Biannual Open Access Journal
Peer-Reviewed/Refereed International Journal
JOURNAL OF GLOBAL RESOURCES
ISDESR, Jaipur, India
www.isdesr.org
ISSN: 2395-3160 (Print)
ISSN: 2455-2445 (Online)
July 2024, Volume 10 (02)
DOI Prefix: 10.46587/JGR

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IMPLICATIONS OF VILLAGE-WATERSHED GEOGRAPHICAL RELATIONSHIPS ON WATERSHED SELECTION/PRIORITISATION

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How to cite this paper:
Solanki Harish Kumar (2024) Watershed Prioritisation, Village-Watershed Geographical Relationships and its Implications on Watershed Works, Journal of Global Resources, Vol. 10 (02)

DOI:
10.46587/JGR.2024.v10i02.004

Received: 28 March 2024
Reviewed: 19 April 2024
Final Accepted: 5 June 2024

OPEN ACCESS
Freely available Online
www.isdesr.org

Abstract: *Watershed prioritisation and selection become essential when operational funds are scarce, and it is not easy to execute the work in all watersheds simultaneously. The needs of watershed areas may also be different based on various criteria. Methods based on different prioritisation and selection parameters have been developed by scientific institutes or by executing organisations/ministries involved. As per the complexity involved in quantifying and analysing these methods and parameters, effective use of modern geospatial technologies with a participatory approach is the way to prioritise and select watersheds better. In the paper, an analysis of the parameters of watershed selection/prioritisation has been done in the context of village-watershed geographical relationships. The need for the involvement of geospatial technology and people's participation is emphasised in the article.*

Key words: Watershed Selection, Watershed Prioritisation, Geospatial Technology, People's Participation

Introduction

The selection and prioritisation of watersheds are critical phases in watershed management. The need for this activity arose from a lack of sufficient funds to treat whole watersheds of the country parallelly. Which micro watershed will be treated on priority and what micro watershed areas will be treated later is called watershed selection/prioritisation. Both the terms are interlinked. Based on a set of parameters and methods, one can select an area based on need or budget availability. Without methods of quantifying parameters and weightage patterns, the whole procedure becomes dependent on the persons involved in the process. Proper standardisation of watershed selection, prioritisation process, and defining the role of PRIs or local representatives in the process are the felt needs.

The geographical relationships between the village and the Watershed are the next challenge in execution after prioritisation. The village or gram panchayat boundaries are administrative units, and the watershed boundaries are geo-hydrological units. Both do not overlap with each other. Solanki (2021) first coined a new term, Micro Surface Water Management Units (MSWMUs), to include the watershed concept in administrative boundaries like villages. This is helpful specifically in the conditions when execution units are administrative boundaries. This can be understood by the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), where execution units are Gram Panchayats, administrative units, and the watershed concept is to be applied to Integrated Natural Resource Management (INRM) works. The concept is like marrying the geo-hydrological units with administrative units. This paper discusses the complexities, challenges and solutions of watershed selection/prioritisation, along with challenges faced in the execution of watersheds in flagships of the government of India due to differences between Watershed and village boundaries. The paper will discuss the aspects related to watershed selection/prioritisation, the geographical relationships of villages and watershed boundaries, and their implications for watershed works.

Methodology

The article is based on a review and analysis of various Government of India Guidelines for selection and prioritisation in chronological order, with an analysis of various scientific watershed prioritisation methods adopted by agencies to prepare watershed atlases. A critical analysis of watershed and village area interrelationships and challenges has been done. The author's vast experience of around 27 years in watersheds and geo-informatics has been incorporated into the article.

Watershed Delineation

A map of a well-delineated watershed or cluster of watersheds at the block, district or state level to start the selection/prioritisation process is the first step in this direction. A well-published work in this area is the National Watershed Atlas at 1:1 million scale, done in 1990 by the Soil and Land Use Survey of India (SLUSI), erstwhile AISLUS. This atlas was a map delineation up to watershed level, having an average area of around 500 Sq. Km. The area was much higher than the requirements of the Ministry of Agriculture and Ministry of Rural Development supported micro watersheds schemes in India, which demanded an average size of watersheds as 500 hectares. Central Ground Water Board (CGWB, n.d.) also conducted delineation work at the country level at 1:250000 scale up to the Watershed level, which again averaged 500 Sq. Km. Area. SLUSI delineated the country in 6 Regions, 35 Basins, 112 Catchments, 500 Sub catchments, and 3237 Watersheds, while CGWB delineated the country in 34 Basins, 94 Sub basins, and 3448 Watersheds. The codification pattern of CGWB was also different from that of the SLUSI codification system.

