Global Water Partnership South Asia

Drought Monitoring System for South Asia

Summary Report of the Need Assessment Survey on the Development of South Asian Drought Monitoring System (SA DMS)

Compiled by Global Water Partnership, South Asia with support from the WMO/GWP Integrated Drought Management Programme (IDMP)
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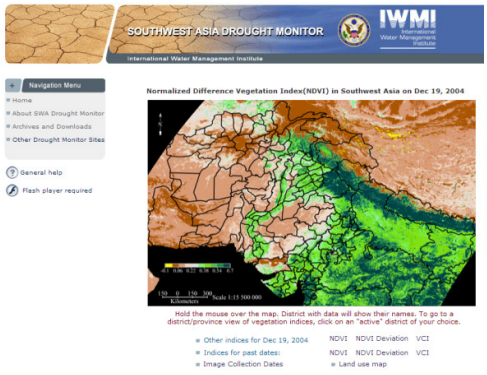
Contents

Background and Approach

Periods of persistent abnormally dry weather, known as droughts, can produce a serious agricultural, ecological, or hydrological imbalance. Over one billion people of South Asia (SA), dependent on agriculture related livelihoods and predominantly poor, are exposed to high levels of vulnerability to drought. In order to gain a better understanding of drought processes, the characteristics of their occurrence need to be systematically formulated. At present countries in the South Asian region, mainly use traditional methods in applying climate indices like SPI in drought assessment and monitoring that are based on rainfall data. Remote sensing technology provides alternative data for operational drought monitoring, with advanced temporal and spatial characteristics. However, additional inputs still need to be incorporated so as to thoroughly explain the anomaly in vegetation caused by drought. The integration of traditional meteorological data, remotely sensed drought indices, together with information on elevation, vegetation type, and man-made irrigation, provides a promising approach to better characterize the spatial extent and intensity of drought.

The International Water Management Institute (IWMI) developed a drought monitoring system for South West Asia that uses vegetation indices to monitor the health of vegetation. The project supported by

