

A perspective study on ground level documentation for the development of a decision support system towards drought management

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Abstract

The damaging intensity of drought warns the society to develop appropriate management system. To control disastrous effect the comprehensive drought management is essentially required. In drought hazard theory it may initiate through precipitation and propagate up to ground water depletion. The drought prone area is identified as the most sensitive to these events. Therefore comprehensive drought management is essentially required to resist social consequences of famine.

The authors have been taking an attempt emphasizing a supportive system which may be called as a Decision Support System (DSS) on trend, monitoring and impact assessment of drought. During the study the state of art of drought management over the area which is a upper Dwarakeswar watershed, administratively under the Drought Prone Area Programme (DPAP) is evaluated with the aid of Geographic Information System (GIS). In this paper the authors attempted to assess the end-users' requirement as baseline information to cope up with drought hazard. The authors' also extended the study on suggestive characterization of area network for which DSS can be developed. During the assessment of ground level information it is also evaluated that the necessary data is available to model the DSS but there is significant gap in spatial as well as temporal data for proper validation and implementation of such DSS for drought hazard. The availability of data has been explored through interaction with several national as well as district line organizations. Hence the data requirement and availability network is scientifically addressed in this study. Finally a feasibility of implementation of DSS is discussed with the help of GIS.

Key words: Decision Support System (DSS), Drought management, End Users, Ground Level Documentation(GLD), Geographic Information System(GIS), Spatial and Temporal Data.

1. Introduction

The deficit from normal availability of water for a short period is usually defined as drought. It disturbs the sustainability of a region. It can be discriminated from aridity as it is a sustained state of water shortage to which life and economic activity is to be adjusted. In dry tropical land water demand and supply are critically balanced in such a manner that the small deficit affects the area significantly(WMO,1985).

Drought measuring primary elements are precipitation, run off, surface storage, soil moisture, ground water and population. The time span of drought phenomenon may be extended from year to month and also to week. The propagation of drought from precipitation to ground water has significant role on water resources management. Further the recurrence of any type of drought has integrated impact on degradation of water use, degeneration of biomass and land quality. It is expected to be sharpening over drought prone area. Therefore comprehensive drought management is essentially required to resist social consequences of famine(Jana, 2002).

In India the irrigation Commission, 1972 recognized 67 drought prone districts comprising of 326 Talukas located in 8 States having an area of 49.73 M.ha. The National Commission on Agriculture, 1976 added a few more drought prone areas with the slightly different criteria. Later Central Water Commission(CWC) , 1982 identified 108 M.ha. area of continental India as drought prone area covering 99 districts in 13 states. For this CWC adopted the same criteria as followed by Irrigation Commission, i.e., drought is a situation occurring in an area:

- when the annual rainfall is less than 75% of the normal in 20% of the years examined.
- Less than 30% of the cultivated area is irrigated.

There are several policies and programme formulated during 8th and 9th Five year plan to tackle the drought specially under Drought Prone Area Programme(DPAP). In view of the drought like situation prevailing in some parts of the country during the year1999-2000 Planning Commission constructed a group to review the possible drought situation in the country, which may be due to inadequate and delayed monsoon. The group considered the criteria followed by different States for declaring drought. It is noted that declaration of drought was primarily based on the quantum of rainfall, damage to kharif crops and lesser availability of drinking water and less moisture in the soil. The group reported that there is no provision for declaration of drought by Government of India and it is in general considered to be occurring when the monsoons fail or are deficit. Drought is declared by each State or part of the State Government under the Relief Manuals or similar documents of the State Government.

However, the potential strategy on drought management needs appropriate ground level documentation (GLD) for monitoring and early warning of drought over an area. To capture indigenous knowledge of farmer or any end user the primary need is to gather the experience in the form of data as well as related information. Systematic compilation of ground level information with the progress of time is called GLD in this paper. The historic storage of relevant information as GLD can generate a self guiding e-support through DSS which helps planner as well as End user to take further action (Palmer and Tull, 1987). In the present study the authors aimed to file the GLD towards strategic management of drought.

2. Objectives

- Assessing end users' requirement as baseline information for drought management delineated area network for DSS
- Assessment of availability of ground level information for development of DSS and
- Finding gap in ground level documentation.

3. State Of Art Of Drought Management

The status of a Drought Prone Area is unique depending on characteristics of it. The authors have monitored the state of art of drought management over a sub-humid watershed in eastern India, which is a drought prone area under Purulia and Bankura districts, West Bengal (Fig. 1).