Seeing the need to delineate up to 500 hectares, under the recommendations of the Hanumantha Rao committee, in 1994, State Remote Sensing Application Centres (SRSACs) of various states and specialised agencies further delineated watersheds for use in the Ministry of Agriculture (MoA), Government of India and Ministry of Rural Development (MoRD), Government of India supported watershed schemes. While almost all agencies followed an alphanumeric codification system suggested by SLUSI, some state agencies adopted a different codification system, such as Rajasthan. SRSAC Rajasthan has separately delineated the state as 13 river valleys further subdivided into Watershed, Macro Watershed and Micro Watershed with a different numeric codification system (State Remote Sensing Application Center, 1999).

Parameters Included in Various Guidelines for the Selection of Watersheds

Guidelines of Watershed (old –with effect from (w.e.f.)- 01.04.1995)

In this guideline, the criteria/parameters for Village and Watershed selection were as follows:

Selections of villages: Keeping in view the strategy of people’s participation in sustainable watershed development, the following criteria are laid down for selecting villages: Selection shall be made of only those villages from where people's participation is assured through voluntary donations/contributions in terms of labour, raw materials or cash for the developmental activities as well as for the operation and maintenance of the assets created.

Selection of watersheds: The following criteria were stated in prioritising the selection of the Watershed: a) Watersheds that have an acute shortage of drinking water. b) Watershed, which has a large population of scheduled castes/scheduled tribes dependent on it. c) Watershed, which has a preponderance of wastelands. d) Watershed, which has a preponderance of common lands. e) Watershed where actual wages are significantly lower than the minimum wages. f) Watershed that is contiguous to another already developed watershed/ is selected for development.

After this guideline, watershed guidelines revised w.e.f. 01.04.2001 was released, then Hariyali guidelines w.e.f. 01.04.2003 was released, and then Common Guidelines w.e.f. 01.04.2008 was released. The parameters in previously released guidelines were almost identical, with few modifications/additions.

Common Guidelines for Watershed Development Projects 2008, Revised Edition 2011

Criteria for selecting watershed projects: The following criteria may broadly be used in selecting and prioritising watershed development projects: a) Acuteness of drinking water scarcity. b) The extent of over-exploitation of groundwater resources. c) The preponderance of wastelands/degraded lands. d) Contiguity to another watershed that has already been developed/treated. d) The willingness of the village community to make voluntary contributions, enforce equitable social regulations for the sharing of common property resources, make equitable distribution of benefits, and create arrangements for the operation and maintenance of the assets created. e) Proportion of scheduled castes/scheduled tribes. f) The area of the project should not be covered under assured irrigation. g) Productivity potential of the land (Planning Commission, Government of India 2011).

Guidelines for Watershed Development Component-Pradhan Mantri Krishi Sinchayee Yojana 2.0 (WDC-PMKSY 2.0)

The WDC-PMKSY 2.0 is the latest guideline for watershed implementation around the country w.e.f. 01.04.2021, highlighted that the watershed development projects would be broadly taken up in the most vulnerable rainfed districts by prioritising micro-watersheds. However, the challenges and issues of North-Eastern and hilly States/UTs will be emphasised. While prioritising the watershed projects in the critical areas of the districts, the following criteria were suggested for selection: a) Frequency of drought occurrence. b) Acute scarcity of drinking water, degree of over-exploitation of groundwater resources. c) Preponderance of degraded lands/wastelands. d) Decline in Normalised Difference Vegetation Index (NDVI). e) Status of soil health, aquifer characteristics and topography. f) Hydrological assessment of surplus runoff from watersheds, contiguity to another watershed that has already been developed/ treated. g) Most of the population belongs to scheduled castes/tribes and other socially and economically backward populations. h) The productivity of major crops is lower than that of the district/state average. i) Willingness of the village community to make voluntary contributions, adopt regulatory norms to maintain common property resources and ensure equitable sharing of the resources/benefits (Department of Land Resources, Ministry of Rural Development, Government of India, 2021).

