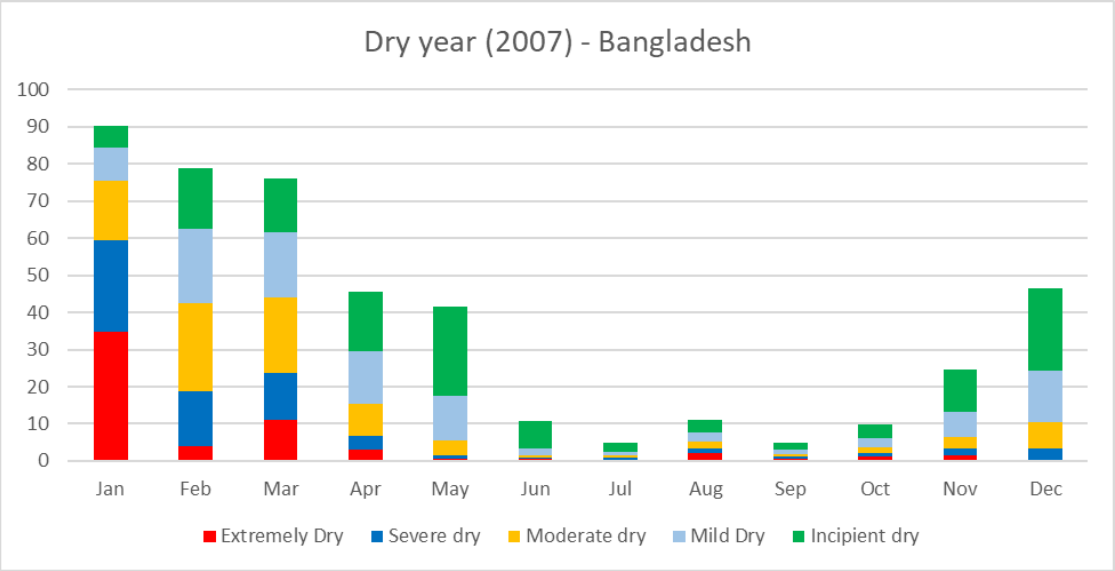


Figure 13. The drought coverage-intensity graph of Bangladesh in the dry year (2007)

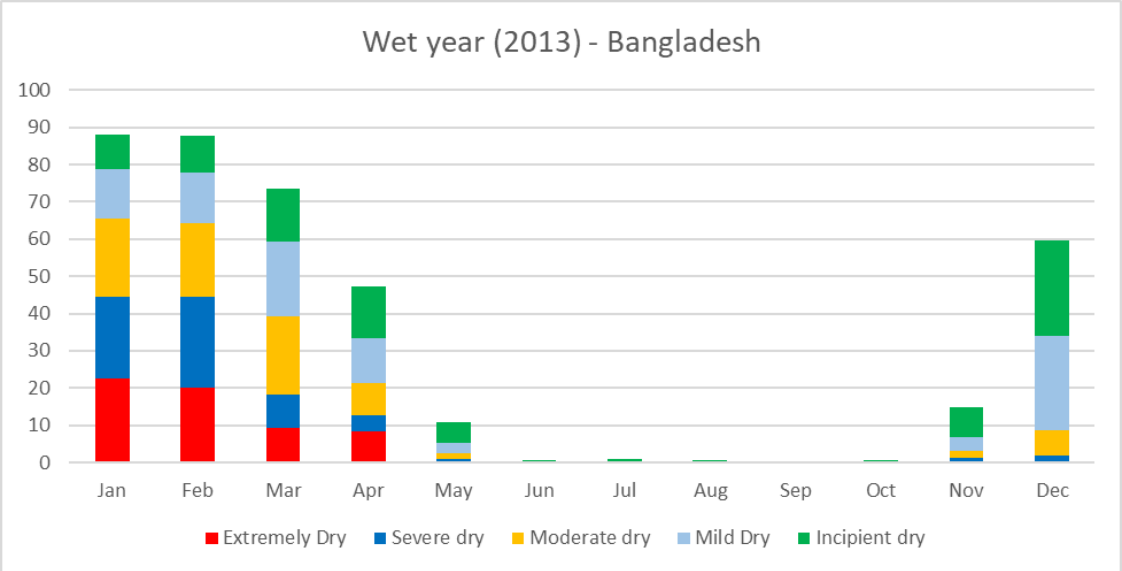


Figure 14. The drought coverage-intensity graph of Bangladesh in the wet year (2013)