Physical status of the study area

Physiographically the region is degraded and dissected upland. The area corresponds to eastern fringe of Chhotonagpur plateau and gradually merges with depositional fluvial terraces of Damodar-Dwarkeswar-Kangsaboti river. The elevation is most pronounced towards northwest in Chhotonagpur plateau belt. The DPAP blocks are mainly under the extended Chhotonagpur plateau. The topography is complex in slope direction. The area is covered by 5 categories of geomorphic features. The terrain is mainly granite and gneiss with enclaves of metasedimentaries and metabasics.

The river system, Dwarkeswar originated from upland of Purulia. This sub-basin covers 5775 Km.² area. Gandheswari is the principal tributary of Dwarkeswar and originated from northwestern upland of Bankura. The study area covers Beko-Dhalkisor-Gangheswari watershed under upper Dwarkeswar sub-basin (1823 Km.² area). The flow pattern is from west to east or south-east in a stepped manner. The main left bank tributaries of the river, Beko Nala, Dangra River and Gandheswari Nala,

Dhapolijor Nala occupy northern part of the study area. Fatuari Nala, Dudhbharia Nala, Kansachara Nala, Arkusa Nala are the right bank tributaries of Dwarkeswar River. The study area ended after joining point of Dhalkisor River and Gandheswari Nala.