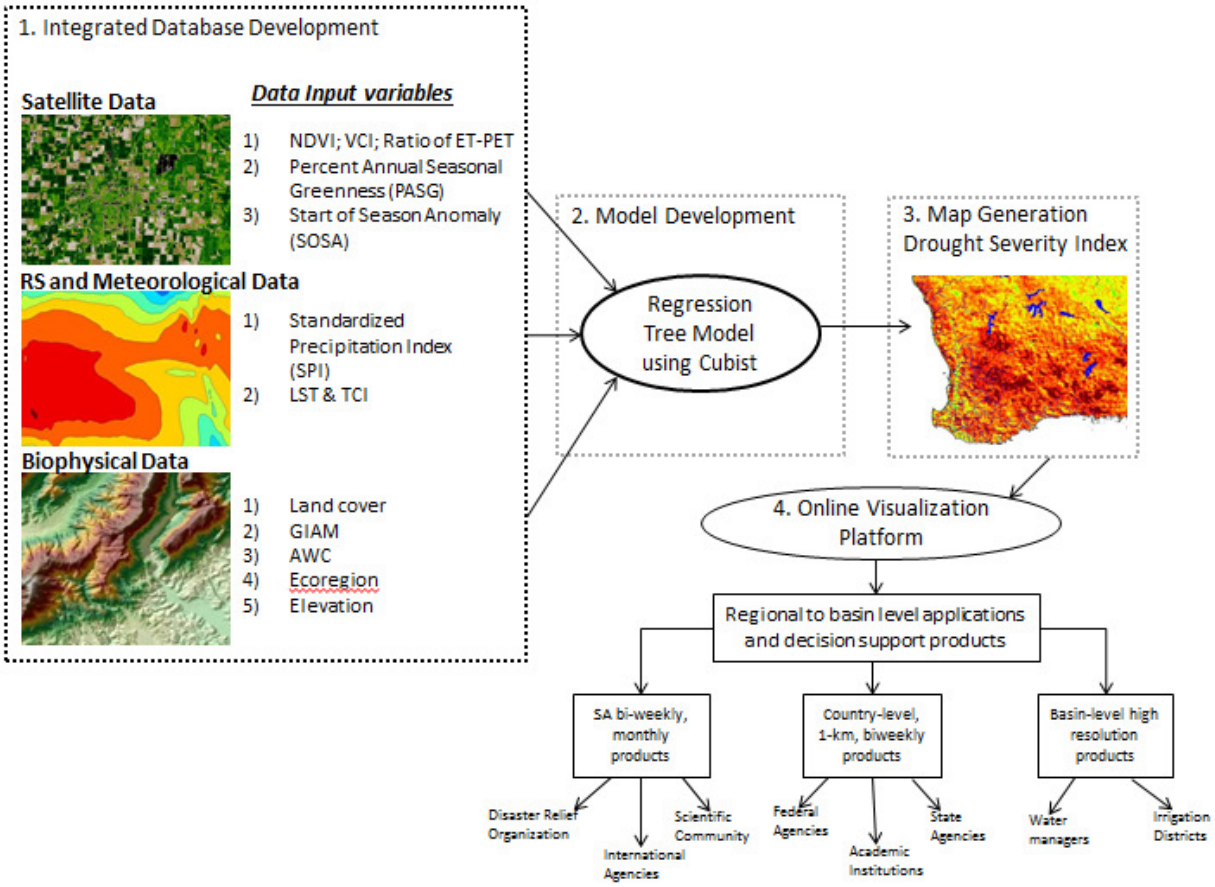


Global Water Partnership (GWP) and the World Meteorological Organization (WMO) as part of the Integrated Drought Management Programme (IDMP) is focusing on developing a prototype model for a South Asian Drought Monitoring System (SA DMS) to meet the diverse needs of decision makers. This Monitor has the potential to also include information on early warning against drought. The goal of this project is to deliver a newly integrated drought monitoring method by selecting the best combination of variables with better accuracy, in order for decision-makers in the region to have a clear understanding of drought risk and take preventive action. This method will integrate the land surface water and thermal environment conditions, vegetation growth conditions, and biophysical information.

The system employs innovative approach for monitoring and assessment of the drought risk based on integration of meteorological data, vegetation canopy indicators from satellite imagery and targeted collection of ground truth moisture and crop-yield data. It will develop an operational drought prototype with well-connected sharing of information with drought authorities in respective countries for planning process by using various decision frameworks to analyse risk scenario. It will be possible to perform drought risk analysis in different regions of the SA as well as analyse and design specific adaptation measures for the prevention of damage in the future. The objective is to develop and illustrate to stakeholders in SA countries a prototype system for a near-real-time drought monitoring system at the

scale of a country, state, district or pixel with an 8-day time interval. The drought monitor primarily will use vegetation canopy indicators and rainfall anomaly from satellite data and targeted in-situ data collection driven moisture and crop-yield data.

This activity is part of the Integrated Drought Management Programme for South Asia region that supports efforts directed at increased resilience to droughts. The prototype drought system will serve as an interface between climate service providers and various stakeholders and GWP partners by communicating information to all stakeholders concerned with drought and its impacts. It will also be a regional drought monitoring platform to coordinate regional interventions on one hand, and develop, where necessary/ desired, customised national drought monitoring products.



Overall Summary of the Need Assessment

A questionnaire (see Annex, page 13) was sent by the GWP Country Water Partnerships in Bhutan, Bangladesh, Nepal, India, Pakistan and Sri Lanka and by the GWP Regional Water Partnership to Afghanistan and the Maldives to relevant government entities and institutes. Not all recipients of the questionnaire responded. The responses received are summarized in the individual country assessments below (pages 7-12). These responses were introduced at the 5th South Asian Climate Outlook Forum (SASCOF-5) held in April 2014 in Pune, India and discussed further.

The responses reveal that there is no validated system of early warning on drought that could meet the requirement for a high spatial resolution in any of the surveyed countries. In India and Pakistan drought monitoring and prediction systems are provided by the respective National Meteorological Departments/Services. These tools enable valuable drought information, but are restricted to particular regions and seasons.

All eight countries that responded to date are capable of contributing to the development of South Asian Drought Monitoring System, although the extent to which this is possible varies considerably. The capabilities range from rainfall prediction, experience in flood forecasting, monitoring of losses caused by drought, experience in international cooperation, expertise in the usage of different drought indices to GIS-based drought identification.

The responses to the questions on support needed show that all the countries wish to receive assistance in order to implement South Asian Drought Monitoring System. Particularly information tailored to drought prone areas is needed. Challenges that the countries are facing are e.g. lack of hydrological / meteorological measurement stations, missing access to satellite data, insufficient rainfall prediction capability or shortage of well-trained staff. It is also emphasized by the respondents that the development of an institutional mechanism of functional collaboration across ministries and departments at the sub-national, national and international level is essential.

Being asked to render their country's individual needs more precisely, the experts indicate that information about frequency, causes and spatial extent of droughts is needed. Evaluation of the most important time scales of drought differ among the respondents, yet seasonal information is stated as important by most of them. It is also pointed out by the respondents that the spatial scale for drought information has to be small (sub-district, village level) in order to maximize the benefit from the South Asian Drought Monitoring System.