The criteria for watershed selection and prioritisation from the initial guidelines and the latest during 1995 to now remain almost the same, and some critical factors like contiguity of watersheds, a preponderance of common lands and wastelands, acuteness of drinking water, lack of assured irrigation, over-exploitation of groundwater, prevalence of backward population, poverty and lack of productivity and soil fertility are common.

Scientific Interventions for Selection/Prioritisation

Models Developed by SLUSI erstwhile AISLUS

SLUSI has developed two models for using their River valley project (RVP) catchments and flood-prone river (FPR) catchments.

Sediment Yield Index (SYI) Model

The Sediment Yield Index (SYI) Model conceptualises sediment delivery into the reservoir as a multiplicative function of potential soil detachment representing the erosivity factor and the transportability of the detached material. The former factor is simulated with the sediment yield weightage value based on assessing the composite effect of a set of parameters that have a direct or reciprocal bearing on the unit of detached soil material. In contrast, the latter termed the delivery ratio, is adjudged by the likely delivery of the eroded material into the stream or reservoir. The numerical sediment yield weightage values assigned to various erosion intensity mapping units imply the combined effect of dynamic inter-relationship of the mapping units' following factors: i. Physiography and slope - influence the velocity and flow of runoff. ii. Soil parameters-depth, texture, reaction, potential for silt yield and resistance to flocculation. iii. Vegetation and cover conditions are aggravators to the impact of Rainfall and runoff. iv. Manifestation of erosion-indicator of the process. v. Dispersion ratio, erosion ratio, aggregate stability index and soil erodibility index indicate the potential for sediment yield.

Factors collectively considered to determine the delivery ratio are as follows:

i. Nature of the soil. ii. Proximity to the reservoir/active stream iii. Relief-length ratio, drainage pattern and drainage density. iv. Slope gradient and surface cover conditions. v. Existing sediment traps like ponds, lakes, etc.

The rating of sub-watersheds into different priority categories is determined by deciding upon each category's lower and upper limits based on the frequency distribution of SYI values.

Runoff Potential Index (RPI) Model

The Runoff Potential Index (RPI) model being used by AISLUS for the prioritisation of sub-watersheds in the FPR catchment areas is a modification and expansion of the SYI Model wherein the assessment of combined weightage values is based on the effect of soil and land attributes on the runoff generating potential. At the same time, the delivery ratio factor is taken as unity. Apart from the factors considered for assigning erosion intensity weightage value, the value of the introductory infiltration rate is taken as additional input for assigning relative runoff potential weights. Rapid reconnaissance surveys are carried out to grade the sub-watersheds into high, high, medium, low and low priority categories. This database is utilised for planning soil conservation treatment and integrated watershed management programmes in very high and high priority category sub-watersheds in RVP and FPR catchment areas, respectively.

State Specific Models

Rajasthan: Prioritisation has been done for the whole state up to each micro watershed level based on drainage density and per cent cultivable land. Alphabetical ordering of prioritisation has been provided to all micro watersheds based on the drainage density and cultivable area available in the micro watersheds.

Karnataka: Prioritisation of sub-watersheds was attempted for a few Taluks using remote sensing and GIS techniques.

The parameters have been finalised by Sarangamath et al. (2006) with a series of discussions with the Watershed Development Department, and details are furnished in the table below.

Table 01: Parameters, Weightages and Factors for Watershed Prioritisation

Parameters	Weightage	Factors
Silt Yield Index	20	The more the SYI, the more priority
SC /ST Population	20	More the population, More the priority
Wasteland	20	More the wastelands, the More the priority
Agricultural labourers population	10	More the population, More the priority
Rainfall	10	Less the Rainfall, the More the priority
Forest Area	10	Less the forest cover, the more the priority
Irrigated Area	10	Less the irrigated area, the more the priority
Total Marks	100	

General Procedures for Selection/Prioritisation of Watersheds

In the time of 1996, when VIII plan watersheds of the National Watershed Development Projects for Rainfed Areas (NWDPRA) scheme of the Ministry of Agriculture, Government of India was in operation, the first and foremost criteria were the contiguity of the previously selected watersheds. In that way, the watershed functionaries also get advantages of already constructed infrastructures like *Chetana Kendra* for storage of inputs, stay, training, etc. The newly elected watershed committee chairpersons also used to come in contact quickly due to short distances with mature WC chairpersons of ongoing watersheds or completed watersheds, and less effort was put into getting them trained in the Watershed works. The rest of the criteria were neither available nor cared if contiguity was satisfied. Political interference was the least.