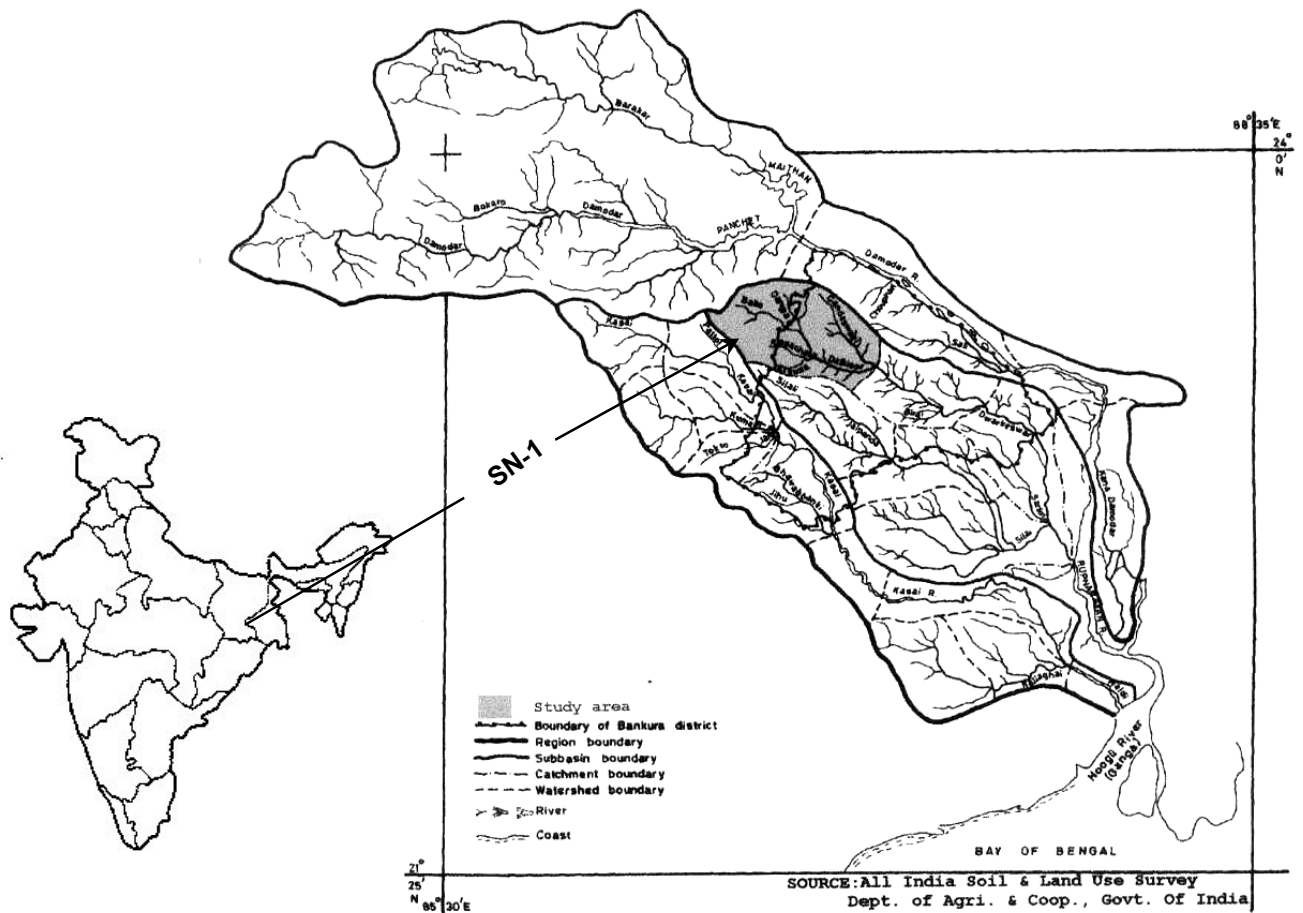


Fig.1 Location map of a study area

It is a sub humid zone. Summer season (March – May) is too hot. Ambient temperature range is between 12-43°C. The humidity varies between 15-100%. The normal annual rainfall of Bankura and Purulia is 1423mm and 1350mm respectively. Southwest monsoon covers 78% of annual rainfall. The DPAP zone is drier than the other surrounding area. As a sub-humid climatic zone the area is not likely to face drought as long as annual rainfall is concerned. The normalized deviation of monthly rainfall extends frequently from -1 (no rainfall condition where normal rainfall exists) to +2 (double of the normal rainfall) and above (Jana, 2000).

Laterites and lateritic soil is found in the study area. The lateritic soils are severely affected by both sheet and gully erosion. The soils are broadly grouped as red soils. Clay soil is found in southeastern Mejia. Agricultural drought is predominated due to soil hazards. Soil depth is mostly moderate(22.5cm - 45cm)in the study area. Severely eroded steep upland with exposed rocks are having shallow soil depth(<7.5cm). Soil depth is deep(45cm-90cm) in light textured soil. In valley bottom soil depth is very deep(90cm-150cm). Soil slope is mostly south-easterly.

The cultivable land is mainly mono-cropped due to water scarcity during Rabi and summer season. No certain plan is yet declared to develop spatially distributed irrigation covering DPAP area. Population density is not significantly high other than the township area.

Agricultural practices and irrigation

Agriculturally the zone is under forestry with rice farming. The land use is primarily unirrigated cropland and planted forestland. Land capability is mainly moderately good. Other types are land with some limitations and land suitable for forestry and grazing. Cultivable land is basically mono-cropped and rainfed during kharif season. Principal crop is rice. Wheat and maize are also under principal crops. Other field crops are pulses, oilseeds and vegetables.

In general 15% of total cultivable land of DPAP blocks is under irrigation in Bankura. The scenario of irrigation is relatively better in Purulia where rate of water draining is more. People prefers jore-bundh from distributary channels (Fig.2). The local administration has an inclination to strengthen jore-bundh principal to increase surface water potential for irrigation. In all these reservoirs seasonal waterline fluctuations were conspicuous. Such mechanism had been adopted in few points under Purulia district. Such schemes are implemented for irrigation in Kharif season. But the success of such dam was not satisfactory as per planning. The drinking water was mainly supplied in township using river lifting mechanism. The river lift pipe goes usually 10-20 feet down to pump raw drinking water. Later it is processed through filtering technique. Ground water storage is used mainly through Dug well. No scientific task has been taken on rainwater harvesting which is essential for such complex terrain. Ground water storage in general is insufficient as most of the dug wells and wells are dry in summer even in winter season. Draft demand is much higher than present recharge rate. The land is mostly single cropped and the principal crop, paddy suffers maximum. The historical study says the geological parameters have significant control on ground water occurrence over the study area. The aquifer systems are three types: weather mantle, saprolitic zones and fractured zones of the country rocks.

Cultural practices

The cultural practices to mitigate drought is through providing relief fund to the end-users to compensate their economic loss. Another cultural practice is to prefer minor irrigation. Such type of practices may be appeared on the basis of necessity.

View of end users

End users experience the late onset as well as early withdrawal of monsoon, a major reason for crop failure. The kharif crop is mainly dependent on distribution of monsoonal rain. Sometimes water scarcity appears through dry spell. According to them the predictability of favourable weather is dominated by uncertainty factors. They frequently face the drought conditions even for their livelihood. The irrigation is required even in kharif season as the crop yield is sensitive to water scarcity. The problem of soil and problem in ground water storage are added complexity to fight against drought.