Pakistan

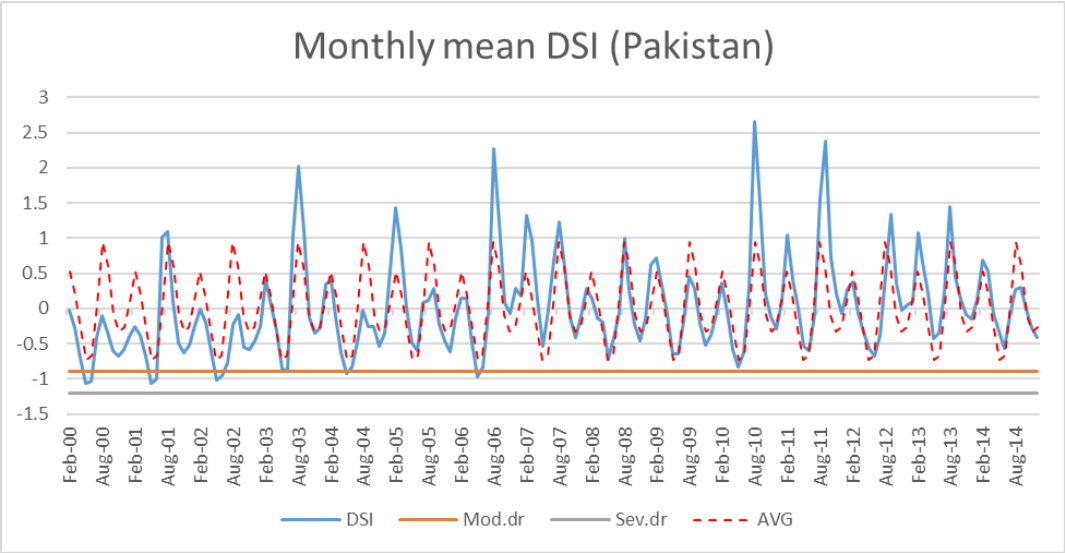


Figure 15. The mean monthly DSI time-series graph of Pakistan for the period 2000-2014

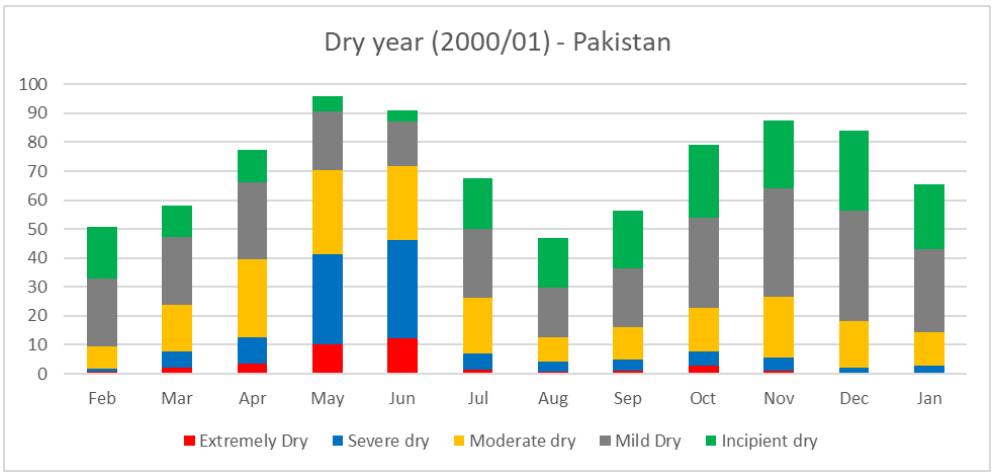


Figure 16. The drought coverage-intensity graph of Pakistan in the dry year (2000/01)