In 2000, contiguity to already treated/ongoing watersheds was also on the top. Little political interference increased, and watersheds were selected more carefully, with due consultation with public representatives and PRIs at the block or district level. SC/ST Population and preponderance of common land also came forward to consider before coming to a final solution to the selection. However, all weightage patterns to the parameters were case or location-specific only.

In 2006, under Hariyali guidelines, increased participation of PRIs was included, affecting all watershed execution procedures in every aspect. Selection and prioritisation were also close to that. The interest of public representatives and PRIs also became a significant part of the selection prioritisation of the watersheds. Except for this factor, contiguity to previous watersheds, SC/ST population, groundwater strata, and preponderance of common lands/wastelands were the prime factors. This process always remained smooth and location and case-specific. When there was a clash between parameters and majority interest, majority interest was taken care of for the smooth operation of works in future.

Suggestions for Proper Selection/Prioritisation of Watersheds
Development of Quantification Methods for Each Parameter

A proper quantification method for each parameter is necessary, and in the absence, the selection of watersheds continues to happen arbitrarily, and parameters will remain subjective only. For the selection and prioritisation, the parameters of various guidelines and their quantification have been discussed in detail in further sections.

Acuteness of Drinking Water Scarcity: Open wells are the general drinking water source in the watershed areas. Overhead water tanks for pipeline supply are also available in selected villages with partial pipeline connections. This is in villages with large populations, and groundwater is available and potable. Somewhere, the water table is regular, but water is not potable, and somewhere, water is potable, but it is too deep to extract without government help or significant investments. Continuity of water availability is also considered as the Groundwater variations may be high, and reinvestment in the deepening of wells may be required periodically. Water tables can be quantified, and the average of widely spread 4-5 wells throughout the micro watersheds may be found. To check the depth of the water table, we can consider the adjacent ground level as a base to calculate depth. If any permanent or semi-permanent benchmark is nearby, we should use a reduced level with mean sea level as a datum

Water quality becomes complex as water quality may vary at minimal distances, and only general ideas about a cluster of villages can be found in public opinion and the support of departments involved in drinking water supply. Groundwater quality-related GIS maps, based on test wells, can also be prepared by State Remote Sensing Agencies (SRSAC). Similarly, state remote sensing agencies can also generate groundwater prospectus maps. The scale should be at least 1:25000 or 1:50000. Due to the difficulty in getting good quality data/maps and the variability of factors, it will have some portion of subjectivity rather than remain entirely objective. However, fair conclusions can be drawn if local persons are also involved.

The Extent of Over-Exploitation of Groundwater Resources: The maps available in the field for assessing this factor are up to Block level, only giving parameters as White, Grey and Dark areas/zones depending on the exploitation of groundwater, but this information has not been further classified for the individual micro watersheds which may be a big task, and in future, we can get maps of that level also. Till then, if we want to quantify this factor, we can relate it to the groundwater table in a particular season or month and to the pumping capacity of wells of widespread four to five wells. We can use local help to get more knowledge, but proper quantification will remain partially subjective and situation-specific only. This parameter is more stressed as an impact assessment indicator than at the Watershed's selection time.

The Preponderance of Wastelands/Degraded Lands: For quantification of this parameter, many states have data on land use land cover to be used for the Watershed, but taking the example of Rajasthan, the area shown in land use/land cover does not match with revenue records as it was generated with considering space technology only to decide any land as arable, non-arable, forest, pasture etc. Eventually, it is far from the ground realities. Wasteland maps issued by MoRD generated by NRSA with the help of many other agencies nationwide are also in PDF form and do not have Micro Watershed boundaries. Only state-wise maps with district administrative boundaries and no geographical coordinates are shown. Superimposition of these maps to the Micro Watershed boundary is not possible. The only way that remains is to assume that each Watershed has the same portion of wasteland as the one given for the respective district in the table of the Wasteland Atlas. High-quality, large-scale georeferenced maps with micro-watershed-wise mapping and the calculation of wastelands/degraded lands are required to make this factor objective; otherwise, this parameter will remain partially subjective.

