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Capacity estimation of small surface water bodies using RS and GIS

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ABSTRACT : Surface water bodies are the major source for irrigation in India. Information on surface water bodies such as water spread area, volume of water stored in a water body is useful for understanding the availability of water resources for the crop season in a river basin / sub basin. The study extensively used satellite based techniques for the estimation of surface water spread at regional level and at temporal scale to facilitate mapping, monitoring visualization of the dynamics unlike conventional methods. Geospatial database on water bodies information has been created for the study area Krishna middle sub basin. The study considers only water bodies where water is stored for irrigation purpose such as reservoirs, tanks, ponds, etc excluding rivers. Study is focused on use of RS and GIS techniques with extensive use of Image processing and GIS software like ERDAS Imagine, ARC Desktop GIS and analyses the spatio- temporal water body layers. Quantitative estimates on WSA under water bodies are worked for analyzing inter / intra seasonal / annual analysis. The present study has brought out geospatial database and provided scope for sub regional / regional analysis. Estimation of regional surface water storage is estimated with separate methodology for larger and smaller water bodies. This is demonstrated within a sub basin namely Krishna middle sub basin. Storage in larger water bodies is estimated by developing satellite based Area -Capacity curves related to Elevation values on the date satellite data acquisition. Storage in smaller water bodies is estimated with the help a methodology frame work developed in this study using digital elevation models, stream order and relating to the extensive observations made on elevation difference between upstream and downstream of water bodies. The study has brought out suitable spatio-temporal information of water bodies useful for analyzing operational issues related to water resources availability. The information generated can be made use for web based regional analysis and for public domain with suitable visualization tools.

KEY WORDS : Water bodies, Capacity, Water spread area, Remote sensing, GIS

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Surface water bodies are the major source for irrigation in India for sustainable crop production. Information on surface water bodies such as water spread area, volume of water stored in a water body regional surface water storage are a main parameters for assessing the availability of water resources for the crop season. Water spread was dynamic production in terms of its spread and volume based on rainfall, runoff in the catchment, and also regulated flows into artificial reservoirs/tanks downstream. Hence, it was necessary to generate such information on a regular basis at higher frequency for effective water resources management and diagnostic analysis for resolving the water crisis at regional level. Conventionally, volume of water stored is measured only in large reservoirs based on Elevation-Area-Capacity curves established before impoundment of the reservoir. However, the storage from the smaller water bodies like irrigation tanks are not addressed and its quantification is not done at regional level though it was best known to village only. In this scenario, it was felt necessary for the use of satellite based techniques for the estimation of surface water spread at regional level and at temporal scale for these water bodies. Satellite sensors can provide synoptic and dynamic coverage of earth surface at frequent intervals which facilitate mapping and monitoring dynamics of surface water bodies. The study is focussed at the use of satellite derived surface water spread of reservoirs, irrigation tanks, lakes, ponds, etc., for characterisation of surface water spread in time scale for various water bodies which are important for irrigation purpose in Krishna and Godavari river basins. In addition, proposition of a model framework investigation for a method of estimating the surface water storages in these water bodies in order to estimate storages at any time period of satellite data acquisition is discussed. The scope available for the best use of satellite derived water spread at regular intervals is explored for the study for characterising the surface water dynamics and also estimation of corresponding surface water storage.

■ METHODOLOGY

Estimation of reservoir volumes at different elevations :

Capacity of water that can be stored between any two levels is estimated using prismoidal volume formula.

Using the reservoir water spread areas at different elevations computed above the reservoir volume between any two successive elevations is estimated using prismoidal formula as below:

$$\Delta V1\text{-}2 = \Delta h/3\ (A1+A2+\sqrt{A1*A2})$$

where,

$\Delta V1\text{-}2$ = Volume between elevation E2 and E1 (E2>E1)

Δh = E2 - E1

A1, A2 = Water spread areas at elevation E1 and E2

After computing volumes between successive elevations (for which water spread areas are estimated), cumulative volumes at different reservoir levels are computed to develop new Elevation- Area- Capacity relationship (curve). Capacity level for the lowest was considered as reference for reservoir which is nearer to dead storage.

Methodology for estimation of capacity of smaller water bodies:

Availability of information on depth of smaller water bodies is generally difficult as they vary based on local catchment conditions and their maintenance. As the study was aimed to develop tool for regional surface water storage, it was proposed to simulate average depth of the smaller water bodies with help of stream information on which water body is existing and elevation values from digital elevation model. This was demonstrated through a sub basin as an example model considering all water bodies in Krishna Middle sub basin and a data frame work was set up which has been extended to other river sub basins. The view of various water bodies in Krishna middle sub basin. View of stream network in the sub basin was shown in Fig. B.

Sample analysis of digital elevation difference from bund to tail surrounding smaller water bodies of varying sizes has been carried out. These observations are taken as guidance for proposing the average depth of water in these water bodies. View of digital elevation model (ASTER DEM) over sub basin in shown in (Fig.A) overlaid with water bodies. Closer view of DEM and stream order information network used was shown Fig.B. Determination of average depth for each of the water bodies was done by observing the surrounding elevation values of a water body from upstream to downstream. An assumption was made that this elevation difference was directly linked to depth of water body.