In the assessment of the impacts of droughts in the countries, the respondents come to similar conclusions. Agriculture is considered one of the most vulnerable sectors to drought in all the countries. Moreover, the respondents state hydrological impacts related to groundwater, drinking water supply and

hydropower generation as crucial, especially in Maldives. In Bhutan forest fires are a fatal implication of drought and in Bangladesh and Nepal transportation on waterways are mentioned as another sector on which droughts have implications.

Concerning the possible realization of South Asian Drought Monitoring System the countries make different proposals. Mostly it is suggested that the respective national hydro-meteorological services should act as national focal points, but also institutions like the Department of Irrigation in Nepal or the Ministry of Agriculture in India are considered candidates to host such a system. Some answers indicate strongly that a new host of the system should unite different institutions and some suggest the creation of a new national organization.

The Disaster Management Centre (SDMC) of the South Asian Association for Regional Cooperation (SAARC) expresses strong interest to play a central role in the development of South Asian Drought Monitoring System. The SAARC Meteorological Research Center (SMRC) was considered by some participants in the South Asian Climate Outlook Forum as another potential host.

In summary, the needs assessment shows that the development of a South Asian Drought Early Warning System is rated very useful by the respondents.

Summary of Country Responses

The following table shows a summary of the eight countries' answers to the questions asked in parts 1-4 of the Questionnaire (see Annex).

	1 Existence of Drought Early Warning System	2 Capability to contribute to Drought Monitor/ Early Warning	3 Requirement for infrastructural support	4 Rating of usefulness of Drought Monitor/Early Warning System
Afghanistan	No	Very Low – No prediction capability	Very High – Technical and Training Support needed	"Very essential"
Bhutan	No	Very low – daily and seasonal rainfall prediction	Very high – satellite images of moisture contents, hydrological models, forecast products	"Important"
Bangladesh	No	Medium – experience in flood warning, usage of drought prediction tools	High – Technical support and training needed	"Very essential to ensure food security"
Maldives	No	Medium – Experience in flood & rainfall early warning	High – Technical support and training needed	"Very essential to ensure drinking w..."
Nepal	No	Low – experience in collecting post-drought information	Very high – more hydro-met stations required	"One of the best initiatives in the region and my country"
India	Yes – especially powerful in certain regions	Very high – experience in usage of different drought indices	Medium – nationalized institution needed who can run a Drought Early Warning System	"Extremely useful and essential"
Pakistan	Yes	Very high – weather radar and GIS spatial integration systems capability to identify drought	Medium – information for specific drought prone areas needed	"Moderate in own country" "Strong in South Asia"
Sri Lanka	No	Low – capacities exist, but need improvement	Very high – information tailored to the area is needed	"Very useful"

Table: Overview of the responses. Colour scale indicating country capacity:

Existing Cooperation Mechanisms in South Asia

Analysis based on information from 1) South Asian Association for Regional Cooperation (SAARC) Disaster Management Centre (SDMC), 2) World Meteorological Organization (WMO) 3) International Commission on Irrigation and Drainage (ICID) and 4) discussions held at the 5th South Asian Climate Outlook Forum in April 2014 in Pune, India

In the late 1990s, the Regional Climate Outlook Forum (RCOF) was initiated by WMO, National Meteorological and Hydrological Services (NMHSs), regional institutions, and other international organizations. It is a forum that brings together the experts from a climatologically homogeneous region and provides consensus based, climate prediction and information usually for the season having critical socio-economic significance. This information has been applied to reducing climate-related risks and supporting sustainable development.[1]

The South Asian Climate Outlook Forum (SASCOF) was established at a meeting of the Permanent Representatives of the South Asian countries with WMO in August 2009. The countries participating in SASCOF are: Afghanistan, Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, Pakistan and Sri Lanka. From 2010 onwards, annual sessions were held in Pune, India and in Kathmandu, Nepal. SASCOF-5 was held in Pune, India in April 2014.[2]

The main objectives of SASCOF are (1) to review the progress made in understanding and long range prediction of summer monsoon both regionally and globally, (2) to make available detailed information on climate variability in South Asia for dissemination along with the seasonal outlook, (3) to provide a platform for the stakeholders of SASCOF to share and exchange experience and knowledge on summer monsoon and its prediction, (3) to initiate capacity building/human resource development activities for the South Asian region, particularly in seasonal prediction, (5) to build collaboration and partnerships among the members of SASCOF for mutual benefit and (5) to identify needs of user sectors through a dialog among different groups.[3]

In the field of drought management, there has not been much cross sharing of knowledge and experience among the countries in the region, although every country of South Asia has decades of experience of dealing with droughts[4].