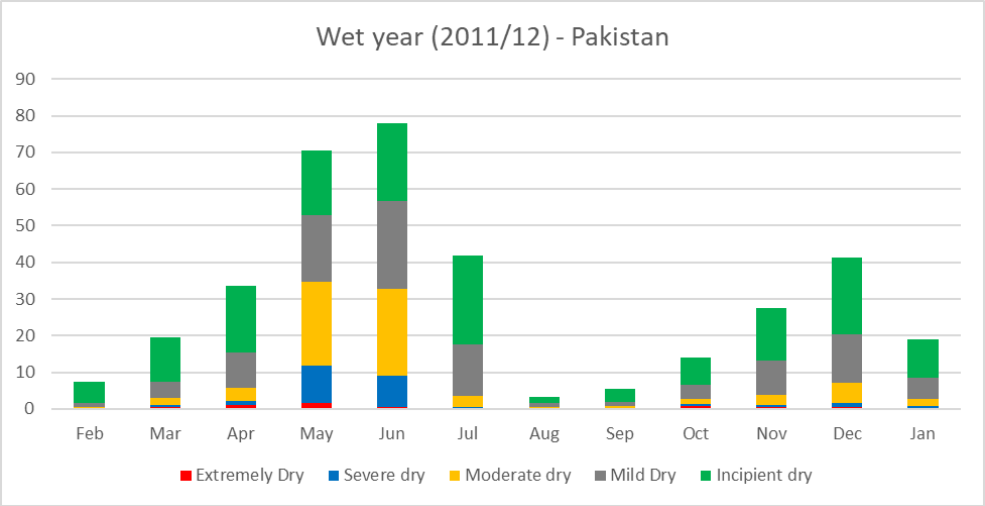


Figure 17. The drought coverage-intensity graph of Pakistan in the wet year (2011/12)

India:

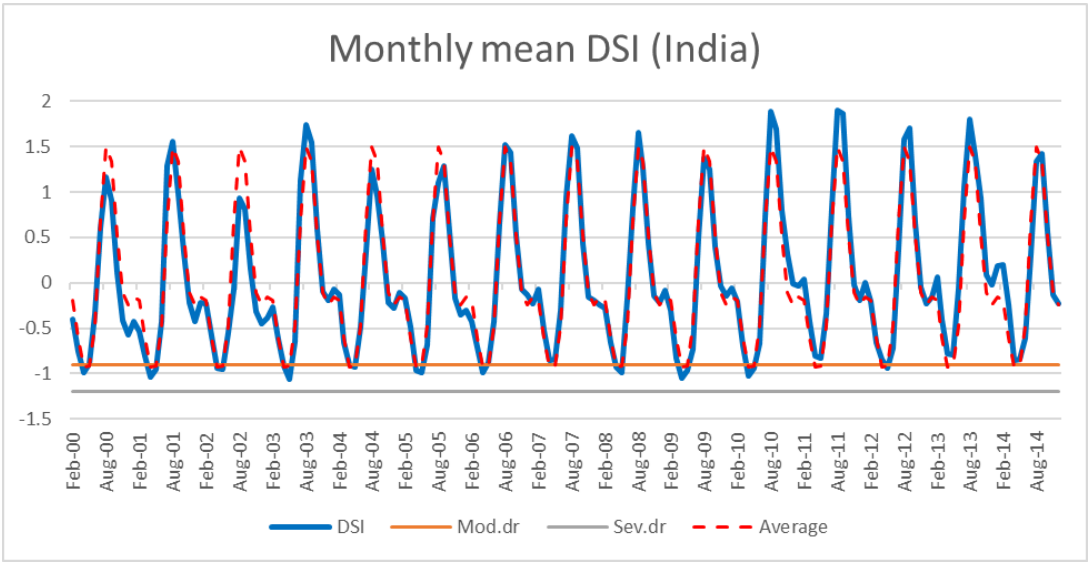


Figure 18. The mean monthly DSI time-series graph of India for the period 2000-2014