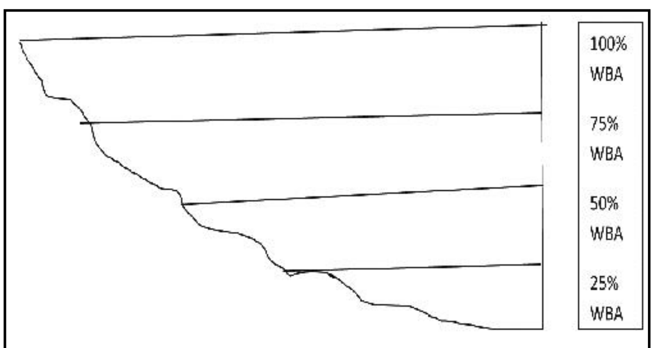

Fig. A : Schematic diagram-various levels of water spread

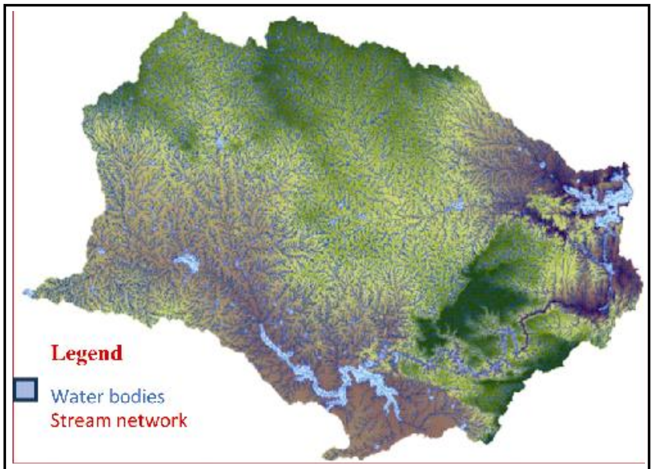

Fig. B : View of Digital elevation model (ASTER DEM) of Krishna middle Sub basin

GIS model- Intersect tool was used to transfer the stream order attribute available in stream network (line layer) to water body layer in desktop GIS. An overlay of stream order network (line layer) and Aster DEM used for sampling. The number of sample water bodies was used for understanding the local slopes and maximum elevation at upstream and further fall was observed. This forms the basis for assuming the average full depth of water body. However, The average full depth assumed may have self-contained error (due to satellite derived elevation) and also it was true that, the average depth assumed have may not represent the same at all water spread area levels (assumed scenario is shown in Fig. A). The understanding of this procedure was depicted in Fig. A.

A GIS model frame work was set up with water body polygons, with attributes on full average depth, depth at 25 per cent, 50 per cent, 75 per cent and 100 per cent of maximum reference water spread area. This layer was combined with Individual regional water spread images as per the data collected over India as per Table A. In view of this, it was assumed that the average depth of water bodies was 25 per cent of full average depth when water bodies area was 25 per cent of Maximum water bodies area 50 per cent of maximum water bodies area, 75 per cent of maximum water bodies area, 90 per cent of maximum water bodies area when it was 100 per cent. Table 1 shows the average depth (Full) and the depth corresponding to various WBA levels. Full average depth may not be representing when the water spread at lower levels. Hence, an assumption was made in the present model frame work for demonstration purpose as per the Table A. These empirical relationships are used in shape file dynamically to estimate the capacity of individual water body for several temporal water

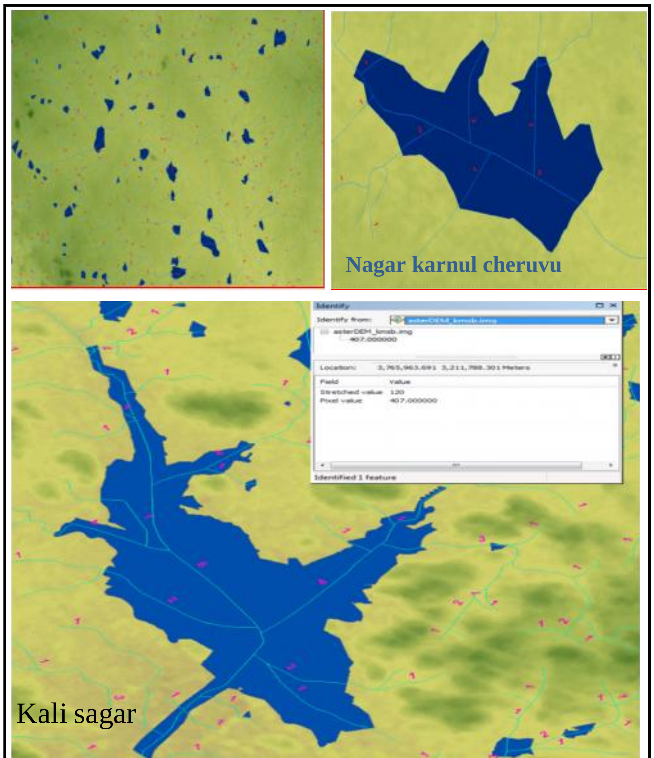

Fig. C : Combined view of Digital elevation model, Water bodies' layer and stream network with stream order