View of local administration

The drought has become a regular phenomenon in both Bankura and Purulia districts. The crisis in surface and ground water leads to the inadequacy of water for livelihood as well as agriculture. The water level recedes abnormally during summer season. The local administration adopted few minor irrigation scheme to feed Kharif crop.

To solve drinking water crisis few minor schemes are working through trial and error technique. These schemes are inadequate to solve the problem. The local administration is looking for sustainable techniques of

- Early warning of drought and
- Integrated monitoring of drought.

The local administration of Bankura appreciated the observation made during status work over the area(Jana & Khire, 2001). The major reasons for adverse situation over this Chhotonagpur plateau is

- Aberrant rainfall,
- High heat effect,
- Geomorphic stress &
- Soil stress.

The human population pressure may not be a major problem as mentioned by the local authority. Population density is varies between 5 persons / Hec. and 2 persons/ Hec.

4. Background Of Decision Support System(DSS) In Drought Management

Decision Support Systems (DSS) are computer based information systems, which helps the planners to take decision on unstructured problems(Turban, 1988). It has three major components- detailed database, models and user interface, each representing different aspect of the problem(Fig.3). It also incorporates the expert's knowledge and experience while making complex decisions. Decision Support Systems thus offers multiple representation of the problem along with the facilities for interactive assessment. The concept of DSS is extended as Spatial Decision Support Systems(SDSS) when DSS is coupled with spatial information through GIS(Densham and Goodchild, 1989).

The user interface as 3rd component of a DSS provides a mechanism for communication between the user and the system. It is also called as dialog sub system The power, flexibility and usability characteristics of DSS depend on the user-system interface(Jayashankar, 1989).

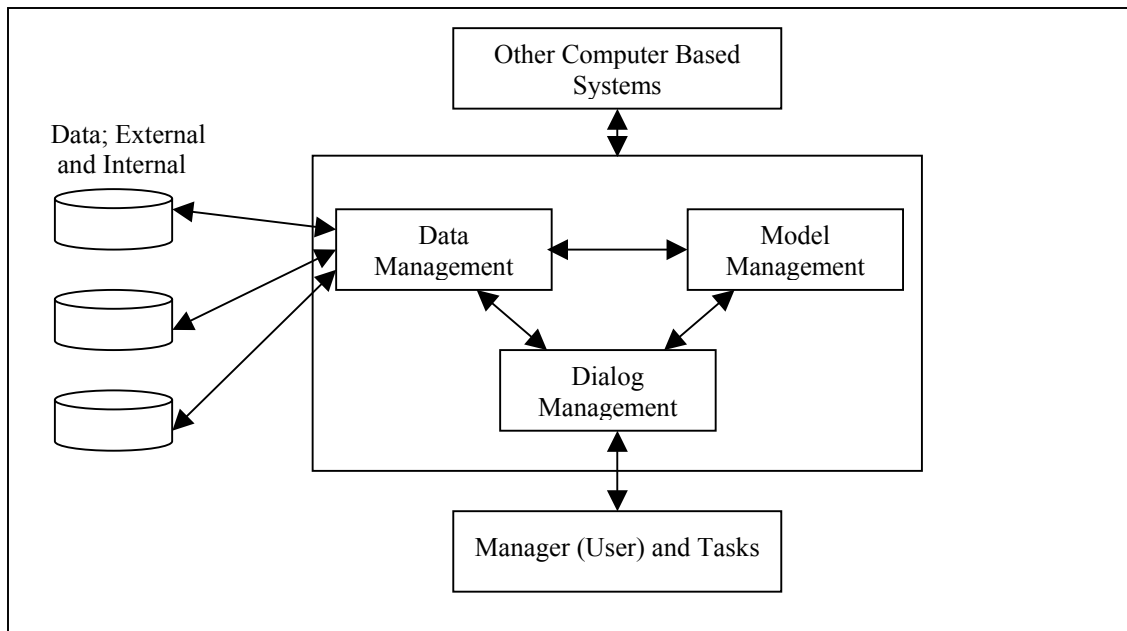


Fig.3 A schematic diagram of a DSS

Similarly DSS helps to predict causes and consequences based on available information. It can be done through model or modules. Under module the problem is disintegrated into different parts to represent each component or aspect of the problem independently. The model base thus includes the principles that govern the system's performance. These models are integrated and linked to the database. The model base thus extracts data from the database, run the models and supplies the results in the required format to support the decisions. In drought hazard management it is most critical part and needs knowledgebase feedback to develop the model. The water management system in drought

prone area consists of three components; pre-drought analysis and real-time drought analysis and water use policies (Palmer and Tull 1987, Recio et al. 1999).