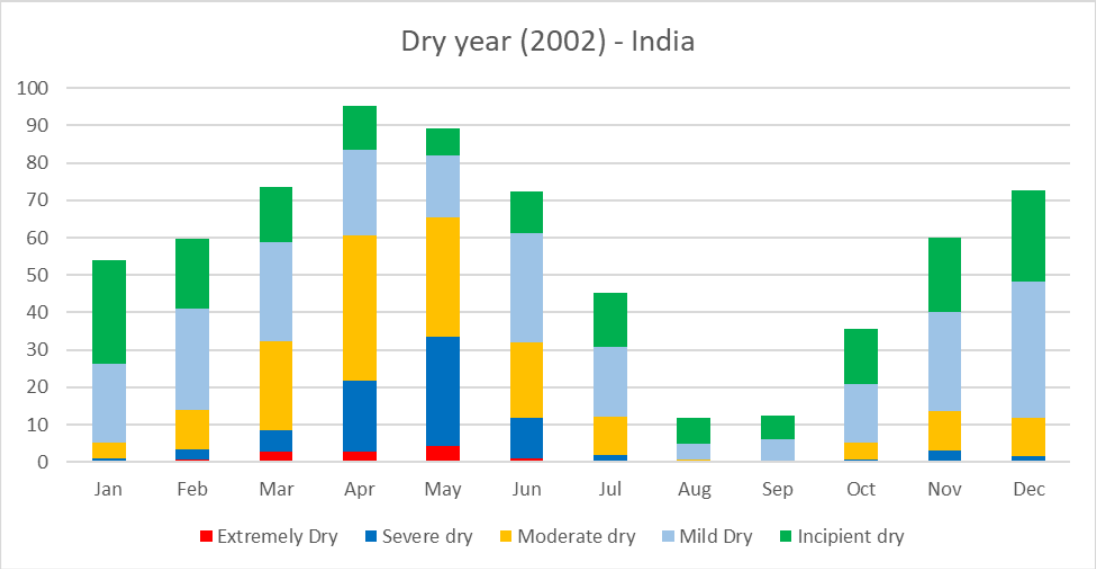


Figure 19. The drought coverage-intensity graph of India in the dry year (2002)

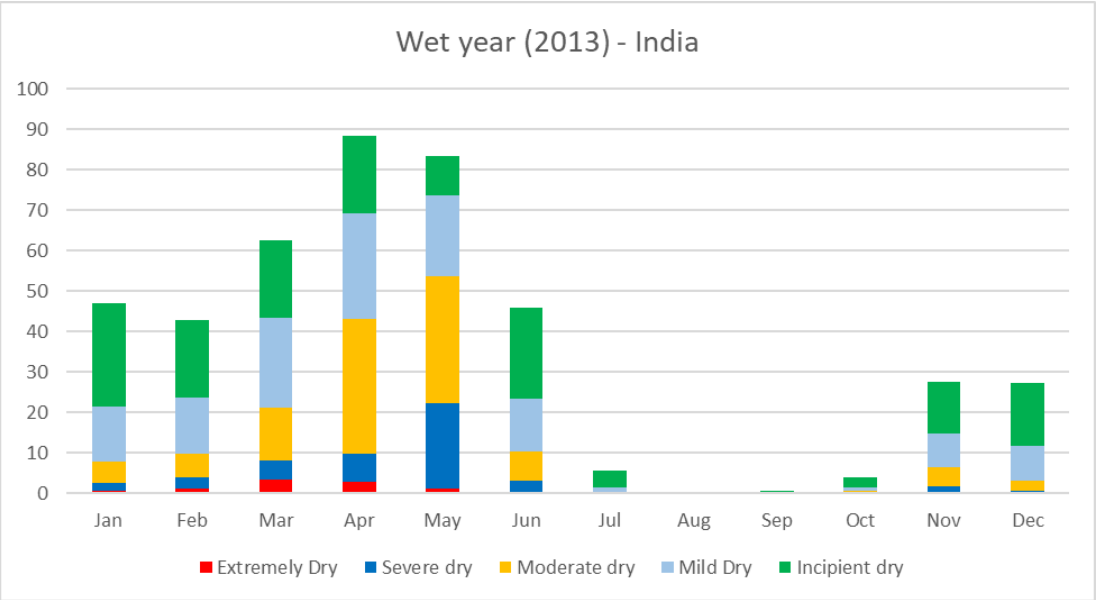


Figure 20. The drought coverage-intensity graph of India in the wet year (2013)