Contiguity to Another Watershed that has already been developed/Treated: This may be the only objective parameter in selecting watersheds. If properly delineated maps are available, every field executive uses this parameter without difficulty and subjectivity. No complexity is there. This parameter's weightage and the contiguity's direction are the only things to consider.

The willingness of the village community to make voluntary contributions, enforce equitable social regulations for the sharing of common property resources, make equitable distribution of benefits, and create arrangements for the operation and maintenance of the assets created. However, it is an important parameter, but quantification of this parameter also has some observations like:

The interrelationships between the Watershed and the village must be studied. If any village has a partial area in the Watershed and with the actual village location inside the Watershed, what weightage will be given to their views or willingness is a matter to be decided. Some villages may have large areas inside the Watershed, but the actual village location may be outside the Watershed. Then what weightage will be given in that case? For a simple solution, consider all villages the same, but large populations of villages and villages covered fully under the Watershed may have differing views. Further, if any village is not showing willingness, can we keep that area untreated in the Watershed, or can we leave the whole Watershed unselected due to the unwillingness of one or two villages?

In this case, the community will decide the willingness, but who is the community? Is it Gram Sabha, Gram Pradhan/Sarpanch or general decision in a simple meeting? What will happen if the present PRI body denies the proposal and the newly elected body after one or two years will accept the proposal? Watershed-oriented works have proved their clear-cut utility in the country for generating prosperity of natural resources and agricultural production while reducing the erosion hazards to land. No wise person can deny the Watershed works in their area. So, this parameter has little weightage in the present scenario, and everywhere, willingness is almost the same. Moreover, we cannot leave watersheds to be selected on behalf of the non-acceptance of one or two villages.

Proportion of Scheduled Castes/Scheduled Tribes: This parameter will remain partially subjective if good quality digitised, georeferenced mosaic of all village revenue maps with attributes like ownership details (SC/ST/General) superimposed with georeferenced watershed boundary are not available. To support this statement, it is essential to understand the interrelationships between the village area and the Watershed, as shown previously. While the village is an administrative unit, the Watershed is a geo-hydrological unit whose ridge lines are delineated by man but created by nature. Any watershed has few villages covered fully by watershed boundaries. Rests of the villages remain partially covered in watersheds. In that case, two possibilities occur one where the actual settlement of the village is inside the Watershed and the second where the actual settlement remains outside the Watershed's boundary. Instructions are required to calculate the population of SC/ST in both cases. The use of GIS maps is highly required to arrive at a conclusion.

There are two types of practices in these fields. In the first easy method, whichever village is covered in the Watershed partially or entirely, the whole census population of SC/ST for that village is assumed to contribute to calculating the total SC/ST population. In the second way, the percentage of village areas coming partially under the Watershed is approximated, and the SC/ST population census is calculated based on that percentage. However, in both cases, how many actual farm fields of SC/ST fall under the Watershed will be a question. To make things simpler, instead of population, we can convert the parameter to the area as 'Percentage of land belonging to SC/ST'; otherwise, subjectively, we can say 'Preponderance of SC/ST lands' because general farm mutations have many owners for a single plot having small-small portions of that parcel in their name. Converting the population to area parameters will also remain helpful in GIS mapping because area calculation is easy and reliable.

The area of the project should not be Covered Under Assured Irrigation: The guideline needs to instruct about watersheds having partial coverage under assured irrigation. Sometimes, watershed areas have partial land under assured irrigation. In that case, judicious use of topographical sheets and GIS maps, with details of the area under assured irrigation, can help identify such areas. The rest of the area can be treated under watershed programmes. The patwari (village revenue official at the local level) can help in the clear-cut demarcation of areas not to be included in the project.

Productivity Potential of the Land: This parameter has interrelationships with many parameters. Some are directly related to productivity, such as soil type/texture and depth. Others may indirectly affect productivity, such as sediment yield, erosion intensity, drainage density and slope. This parameter fully matches the prime objectives and basics of watershed development. Quantification may be difficult, but we can come to a fair conclusion with little approximation. Using complex formulas or conclusions based on local area knowledge and topographical sheets with other available maps will yield almost the same results. It is better to use a simplified formula if unanimity and sufficient data/software are available.