A Data Base Management System (DBMS) as 1st component of DSS is a powerful computer program that can effectively manage a huge number of data elements. In drought hazard management Relational Data Base Management Systems(RDBMS) is essentially required instead of only DBMS. RDBMS in a DSS provides data storage, data retrieval and data maintenance. It should have rational capability as a component of SDSS to handle hydrological, physiographical, soil, crop and demographical database in drought management. It behaves as the base line structure of drought management, which accumulates it's strength through ground level documentation(GLD). In case of SDSS, characterization of space, as watershed here is the unit for GLD.

5. Characterizing Spatial Network For Drought Management

The understanding of natural processes and it's distribution are key knowledge to characterize an area. The area boundary under this study is a watershed, Beko-Dhalkisor-Gandheswari watershed, the SN-1 level spatial network (SN-1), which has a real time control and constraint on drought rather than administratively bounded drought prone area. It is delineated after a study on the status of river system(Fig.1) and development planning in and around drought prone area of Bankura and Purulia. The present study area is designated as shadow zone which needs sustainable development coping to chronic drought hazard.

In this view point it has been attempted to divide a watershed gradually into smaller units. Considering the physiographic features, the entire watershed has been subdivided into sub-watersheds and main stream inter-watersheds. This is represented conceptually by an open book type model, using rectangles arranged along the main stream. This representation gives a better insight to the physical and hydrological processes taking place within the watershed. Each sub-watershed and main stream inter-watershed are further subdivided into milli- and micro-watersheds considering the internal water divide.

The watershed under this study is distributed among the Purulia and Bankura districts of West Bengal. The administrative boundary between these districts passes approximately through the centre of the watershed dividing it into two halves, upper part and lower part with certain deviation from the natural water divide. This district boundary defines the boundary for the administration to take care of social and economic aspects. A compromised spatial network can be developed considering both

administrative boundary as well as natural water divides at various levels, viz., sub-watershed, milli-watershed and micro-watershed. If sub-watershed divide between two districts are not decisive, the water divide of milli-watershed has got next priority. Accordingly the process will be continued to micro-water divide to minimize discrepancy between watershed and district boundary(Fig.4).

