Confronting scale in watershed development in India

Geoffrey J. Syme · V. Ratna Reddy · Paul Pavelic · Barry Croke · Ram Ranjan

Abstract The issue of scale is examined in the context of a watershed development policy (WSD) in India. WSD policy goals, by improving the natural resource base, aim to improve the livelihoods of rural communities through increased sustainable production. It has generally been practiced at a micro-level of less than 500ha, as this was seen to be a scale that would encourage participative management. There has been some concern that this land area may be too small and may lead to less than optimal hydrological, economic and equity outcomes. As a result there has been a move to create guidelines for meso-scale WSD of above 5,000ha in an endeavour to improve outcomes. A multidisciplinary team was assembled to evaluate the proposed meso-scale approach. In developing an adequate methodology for the evaluation it soon became clear that scale in itself was not the only determinant of success. The effect of geographical scale (or level) on WSD is determined by the variation in other drivers that will influence WSD success such as hydrological conditions, land use and available institutional structures. How this should be interpreted at different levels in the light of interactions between biophysical and socio-economic scales is discussed.

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Introduction

In this paper the issue of scale is examined in a watershed development (WSD) policy environment that has operated for some30 years in India to improve the livelihoods of people in the rainfed areas that extend over the greater proportion of the country. The WSD policy has clear goals in terms of improving the natural resource base and increasing sustainable production through the creation of a host of physical structures designed to capture and retain water resources and minimize erosion. It has generally been practiced at a micro (i.e. village) level of less than 500 ha, with prioritisation of treated areas based upon a range of factors that include the level of land degradation, degree of groundwater stress, coverage of "scheduled cast' and "scheduled tribe" households, location in relation to the ridge and valley and the availability of drinking water. Consequently, not all areas within a catchment can be covered. Further, there has been some concern that this land area may be somewhat too small and may lead to less than optimal hydrological, economic and equity outcomes. Therefore it has been suggested that the area of application of WSD should be increased. As a result, guidelines have recently been created for meso-scale WSD of above 5,000 ha in an endeavour to improve the outcomes for WSD while creating implementation efficiencies. Perhaps the most significant motivation for this change has been increased efficiency in terms of administration (Government of India 2008).

In moving from a micro- to meso-scale of WSD, the key issue of evaluation of meso-scale WSD was initially approached primarily as one of "scale". The issue of scale has been of ongoing interest in hydrology for some time (e.g. Bergstrom and Graham 1998; Klemes 1983; Merz et al. 2009; Sivapalan et al. 2004). As the study has developed, however, it has become necessary to become much more precise about what scale means when pragmatically evaluating WSD in the context of clear socio-economic goals. This paper describes the background to WSD and the conceptual issues associated with scale when endeavouring to evaluate the potential

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outcomes of meso-scale WSD programs and their significance from a design and implementation perspective.

Before specifically addressing meso-scale WSD, it should be noted that while scale is commonly used and understood to reflect the reach or size of land area that is under consideration, Gibson et al. (2000) have distinguished between the concepts of scale and level. Scale is referred to as describing the nature of what is being measured. In this case scale would refer to the qualitatively different realms of hydrology, land use, livelihoods and equity. Level relates to the breadth of the dimension. For hydrology the level units could be, for example, basin, sub basin, meso and micro. For equity, level could be represented as perceived fairness of WSD among groups within villages, the level of personal investment in time or money in WSD, the degree of deservingness as measured on current income, relative outcomes for land owners versus landless and so on. Thus, there may be multiple dimensions and levels within one scale; therefore, this paper deals with both scale and level in terms of their integration to provide a sustainable and resilient WSD program.

Conceptually the issue of dealing with levels has been well discussed. The ultimate unit of hydrological analysis is seen to be the catchment level, whilst the unit for hydrogeologic analysis is at the basin or aquifer boundary level (for limited cases they may coincide). The components of the surface water or groundwater "catchment" should be managed to avoid negative externalities (or spillage) on their surrounding areas either in terms of water quality or quantity, livelihoods impacts, or, as far as possible, preferred land use. It must be noted, however, that the size of some groundwater systems may make this impossible in practice.

Ideally, institutions should also be fundamentally based on the catchment level with appropriate formal and informal structures at matching levels with the WSD implementation (e.g. Lee 1993; Scoones 1999; Folke et al. 2007; Dore and Lebel 2010). This institutional functioning is not restricted to formal and informal group entities but includes those rules which govern how the catchment is managed (Olsson et al. 2007). The issue that this evaluation has had to face is that the program has not been developed on a catchment basis and the implementation of the program has been often on a prioritised basis with little bearing of the constraints within the catchment. At a whole-of-catchment level there is the hope that the benefits arising from WSD will diffuse from the programmatic sites to others who through observation will see the benefits of WSD.