[1] WMO Brochure on RCOFs: https://www.wmo.int/pages/prog/wcp/wcasp/documents/RCOFsBrochure.pdf
[2] WMO Website on RCOFs: http://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecasts.html
[3] India Meteorological Department Background Document about Long Range Forecasting, Chapter 9: http://www.imdpune.gov.in/research/ncc/longrange/longrange_index.html
[4] SAARC Disaster Management Centre. 2011. New Delhi: Road Maps on Risk Management in South Asia.

In order to meet the lack of an initiative for institutionalizing regional cooperation on drought risk management in South Asia, the Disaster Management Centre (SDMC) of the South Asian Association for Regional Cooperation (SAARC) organized a Workshop on Drought Risk Management in Kabul, Afghanistan in August 2010. The workshop reviewed the progress made by each country of the region for drought risk management and analysed the strength, weakness and gaps in the systems[5].

Among the outcomes of this workshop was the definition of five broad areas of regional cooperation, namely Drought Monitoring and Early Warning, Drought Research and Documentation, Training and Capacity Building for Drought Management, Sharing of Good Practices on Drought Risk Management and the development of a South Asia Drought Network.

The SDMC is involved in these five broad areas of regional cooperation. It was established in 2006 in New Delhi with the objective to serve eight Member Countries of South Asia Association of Regional Cooperation (SAARC) - Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka - by providing policy advice and facilitating capacity building services for effective disaster risk reduction and management in South Asia.

SDMC maintains a database of all disasters in the region, including droughts. Updates on disasters and other potential hazards are published and widely circulated on a daily, weekly, quarterly and annual basis. In order to facilitate exchange and flow of information and knowledge, SDMC has also developed the web portal South Asia Disaster Knowledge Network (SADKN)[6].

The centre works towards a regional early warning system and is developing a template for District Level Emergency Plans for Drought for collecting detailed information about land use, climatic conditions and drought impacts. Therefore it is suggested in the response to the questionnaire that SDMC would be a suitable organization to host the system and it is indicated that the SAARC Meteorological Research Centre (SMRC) in Dhaka, Bangladesh could take this role as well. In the response of the International Commission on Irrigation and Drainage (ICID) it is also suggested, that SDMC could be the coordinator for capacity building, stakeholder interaction and overall administrative management and that the "copy" in each country should be within the Meteorological Departments or the Agricultural Ministry or Disaster response agency (for drought). In summary, SDMC expresses strong interest to contribute significantly to South Asian Drought Monitoring System, which the respondents to the questionnaire rate as an initiative of "critical importance" and a "need of the hour".

[5] Publication of 2010 SAARC Workshop on Drought Risk Management in South Asia.http://saarc-sdmc.nic.in/pdf/Publications/Drought/drought.pdf
[6] SAARC South Asia Disaster Knowledge Network (SADKN). http://saarc-sadkn.org/

The 5th South Asian Climate Outlook Forum in April 2014 in Pune, India, provided an opportunity discuss with representatives from international, regional and national government, intergovernmental and research entities the South Asian Drought Monitoring System. The discussion stressed that the involvement and ownership of government agencies involved in drought issues and the users of such a product is key from the beginning. The participants therefore welcomed these early discussions. Inputs in product design, data vetting, and the way the model performs and which aspects to cover (meteorology, biophysical characteristics, social vulnerability, drought preparedness) is important. Keeping the input data simple and ensuring that there is an understanding on what basis drought risks are being generated is important for SA DMS to gain acceptance. Including ground verification of the results was also considered important. Uncertainty should be communicated clearly and an effort made to include the outputs of the SASCOF as well as any National Climate Outlook Forums.

Individual Country Assessments

Afghanistan

Analysis based on response from Ministry of Agriculture, Irrigation & Livestock (MAIL).

1: Existence of Drought Early Warning System

There is **no drought early warning system in Afghanistan**. There is no specific organisation deal with drought. As per the respondents, there is no drought information used at present and there is no drought prediction capability

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

According to the respondent, the capability is very low.

3: Requirement for infrastructural support

Need technical and training is very much essential.

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

Very high and it is particularly useful for the Afghanistan & South Asia as a whole.

5: Specification of needs

It has been noted that the most important time scale for drought monitoring and prediction is seasonal.

6: Assessment of vulnerable sectors

Agriculture, water supply & public health are the most vulnerable sectors in Afghanistan.

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

Civil Aviation Authority in Afghanistan is the used SADEWS for decision making and respondent has not really identified the organisation who can implement the DEWS.