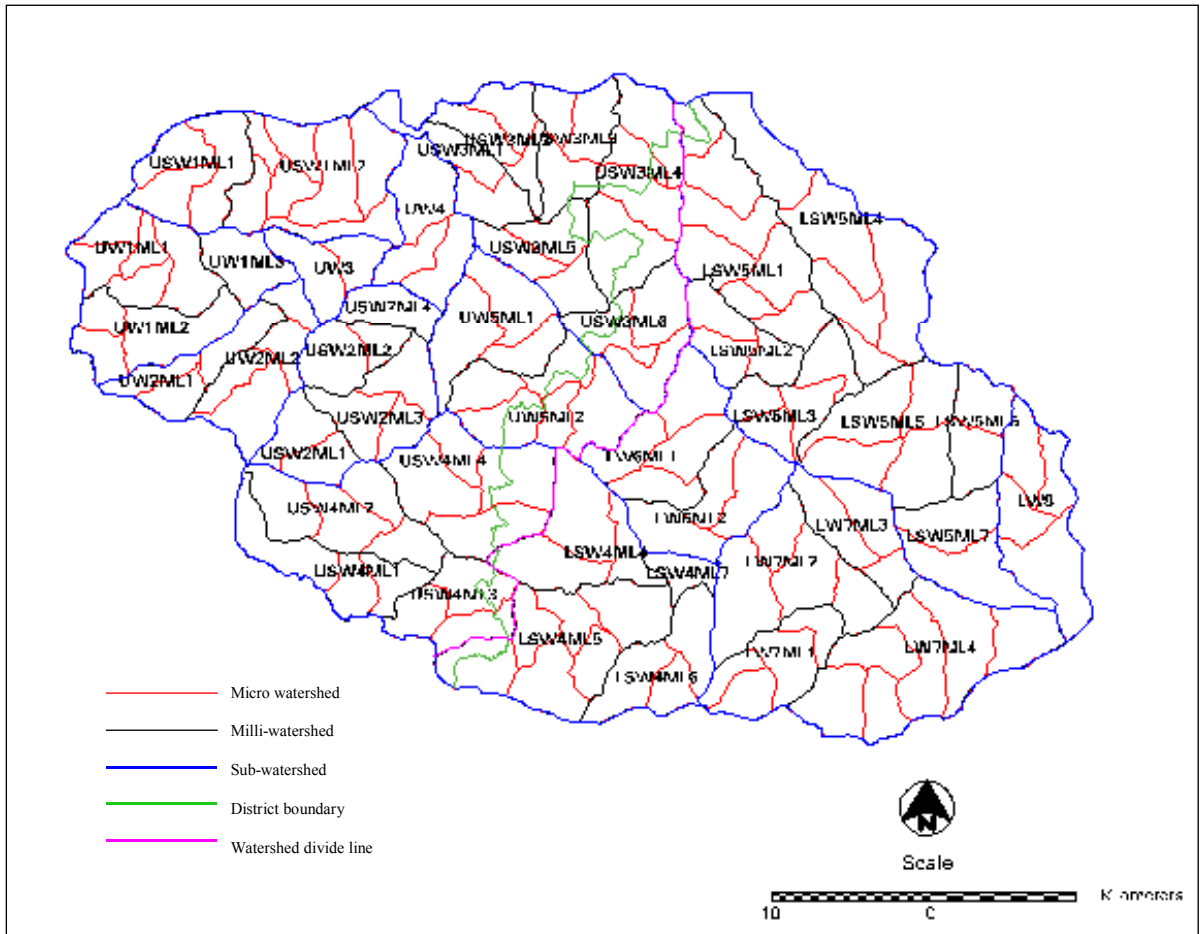


Fig.4 Spatial Network at different level for drought management

Eventually the watershed is divided as the upper(U) and lower(L) part of the watershed, which is assumed as SN-2 level spatial network(SN-2) for watershed management of DPAP area. The complication can be reduced in SN-3 level spatial network(SN-3) which is followed the sub-watersheds and the inter-watersheds. This is based on the drainage area of the tributaries defined by internal water divides. Following the same methodology SN-4 level spatial network(SN-4) is delineated as subdivision of sub-watersheds into milli-watersheds. Similarly SN-5 level spatial network(SN-5) divides the milli-watersheds into micro-watersheds. Micro watersheds are considered as the smallest hydrologic unit with surface area varying from 400 ha to 2500 ha. Such a spatial

network can be used for detailed planning for agricultural and water management through micro level studies spatially over Drought Prone Area(Table-1).

6. Fetching Comprehensive Ground Level Documents (C-GLD) For DSS In Drought Management

The historic storage of relevant information as GLD can generate a self guiding e-support through DSS which helps planner as well as End user to take further action. The hypothetical dependency of GLD and DSS is presented in figure-5. The GLD can be formulated as R-GLD where the required documents can be sketched specific to the DSS. But the real time DSS is dependent on the A-GLD. The gap analysis in DSS can help to improve R-GLD. It is a heuristic method to fill up the gap between ground truth and DSS accuracy(Fig.5).

A case study has been done on this hypothesis where the feasibility of development of DSS in particular to drought management is carried out considering spatial and temporal control on A-GLD. The constraint is also documented through G-GLD.

The required baseline information/data is presented in table-2 targeting drought hazard management. The availability status is presented in the table considering the temporal as well as spatial need.

7. Discussions and conclusions

There are overall criteria to declare drought prone area but planning commission noticed the requirement of scientific approach to monitor integrated drought and its impacts. All aspects of drought are predominated due to aberrant of rainfall, high heat effect, geomorphologic stress, soil stress in Boko-Dhalkisor-Gandheswari watershed, designated as SN-1. Exogenous inputs of water are negligible in the study area. The study should take care of both cause and effect of several types of drought. The drought forecasting strategy has to be well explored. The recurrence of existing drought can be taken into account for immediate future. Experience on trend of drought occurrence and severity can be a precautionary measure. The dally/seasonal drought warning system has to be aimed to model. This study will also support for the livelihood of the local people. The authority can take respective cultural and economic precautions.

Based on state of art a detailed methodology is under research which will have a potential to develop a DSS for the management of drought over the area. In a DSS of drought hazard RDBMS is the base line capture by the manager, which helps maintenance and retrieval from/to modelbase. The

availability of ground level documents has a perspective role to the applicability to the expected system as DSS. The Gap as G-GLD is analytically detected which helps to improve the availability as A-GLD by filling the requirement as R-GLD. Hence the real time DSS can be improved in particular to drought hazard.