There are also other issues which make the simple hierarchical approach difficult in the view of some. In hydrology some favour a "bottom up" approach in which water flows are modelled from an initially small scale outwards, whereas others prefer to start at a catchment level and hierarchically scale their modelling down to the area of interest. Needless to say the micro-approach does not necessarily lend itself to simple upscaling to the macro level and the statistical approaches at the macro level do not necessarily scale down to the micro-level given the variability and non linearity that is so evident at that scale. Nevertheless there has been some progress on this problem (e.g. Viney and Sivapalan 2004; Savenije 2009).

In addition, level is among a number of things that cannot be viewed in their own right for sustainable water management. Hydrological processes depend on level of rainfall, soil type, slope, land use and specific groundwater/surface-water interactions, amongst other things. Thus the area of land chosen for WSD policy needs to be considered as only one of a number of interacting variables if the application is to make hydrological sense. If these relationships are not considered there is no automatic reason to consider that a meso approach will lead to better results than a micro-approach. Further, many hydrological processes are non linear as are the impacts of WSD itself, which, are in-part, a function of those processes. Not only are they non linear in a spatial sense but the externality effects of interventions such as WSD take time to emerge so that there is a need to also consider the temporal aspect. Similar arguments can be made in relation to economic, livelihood, equity and resilience issues. How then should one confront the issues and interactions between scale and level when designing and evaluating WSD delivery in an integrated manner?

Background to WSD and its evaluation

WSD rationale

The watershed management approach has emerged to deal with the complex challenges of natural resource management. Watersheds consist of areas of varying sizes, as small watersheds are part of large watersheds that themselves can be located within larger watersheds up to entire river basins. Review of the literature on this aspect indicates that discussions on watershed management vary from 2 ha (White and Runge 1995) to 30,000 ha in size (World Bank 2007). Though a watershed can be defined at different levels, international practice reveals that the micro-watershed has usually been the chosen level of implementation for watershed management. This level facilitates a program to act in response to human needs and natural resource problems at the local level.

Watershed management at micro-level (500–1,000 ha) has been demonstrated to be both ecologically and institutionally sustainable and capable under the right conditions of empowering vulnerable segments of the society (Farrington et al. 1999). The micro-watershed approach enables amicable integration of land, water, and infrastructure development, particularly because of the homogenous nature of soil, water, and overall physical conditions within the micro-watershed. Theory and experience have shown that small village-level watersheds, because of their ongoing social cohesion, are conducive for promoting the collective action that is critical for watershed management. Moreover, collective action at the micro-watershed level has generally proved to result in *lower costs*, through efficient use of financial and human

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resources, particularly for the management of common resources. As a result watersheds with active participation are also found to be performing better than others.

Evaluating micro WSD from hydrological and social perspectives

However, the micro-watershed approach encounters problems when it comes to up-scaling. Operating at the micro-watershed level does not necessarily aggregate or capture upstream–downstream interactions. Watershed management projects are generally anticipated not only to provide local on-site benefits at the micro-watershed level, but also to offer positive or negative externalities in the form of valuable environmental services or disservices downstream. They can also provide a means of correcting downstream negative externalities within the larger watershed. Therefore, investment in upstream areas cannot be justified by their on-site benefits alone and can only be justified in an economic sense when downstream benefits–disbenefits are embodied (e.g. Oates 1972; Ostrom 1999).

However, watershed management programs have usually paid attention to on-site interventions and their benefits. Whether these actions were of benefit also to the downstream location or were the best possible approach to minimizing negative externalities was often not ascertained. Similarly, stakeholder involvement and participation normally covered on-site requirements of local farmers, and the spatial dimension was tackled through community-based planning of their region. The WSD institutional approach only focused on the micro-watershed, with no conscious attempt to create cooperation across the watersheds or between upstream and downstream populations. The success of the WSD project was assessed on-site, and the individual level outcomes (income increase, land area treated, yield increase) were, in general, aggregated across the watershed area.

Despite their apparent objective of improving natural resource conditions in a watershed, WSD programs may improve the conditions in one place (on site) at the cost of resources in the downstream areas. Research has revealed that the micro-watershed approach may result in hydrological problems that would be minimised by operating at a macro-watershed level. For example, in India, recent hydrological research cautions that watershed projects may be aggravating precisely the water scarcity they intend to overcome. The study by Batchelor et al. (2003) reported that capturing water in upper watersheds came at the expense of lower watershed areas. On the basis of the data from macro-watershed level (covering many villages), they document cases where water harvesting in upper watersheds reduced water availability downstream. With the lowering of the water-table downstream, deepening of wells was needed, which the poor could often not afford, leading to inequitable distribution and use of water (Calder 2005). Calder et al. (2008a) cites this as “catchment closure”, whereby water harvesting upstream accumulates groundwater locally and then intensive pumping depletes the shallow aquifer.