Use of Scientific Methods/Formula/State-Specific Models

Those formulas, which were developed for the specific needs of the departments, for the large area watersheds like RVP and FPR catchments should be tested and simplified by the scientific community for implementation with small areas like micro watersheds. States must also get their formulae developed/modified based on scientific experimentations to conclude the production potential of the micro watersheds or erosion intensity of the Micro watersheds. This exercise may give some additional scientific factors to be considered as a basis for prioritisation. The exercise should be at the state level or at least the district level so that uniformity can be maintained at least within the State or District.

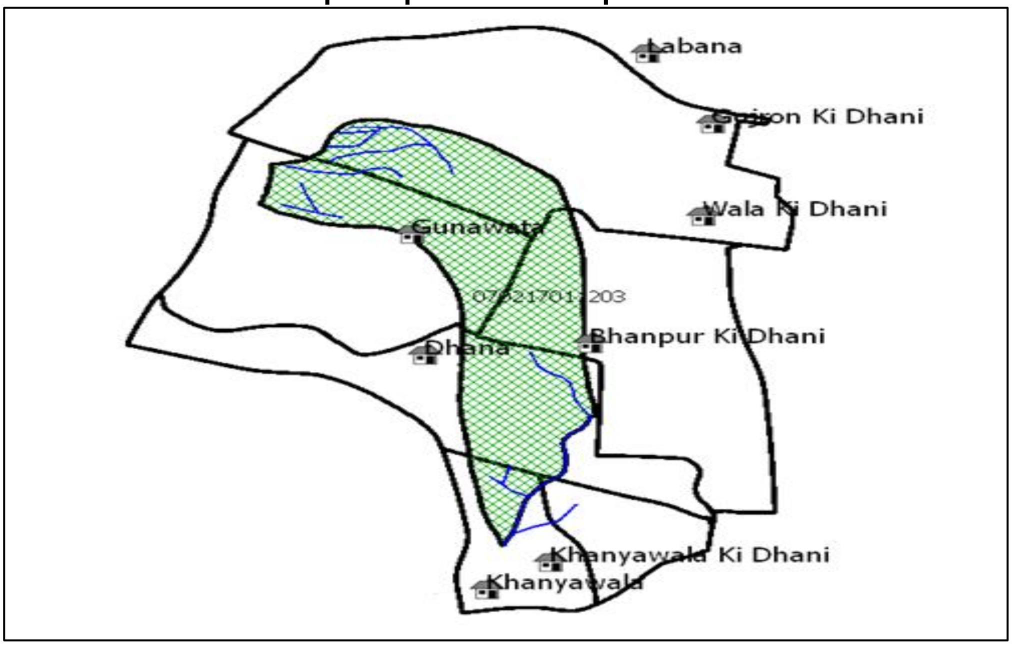
Association and Weightage to Various Factors/Parameters

The process should be standardised and defined at the state or district level, and all the parameters may be given weightage. Where subjectivity is included and clear-cut quantification is impossible, we can divide the parameters within the very high, high, moderate, poor, and very poor limits. We can give them numbers and percentage values, and finally, we can associate them with contiguity to the ongoing or completed Watershed. SC/ST population, the severity of erosion, and the preponderance of wasteland/degraded land deserve the high priorities/weights to be considered for the selection process. The whole procedure/responsibility of watershed prioritisation/selection should be allocated to one agency in the hierarchy, like Block (PIA), District (WCDC) or State (SLNA), preferably to SLNA. Once the priority is finalised or the watershed selection procedure is done, it should remain final or non-challengeable. As the procedure involves some subjectivity, without firmness or clear circular/instructions, anybody can question field workers.