The data availability is scattered over the study area as data is generated through executed project of data generating organizations. In the present context it is realized that sustainable development of drought management is only possible through the systematic development of a basin/catchment/watershed as model of water distribution targeting to drought hazard. The spatial network has to be addressed scientifically as designated in the present study area under SN- 1 to 5.

The necessary data is available to model the Decision Support System (DSS) but there is still data gap spatially as well as temporally. Eventually database management system can be updated which gives further feed back to improve the DSS.

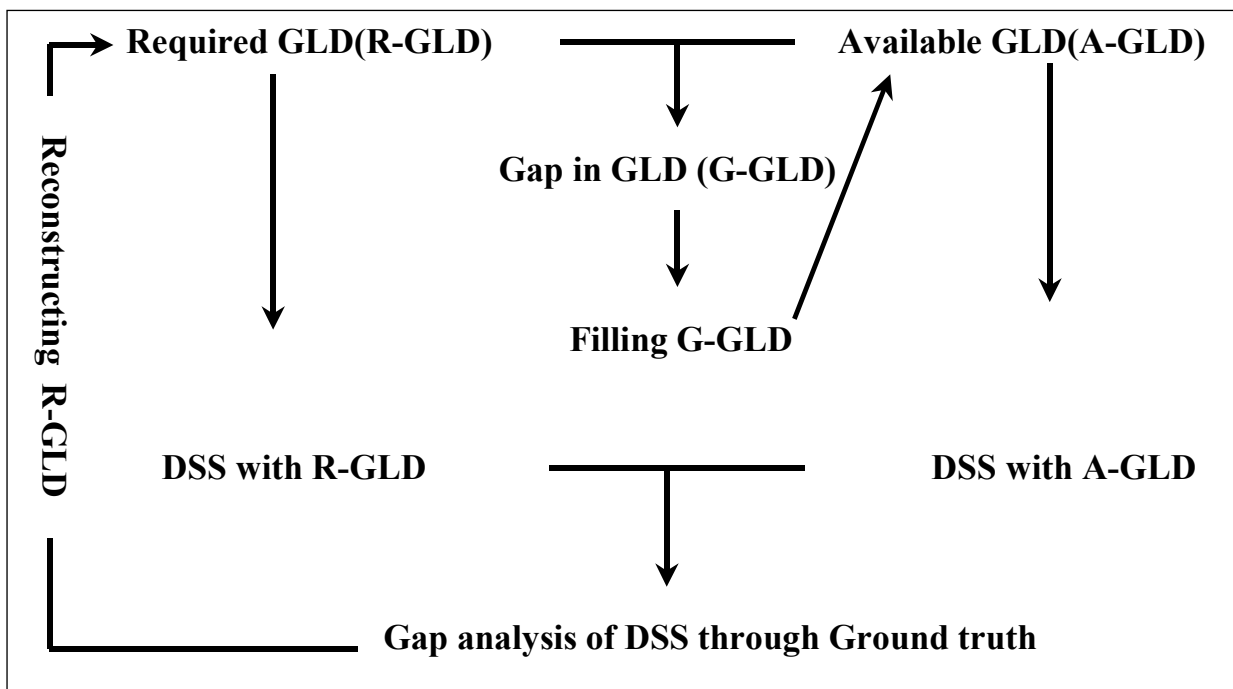


Fig.5 Cycle of Ground Level Documentation for DSS of Drought Management

Table-1: Tabulated Spatial Network of Watershed

Sl. No:	Watershed Unit as SN-1	Watershed divide as SN-2	Watershed divide as sub-watershed (SN-3)	Watershed divide as Milli-watershed (SN-4)	Overland area of Milli-watershed (ha)	No. of Watershed divide as micro-watershed (SN-5)
1	Beko - Dhalkisor - Gandheswari	Upper part (U)	UW1	UW1ML1	4365.81	5
2				UW1ML2	3659.63	3
3				UW1ML3	1800.34	1
4			UW2	UW2ML1	2643.74	3
5				UW2ML2	3853.01	4
6			UW3	UW3	2370.14	2
7			UW4	UW4	4045.90	3
8			UW5	UW5ML1	4791.70	3
9				UW5ML2	5667.08	5
10			USW1	USW1ML1	4090.50	3
11				USW1ML2	7099.87	7
12			USW2	USW2ML1	2218.05	2
13				USW2ML2	2240.93	2
14				USW2ML3	3455.88	3
15				USW2ML4	1388.42	1
16			USW3	USW3ML1	2624.29	2
17				USW3ML2	2644.29	3
18				USW3ML3	3227.90	3
19				USW3ML4	6022.49	4
20				USW3ML5	3122.20	5
21			USW4	USW3ML6	4015.25	3
22				USW4ML1	3594.60	3
23				USW4ML2	4886.02	3
24				USW4ML3	3277.33	3
25				USW4ML4	6312.18	4
26		Lower part (L)	LW6	LW6ML1	4868.93	4
27				LW6ML2	4272.22	3
28			LW7	LW7ML1	3597.83	4
29				LW7ML2	6188.59	4
30				LW7ML3	3314.23	3
31				LW7ML4	9210.05	6
32			LW8	LW8	5286.38	4
33			LSW4	LSW4ML4	4793.63	3
34				LSW4ML5	7439.51	6
35				LSW4ML6	3627.06	3
36				LSW4ML7	817.43	2
37			LSW5	LSW5ML1	7814.61	7
38				LSW5ML2	2753.49	3
39				LSW5ML3	3471.18	4
40				LSW5ML4	9036.64	5
41		LSW5ML5		6205.45	4	
42		LSW5ML6		2420.29	2	
43		LSW5ML7		3945.95	2	
Total area = 182480.99 ha						

Table-2: Tabulated Availability /Gap in Database

Type of data/Information	Temporal duration of availability/gap (✓ Available, ✗not available, ⊙ not applicable)						Spatial Network of availability
	Daily	Monthly	Seasonal	Annual	Decadal	• Regular/ *Reference	
Rainfall	✓	✓	✓	✓	✓	•	SN-1, SN-2, SN-3 partially
Temperature	✓	✓	✓	✓	✓	•	SN-1 & SN-2
Humidity	✓	✓	✓	✓	✓	•	SN-1 & SN-2
Actual evapo(transpi)ration	✗	✓	✓	✓	✗	*	SN-1