Bhutan

Analysis based on responses from 1) Department of Hydro-Meteorological Services (DHMS), Snow and Glacier Division and 2) Department of Disaster Management

1: Existence of Drought Early Warning System

There is **no drought early warning system in Bhutan**. The Disaster Management Department has an early warning system for the Glacial Lake Outburst Flood (GLOF) in Punakha-Wangdue valley, but not for drought. As per the respondents, there is no drought information used at present and there is no drought prediction capability.

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

According to the respondent of the DHMS Snow and Glacier Division, **daily and seasonal rainfall prediction is done by the Meteorological Division of DHMS** and it is mentioned that drought prediction could be developed with some additional capacity.

3: Requirement for infrastructural support

Since drought monitoring/early warning has never been tried or implemented before, **specific information and support would be needed** in Bhutan.

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

The respondents rate the system **important** in both Bhutan and the South Asian region in order to give good boundary conditions.

5: Specification of needs

It has been noted that **information about frequency, impacts, causes and spatial extent** is most needed for Bhutan and that the most important time scale for drought monitoring and prediction is seasonal. More precisely, satellite images of moisture contents, hydrological models, access to forecast products, and linking to real-time hydro-meteorological stations' data are required.

6: Assessment of vulnerable sectors

The respondents state that the **forest fires** in winter dry season, **hydropower generation, agriculture and drinking water supply** are among the sectors most vulnerable to drought.

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

The **Department of Forest and Park Services**, the **Department of Agriculture** and **hydropower authorities** are considered to be the main users of SA DMS. Ideally, the **Hydro-Meteorological Department** as a national Hydrological-Meteorological service provider should be in position to predict drought even though drought is not a major concern at present.

Bangladesh

Analysis based on responses from 1) Bangladesh Agriculture Research Institute (BARI), 2) Bangladesh Agriculture Research Council (BARC), 3) Institute of Water Modelling (IWM), 4) Flood Forecasting and Warning Centre (FFWC), Bangladesh Water Development Board (BWDB), 5) Centre for Environment and Geographical Information System (CEGIS) and 6) Bangladesh Academy for Rural Development (BARD)

1: Existence of Drought Early Warning System

There is **no drought early warning system in Bangladesh**. The Centre for Environment and Geographical Information System (CEGIS) developed a drought monitoring and prediction tool, the Drought Assessment Model (DRAS), but the other institutions do not mention using it. Based on the climate parameters, this model is able to generate agricultural drought (water stress condition), net irrigation water requirement (NIR) as well as crop yield under changing climate conditions. It can predict drought onset indirectly, for specific crops.

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

The Institute of Water Modelling (IWM) in collaboration with Bangladesh Water Development Board (BWDB) has **expertise in flood forecasting and warning activities** as well as in **modelling of surface and groundwater resources** that can contribute to the development of a drought early warning system.

The respondents use different drought information, for example temperature and precipitation data, the hydrological model SWAT (soil water assessment tool), provided by Soil and Water Research Laboratory in Texas, USA or cooperate with Indian institutions providing drought information. This **knowledge of available products** can contribute to South Asian Drought Monitoring System as well. The DRAS model used by CEGIS can be developed further, e.g. conversion into a web-enabled model.

3: Requirement for infrastructural support

According to the respondents, **technical knowledge and institutionalization of drought monitoring/prediction tools** are needed in Bangladesh. The possibility to tailor and customize the output from the regional system to specific local needs (i.e. river flow, groundwater recharge) would be useful.

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

The introduction of South Asian Drought Monitoring System is considered **very useful** for both Bangladesh and for South Asia.

5: Specification of needs

The respondents see a strong need in upgrading drought prediction capabilities and wish to have detailed information about the **frequency of droughts, the causes and impacts** (both short term and long term), desirably with a **high spatial resolution** (regional down to sub district). The importance of developing coping strategies as well as the need to **exchange experience with other countries** (e.g. India) and the initialization of public private partnership (PPP) is stressed by the respondents.

6: Assessment of vulnerable sectors

The most vulnerable sectors, according to the respondents, are **agriculture and food security, especially in rural areas**, where droughts can have strong effects on the socio-economic condition, e.g. spread of diseases. But also the effect of drought on **groundwater, hydropower generation, water transportation and aquatic environment (fishery)** are considered crucial.

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

Challenges are mostly seen in the infrastructural conditions and technical capabilities. But when proper training and capacity development is provided, Bangladesh can contribute some experiences and human expertise to the development of SA DMS in the region through **cooperation among BARI, BARC, CEGIS and BMD** (Bangladesh Meteorological Department). It is noted by the respondents from other institutions that **BMD could be approached to take the role of a national focal point of SA DMS in Bangladesh**.