The Challenge of Non-Overlapping Village and Watershed Boundaries

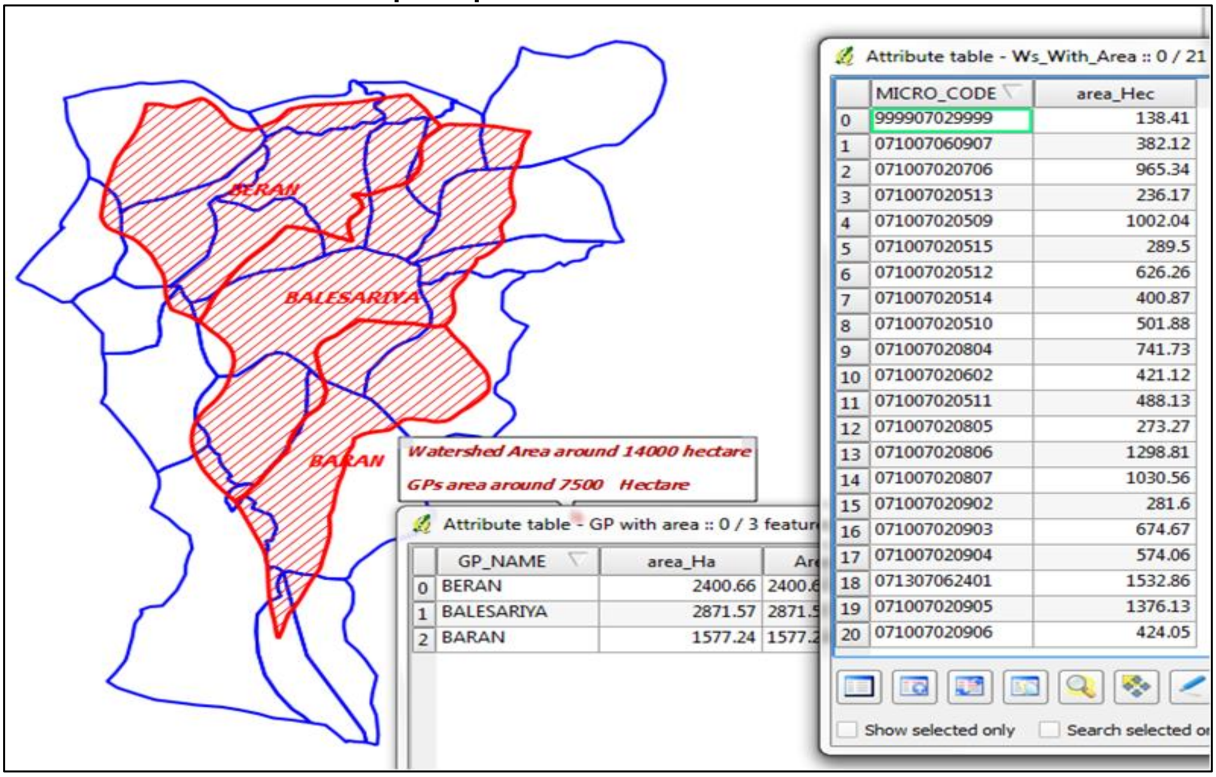
In MGNREGA and Watershed schemes, at the micro-watershed boundaries, the non-overlapping administrative boundaries of villages and Gram Panchayats with watersheds create a challenge at the execution level. This phenomenon can be understood in some cases, as given below. An illustration below helps see the pattern of the actual interrelationship between Watershed the watershed and surrounding villages. This is a map for showing micro watershed code no. 070217011203 of Amer Block in Jaipur District of Rajasthan:

Figure 01: An example of Village and Micro Watershed Boundary Superimposition of Jaipur District



The Watershed has an area that includes a total of six villages. Many villages have areas inside, but actual settlements are falling outside. Only two village settlements are near the Watershed's ridge line. Seeing the village/watershed area relationships, we need to reconsider the willingness of village community points. Similarly, as shown in Figure 2 below, the three-gram panchayats of the Bera block of Bhilwara districts of Rajasthan cover 20 micro-watersheds, partially or fully. This challenge becomes severe when the executing agency and area jurisdiction is Gram Panchayat, and the work is to be performed on a watershed basis while taking care of the ridge to the valley, like in the MGNREGA scheme.

Figure 02: An example of Gram Panchayats and Micro-Watershed Boundaries Superimposition in Bhilwara district



Seeing this, a new term, Micro Surface Water Management Unit (MSWMU), was coined in 2021 with a case of the boundary of the National Institute of Rural Development and Panchayati Raj (NIRDPR), Hyderabad, India, as an administrative boundary and the area was divided into seven MSWMUs based on the natural flow of water as per ridges, slopes and drainage lines. As these units do not fall under the strict definition of Watershed and are a mix of administrative and natural boundaries, the definition of MSWMUs was given as follows;