River discharge	✓	✓	✓	✓	✓	*	SN-1
Ground water-table depth	✗	✗	✓	✓	✓	•	SN-1 , SN-2 , SN-3 &SN-4, SN-5 partially
Reservoir level data	✓	✓	✓	✓	✗	*	SN-1 , SN-2 & SN-3
Soil moisture	✓	✓	✓	✓	✗	*	SN-1
Water holding capacity of soil	✓	✓	✓	✓	✗	*	SN-1
Demographic information	✗	✗	✗	✗	✓	•	SN-1 , SN-2 , SN-3 , SN-4 & SN-5
Satellite data (Digital data & Imagery)	✓	✓	✓	✓	✓	•	SN-1 , SN-2 , SN-3 , SN-4 & SN-5
Topographic sheet, Soil map & Land capability map	⊙	⊙	⊙	⊙	✗	*	SN-1 , SN-2 , SN-3 & SN-4
Information on historic drought events	✗	✗	✗	✗	✗	*	SN-1 & SN-2 No Reference on past annual drought
Data on Productivity	✗	✗	✓	✓	✗	✗	SN-1 , SN-2 & SN-3

The availability of data has been explored through interaction with several district line organizations. Monthly Rainfall data over few stations which covers area upto the level of SN-3. The G-GLD is found for SN-4 and 5 for this particular DSS. The daily meteorological data is not available in general for SN-3, 4 and 5 except two meteorological observatories situated in SN-1 and 2. Spatially distributed seasonal ground water table data is available from several resources but proper shifting of data to a spatial point itself is a major task. Scattered river discharge data from few river gauging stations for selected period is available, which indicate remarkable G-GLD for the development of

DSS. The classified soil map and related parameters are available in different geographical scale. The appropriate transformation of scale may reduce the inaccuracy in geo referencing of the DSS. Soil moisture data is not adequate but can be used as reference data. Population and statistical data of land use can be coined from statistical handbook. Remotely sensed data (Source: National Remote Sensing Agency) can be used as through image analysis and GIS. Overall implementation of DSS is mostly restricted to SN-1 and 2 considering A-GLD and G-GLD together (Table-2). Moreover in drought hazard the availability of decadal daily/monthly data is required to capture indigenous experience of end users' as DBMS. Under this requirement G-GLD is huge over the study area.

More research in the field of early warning system of drought over the area is to be focused in future. It has been noticed that the techniques for drought watch, monitoring and impact assessment are awaited vast research to configure a proper early warning system. The data gap should be minimized along with availability of smooth procurement facility. The extensive research is the necessity to construct historical data over focused area.

8. Acknowledgement

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