Maldives

Analysis based on response from Maldives Meteorological Services (MMS).

1: Existence of Drought Early Warning System

Maldives do not have DEWS in place. Weather condition over the country is monitored by the Maldives Meteorological Service. Drought" has not been defined in the context of Maldives and it should be defined in the context of Maldives since it can be very different from other countries

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

The early warning mechanism for rainfall and flood are being done at present and it is supported by 5 manned weather stations. So, data from these locations could contribute for the drought monitoring & prediction system in South Asia.

3: Requirement for infrastructural support

Long-term historical datasets, specialized training on Climate modeling and modeling capacity, accurate and precise seasonal forecast and research facilities

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

According to the respondent this is a **very important tool** which helps to manage socio-economic impact of drought.

5: Specification of needs

Information about the **frequency, the spatial extent as well as duration of drought** are most needed. Regarding different time scales, the respondent think that seasonal prediction information is important, as well as providing information on a shorter time scale such as weekly.

6: Assessment of vulnerable sectors

Water supply & agriculture sector in Maldives will be the most vulnerable sector

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

According to the respondent, with the technical & training support to Maldives Meteorological services, can implement the SADEWS.

Nepal

Analysis based on responses from 1) Climate Change Council-Nepal, 2) Ministry of Energy, 3) Department of Agriculture, 4) Department of Hydrology and Meteorology, 5) Department of Irrigation, 6) National Planning Commission, 7) Ministry of Agricultural Development, 8) Water and Energy Commission Secretariat, 9) Environment and Social Studies Department, Nepal Electricity Authority and 10) Nepal Agricultural Research Council

1: Existence of Drought Early Warning System

There is **no Drought Early Warning System** in Nepal. Post drought recording and case by case assistance are provided by the government for drought affected communities.

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

Drought induced fire, crop loss and crop affected area are being recorded by various agencies. **Seasonal and annual variation of temperature and rainfall** provide an indication of drought which is being monitored in Nepal. Ideas for an **insurance scheme for farmers** are being discussed nationally, yet its affordability for the farmers poses difficulties.

3: Requirement for infrastructural support

Outdated equipment, undulating terrain, lack of hydro-met statistics lead to insufficient/unreliable meteorological prediction and therefore **adequate human resources** and technical capacity development (access to satellite data, reliable meteorological and hydrological datasets, enhancing interpretation skills) is required for Nepal.

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

According to the answers that were evaluated, SA DMS is considered a **very important system** for both the country and the region, especially because many people in Nepal relying directly on agriculture live below the poverty line.

5: Specification of needs

Information about the **frequency, the spatial extent as well as causes and impacts of drought** are most needed. Regarding different time scales, most of the respondents think that seasonal prediction information is important, as well as providing information on a shorter time scale (weekly, even daily during dry season) and following multi-annual trends. Monitoring/predicting drought on the basis of agro-ecological zones is suggested, with further extension to **district and municipality level**.

The network of meteorological measurements needs to be expanded and upgraded to obtain reliable data for precipitation-based indices for monitoring and predicting drought. One of the challenges is Nepal's topographic variation.

6: Assessment of vulnerable sectors

Agriculture is assessed to be the sector most affected by drought, followed by **water supply systems, hydropower generations, public health and transportation**.

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

The respondents expect that drought information will be used by irrigation engineers and agricultural engineers to prepare canal operation plans and to suggest cropping pattern to farmers. It is suggested that the **Department of Hydrology and Meteorology (DHM) or the Department of Irrigation (DoI)** could be the national institutions to host the system. At present **DoI is planning to develop link with Asian Water Cycle Initiative (AWCI)** to carry out climatological downscaling and drought prediction.

India

Analysis based on responses from 1) Indian Agriculture Research Institute (IARI), Water Technology Centre (WTC) 2) Karnataka State Disaster Management Centre (KSNDMC), 3) NRM Division, Indian Council of Agricultural Research (ICAR), 4) India Meteorological Department (IMD) and 5) Central Water Commission (CWC). Awaiting responses from Ministry of Home Affairs, National Institute of Disaster Management (NIDM); and National Remote Sensing Agency, Department of Space, Government of India (March 2014)

1: Existence of Drought Early Warning System

A **Drought Early Warning System is used by India Meteorological Department (IMD)** providing drought outlook maps for the winter monsoon season and has developed an experimental drought monitor (https://sites.google.com/a/iitgn.ac.in/india_drought_monitor/forecast). The **IARI WTC uses the National Agricultural Drought Assessment System (NADAMS)**, provided by the National Remote Sensing Centre (NRSC) and **is in process of developing drought early warning system in collaboration with the National Drought Mitigation Centre, of the University of Nebraska-Lincoln, USA**. The Department of Agriculture and Cooperation of the Ministry of Agriculture (MoA) uses several criteria for monitoring drought among which the most important is moisture adequacy index (MAI) which has been provided by the Institutes of ICAR. MoA also established the Crop Weather Watch Group (CWWG) that carries out impact assessment and accordingly takes remedial measures.