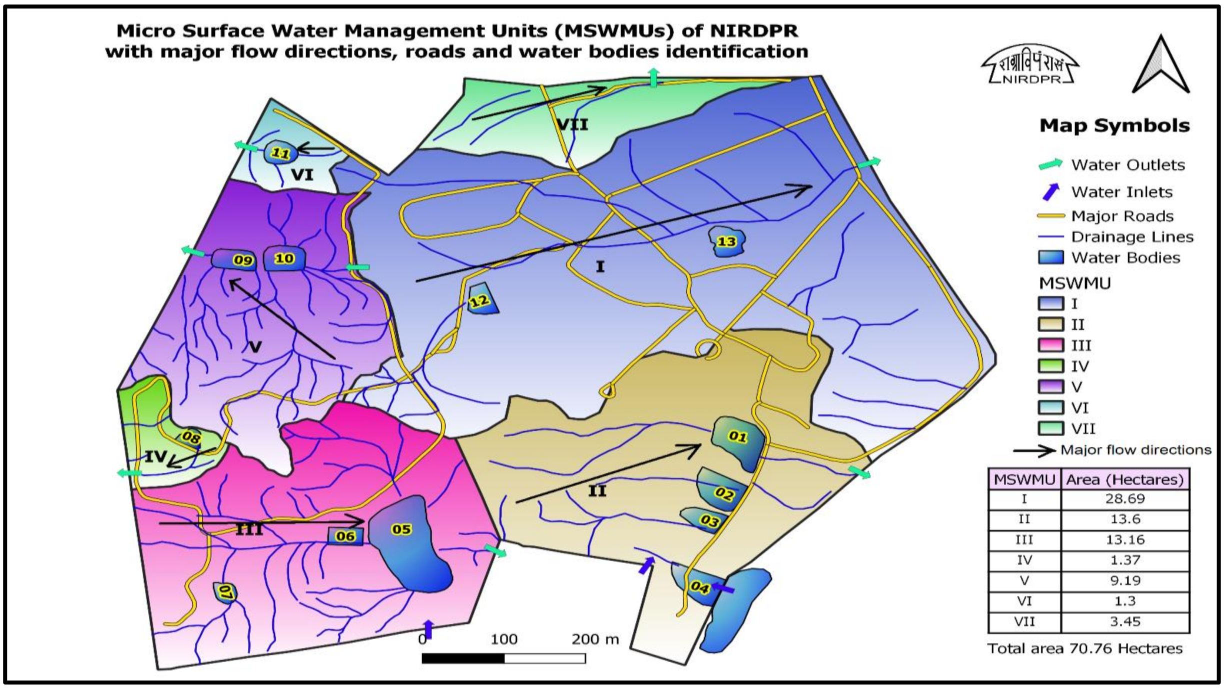
> "*Geo-hydrological area sub-units delineated based on natural slopes, flow directions and ridge lines within administrative areas where area boundaries do not coincide with watershed boundaries. Apart from having precipitation within the boundaries as a primary source of surface water, these area units can have surface water inflow from contiguous areas through drains/inlets" (Solanki, 2021)*

These units are essential for adequately implementing INRM works under administrative boundaries like Gram Panchayats. However, precise contour maps, Digital Elevation Models of higher resolutions and accuracy, field verifications and people's participation are necessary for further dividing the area in MSWMUs, especially in plain terrains and areas covered with trees. The map of the seven MSWMUs within NIRDPR is shown in Figure 3 below.

Role of PRIs and Local Public Representatives in Selection/Prioritisation

It will always be good to confidently take PRIs and local representatives when the final watershed prioritisation or selection is done. Lack of this factor sometimes may cause significant difficulties as the watershed development is entirely a community-based programme.

Figure 03: Seven MSWMUs Divided under the Administrative Boundary of NIRDPR based on Watershed Concept and Contour Lines



Conclusion

Prioritisation and selection of watersheds for treatment are primary concerns, and prioritisation should be done correctly to avoid selecting the wrong areas for treatment. Moreover, wrong interpretation/delineation of watershed boundaries may increase the quantum of error, and deserving beneficiaries may need more benefits from the schemes. Detailed instructions are required to decide the watershed selection parameters, considering the complexity of village and watershed area inter-relationships, considering that both never superimpose on each other completely. This complexity can be solved by the enhanced use of modern technologies like GPS/GIS/Remote Sensing along with matching scales of maps and a participatory approach to exploit local wisdom. Open-source software and data may play a crucial role in this regard.

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