Table A : Criteria suggested for assigning average depth to water bodies

Stream order	Average full Depth (m)	1-25 % of Max. WBA	25-50 % of Max. WBA	50-75 % of Max. WBA	75-100 % of Max. WBA
1	3	0.75	1.50	2.25	2.70
2	5	1.25	2.50	3.75	4.50
3	8	2.00	4.00	6.00	7.20
4	10	2.50	5.00	7.50	9.00
≥5	15	3.75	7.50	11.25	13.50

spreads.

A software tool was developed by NRSC for implementation of this methodology to consult this GIS – layer and cross with temporal water spread images of last 10 years. Implemantation of methodology for Krishna middle river basin to estimation of capacity at regional level is taken up.

Fig. D represent the view of GIS attribute showing full average depth, stream order and maximum water spread and depth co-efficients assumed for analysis. A view of temporal variations in terms of available water in two water bodies over a period of last 10 years. Analysis at Krishna middle sub basin is presented in result section.

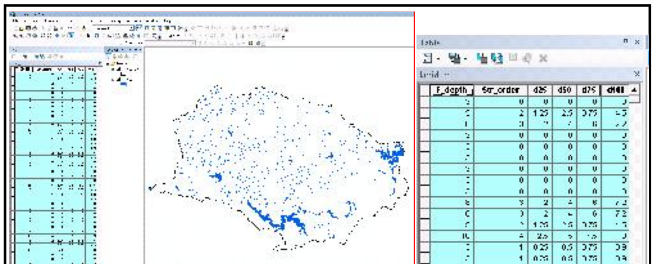

Fig. D : View of water body layer assigned with average depth values

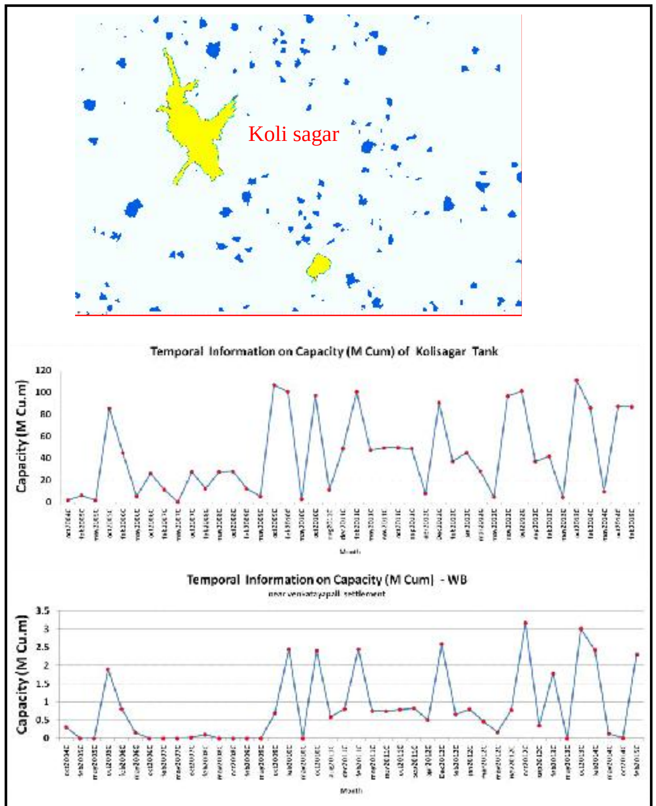

Fig. 1 : View of temporal variation in two water bodies since last 10 years in various seasons of the years

RESULTS AND DISCUSSION

Satellite derived capacity information across last ten years in Kolisagar tank indicate that, most of October months received a storage of approximately 100 M cum. This means that, if there was any reduction in October in further years indicates the existence of hydrological draught. Similar trends are shown for a selected small water body.

If the analysis out at regional level for each of water body, over a season, it was a scientific way of analysing the hydrological drought scenario. Results are demonstrated through an example showing capacity variations in two water bodies across ten years as shown in Fig. 1.

These figures are calculated for each of river basin and also at river sub basin level. Estimation of regional surface water storage is estimated with separate methodology for larger and smaller water bodies. This is demonstrated within a sub basin namely Krishna middle sub basin. Storage in larger water bodies is estimated by developing satellite based Area -Capacity curves related Elevation values on the date satellite data acquisition. Storage in smaller water bodies is estimated with the help a methodology frame work proposed in this study using digital elevation models, stream order and relating to the extensive observation made on elevation difference between upstream and downstream of water bodies.

Conclusion:

This is performed with the help of RS and GIS techniques with extensive use of Image processing and GIS software like ERDAS Imagine, ARC Desktop GIS. Quantitative estimates on WBA under water bodies are worked for analysing inter/ intra seasonal/annual analysis.

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