The KSNDMC monitors and predicts drought in Karnataka. According to the respondent of this institute, the drought data are available to farmers through a help desk. NGOs are supporting KSNDMC to train farmers to use the system. The users of the products provided by KSNDMC can comment through feedback groups located at different administration units or through online portals.

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

Meteorological and hydrological drought indices (such as SPI, SWI) and remote sensing drought indices (such as NDVI, NDWI, VCI, TCI etc.) are used by IARI WTC to predict drought and it is being successfully tested in North and North Western India, according to the respondent. It is specified that **IARI WTC, IMD and CWC have the institutional and human resources capability to run a drought monitoring/ early warning system for South Asia**. The capability of **drought monitoring** is very good in India, but customized products to land parcel level still need to be developed.

3: Requirement of infrastructural support

The answers obtained from the survey suggest that development, calibration and validation of different mathematical models (agricultural, hydrological, weather) is needed, especially **improvement of rainfall prediction at district level**. Another challenge is to share data between different agencies in the state or the entire country and to conduct standardization of the products that are used.

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

The development of a drought monitor is rated as **extremely useful** by the respondents, both for South Asia and India.

5: Specification of needs

The respondents underline the importance of reliable meteorological, hydrological and agricultural indices and suggest the development of a **composite index integrating all the information**. There is strong emphasis in the responses to expand the skill of existing drought prediction tools to a **smaller spatial level** (village level). Drought information should be available on a weekly basis.

6: Assessment of vulnerable sectors

Agriculture (including animal husbandry), water supply and livelihood are considered to be the sectors most vulnerable to drought.

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

Different propositions for a potential host of the system are made by the respondents, either the creation of a **new national organization** under the Ministry of Agriculture or a **collaboration of different institutes**.

Pakistan

Analysis based on response from 1) Global Change Impact Study Centre

The most important agencies have not responded to the questionnaire, namely Pakistan Meteorological Department and National Disaster Management Authority.

1: Existence of Drought Early Warning System

The Pakistan Meteorological Department (PMD) provides a National Drought Monitoring Centre (NDMC). It includes capability to monitor and predict drought and also has information generation capability to collect impact information. Recovery and support systems are organized by National Disaster Management Authority (NDMA). Products issued are made available through the website and there is international coordination, e.g. with WMO. **Ability to predict on-set of drought is reasonable** whereas predictability of long-term drought requires considerable collaborative information from international sources.

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

Pakistan has capabilities in **weather radar usage and GIS spatial integration systems** to identify and determine density of drought under series of parameters. Much of this information can **contribute to Drought Early Warning System** and supplement information needs within South Asia, particularly for bordering states. Indices recommended by WMO, NASA, and others are used, along with other net based forecasting and meteorological websites i.e. ACCUWEATHER that uses real-time information. While Pakistan generates a fair amount of technical information, it **requires heavy information in capacity building to strengthen interpretive capabilities at the district and sub-district levels**. Investments in both hardware and software upgrades are required.

3: Requirement of infrastructural support

Reliable data-sets, models among other capacities are required especially **information tailored to Pakistan's specific drought prone areas**.

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

The usefulness of the initiative of developing a drought monitor is rated by the respondents **strong in South Asia**, but **moderate in Pakistan**.

5: Specification of needs

Causes and spatial extent of drought are among the information most needed in Pakistan, according to the respondent. Drought information should be available preferably on **a seasonal and multi-annual** time scale and enable the spatial resolution of **districts and agro-ecological zones**.

Useful variables for drought monitoring and prediction are leaf index, day and night time temperature variability, soil temperature variability and UV radiation variability.

6: Assessment of vulnerable sectors

The impacts of drought are assumed to be most fatal in the **agricultural** sector as well as for **water supply, socio-economic and hydropower generation**.

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

The respondent proposes to **install Drought Early Warning System through national hubs** (not specified) with strong **coordination** among national level institutions.

Farmers, media, water resources planners, Ministry of Finance, Revenue Dept. and Disaster Management Centres are considered to be the main users.

Sri Lanka

Analysis based on responses from 1) Ministry of Irrigation and Water Resources Management and 2) Ministry of Water Supply and Drainage

1: Existence of Drought Early Warning System

There is **no drought early warning system in Sri Lanka**.

2: Capability to contribute to South Asian Drought Monitor/ Drought Early Warning System

Sri Lanka's Department of Meteorology and some individuals have the **technical und human capacity to run and use a drought early warning system**.

3: Requirement of infrastructural support

Data sets, forecasts and information tailored to the area are needs for a SA DMS in Sri Lanka. The institutions that run and use SA DMS should be supported in upgrading their capacities and in developing an inter coordination mechanism among relevant institutions.

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

In Sri Lanka a drought monitoring system would be **very useful** in planning stage of development projects, to introduce relevant crop pattern and to **mitigate the damages and accidents caused by drought**.

5: Specification of needs

Characterization of regional drought needs information about **frequency and spatial extent of drought**. This information is required most importantly on a **seasonal time scale** and for **province level**.

6: Assessment of vulnerable sectors

The sectors that are considered most vulnerable to drought are **agriculture, ground water, water sources, water supply and hydro power generation**.

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning

The respondents presume that Agriculture Department, Meteorological Department and Disaster Management Centre would be the main users of drought monitoring system products and suggest that **National Institutions (not specified) should host this system**.

Annex

The questionnaire that was sent to different institutes in Afghanistan, Bhutan, Bangladesh, Maldives, Nepal, India, Pakistan and Sri Lanka constituted of the following questions that can be grouped to seven parts:

1: Existence of Drought Early Warning System

- Do you already have a drought early warning system (DEWS), and if yes, what does that entail (e.g., monitoring/prediction capabilities and products, plans and/or triggers in place to respond to warnings, impact collection and drought mitigation/recovery support)?
- How does the DEWS function (frequency of issuance of products, interaction with other organizational entities within South Asia region/neighbouring nations, etc.)?
- What is your assessment of current drought prediction capabilities (e.g., the ability to predict the onset, persistence, and end of a drought)?

2: Capability to contribute to a South Asian Drought Monitor/ Drought Early Warning System

- What regional and/or national drought information and prediction capabilities do you have (if any) that could contribute to a South Asian DEWS?
- What other (outside your own capabilities/products) drought information capabilities/products do you currently use?
- From your understanding of the introduction of the system (above) do the relevant national institutes in your country have the technical and human capacity to (a) run or (b) use such a system? Please explain where you see any challenges?

3: Requirement for infrastructural support

- What are your specific infrastructural needs for a SADEWS (e.g., data sets, programs, forecasts)?
- Do you need information tailored to your specific area, or you are able to generate your own DEWS if information is available?

4: Rating of usefulness of South Asian Drought Monitor/ Drought Early Warning System

- How useful the respondent rates this initiative of developing a drought monitor overall (a) South Asia and (b) in your country?

5: Specification of needs

- What kinds of information about the characterization of regional drought do you most need (e.g., frequency, causes, impacts, spatial extent, etc.)?
- What are the most important time scales of drought for region/your applications (daily, weekly, seasonal, annual, multi-annual and trends)?
- What are the most important spatial scales at which drought need to be monitored and/or predicted?
- What quantities/variables (indices, etc.) are most important to monitor and predict as part of a drought early warning system, in your opinion?

6: Assessment of vulnerable sectors

- What are the most important impacts of droughts for your region & country (agricultural, hydrological, groundwater, socio-economic (specify), other)?
- What sectors are most vulnerable to drought in region and your country (e.g., agriculture, water supply, public health, transportation, hydropower generation)?

7: Suggestions for implementation of South Asian Drought Monitor/ Drought Early Warning System

- Who would be the main users of DEWS products and how would SADEWS information be used in decision-making?
- How do you get feedback from the users of these products?
- Who should host this system (regional hub (suggestions?), national institutions (e.g. every country has a “copy” of the system (which organization in your country?), other suggestions on hosting the system?

The Global Water partnership (GWP), established in 1996, is an international network open to all organizations involved in water resources management , developed & developing country institutes, agencies of the United nations, bi-multilateral development banks, professional associations, research institutes, non-governmental organizations, and, private sector. GWP Head Office is in Stockholm. GWP SAS is the Regional Network comprises of Country Water Partnerships in India, Nepal, Pakistan, Bangladesh, Bhutan and Sri Lanka

www.gwp.org/en/gwp-south-asia

The WMO GWP Integrated Drought Management Programme (IDMP) works with a wide range of partners with the objective of supporting stakeholders at all levels by providing them with policy and management guidance through globally coordinated generation of scientific information and sharing best practices and knowledge for integrated drought management. It especially seeks to support regions and countries to develop more proactive drought policies and better predictive mechanisms.

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