The closure of catchments may also occur at the regional level such as for the Krishna River Basin in southern India (Biggs et al. 2007), whereby WSD is one of a number of factors for diminishing coastal outflows. In this case, watershed development checks the movements of surface runoff downstream that may be transferred to the groundwater system where downstream migration may or may not be constrained. It indicates that hydrologically what is good for one micro-watershed can be bad for others downstream. Thus, whereas addressing social and economic considerations favours small micro-watersheds as the unit of operation, approaching this hydrological problem calls for working in large macro-watersheds.

Society and administration

While successful WSD projects have overcome the inherent constraints to collective action through mechanisms such as obtaining commitment through private contributions to infrastructure development, localising rainfall and groundwater data collection and interpretation, and enhancing the inclusiveness of local water user groups, they have not conquered two outstanding barriers. First, projects with high investment in social organisation may not be replicable beyond a small number of cases. Second, operating on the basis of a feasible social unit (a village micro-watershed instead of a macro-watershed that crosses administrative boundaries), in fact, trades one set of problems for another. This would involve working simultaneously to promote watershed governance capacity both within and between micro-watersheds. However, there may potentially be difficult tradeoffs between these two approaches. For example, production benefits enhanced by WSD at the village level may need to be curtailed if a wider perspective is adopted. Changes in reliability of water supply may also occur differentially between micro-watersheds. Resolving the tradeoffs is necessary for the widespread success of the watershed development program but there are no obvious solutions. The difficulty of managing watershed interventions at diverse levels so as to achieve the larger-level objectives of downstream impacts is further complicated because of participatory approaches, which basically give the option of interventions to the communities rather than the planners (Reddy et al 2004). While there is significant literature examining a wide range of coordinating mechanisms, including property rights formulations, market mechanisms and social agreements for collaboratively based management, in the Indian context (e.g. Ebrahim 2004) these have yet to be applied at various scales in the WSD context.

Basically WSD management is critically dependent on ecological/environmental and social aspects—ecological/environmental because the technology per se strengthens the resource base and hence the environmental benefits have the potential to be greater when watersheds are implemented in a holistic manner (i.e. covering the entire watershed, which is often very big in scale). This is beneficial in the long run and also helps environmental

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sustainability and, hence, resource dependent livelihoods. Nevertheless, the ability to do this depends on the successful development of integrated institutions often at a regional level and sometimes across political boundaries.

Social aspects arise as watershed management transcends across households, communities or villages covering both private and public (common) lands and water bodies. Inter household/community/village coordination or cooperation is necessary for successful implementation and management of watersheds. As a result collective action and participation of communities has been treated as mandatory and become part of the guidelines since 1994. The theory of collective action suggests that the smaller the group the greater the chances for collective action or cooperation—e.g. see De Groot and Tadepally (2008) for an Indian perspective. That is, while micro-watersheds have achieved the much needed participation, to a large extent the environmental gains have been limited due to the limited coverage. Nevertheless, such an assertion may be too simplistic for meso-level WSD as there is still the possibility of shared values through similar socio-economic and cultural status (e.g. Brown and Purcell 2005). Huchtemann and Frondel (2010), for example, have suggested a settlement clustering pattern for identifying compatible social units on the same catchment with similar environmental conditions to create efficiency in trans boundary water management.

As the shift from micro to meso-scale is taking place, there is tradeoff between environmental impacts and social or institutional requirements. Generally it is thought that enhancing the match between the hydrological, social and institutional scales of operation will enhance the effective governance of the catchment. In framing the appropriate scale for adaptive governance, Cash et al. (2006) suggest that there is a need to deal with the hierarchy of constitutions (institutional scale), the levels of engagement (network scale) and the linkages between general and specific knowledge (knowledge scale). These three considerations will be pre-eminent when considering evaluating the meso-scale.

With the new meso-approach, there is potential for significant efficiencies to be made by ensuring that WSD funds are invested in ways to achieve better outcomes by considering meso-level issues. However, there is little economic analysis to underpin this. Moreover, often the wide range of technical interventions utilised in watershed development may not always be the most appropriate or effective measures. In addition, often, serious equity issues arise out of water harvesting benefits being realised in one part of the watershed by one group of farmers, and those who may not necessarily have access to the increased surface water or groundwater resources in another part of the watershed. Equity issues have to date not been satisfactorily incorporated into assessment of WSD.

Internalising externalities

One of the most important characteristics of watershed management is the ability to improve the management of externalities which generally emerges because of land and water interactions. There exist a number of approaches to "internalizing externalities"—that is, compensating those who generate positive externalities and taxing those who cause negative ones. These approaches include attaching the adoption of conservation practices to other benefits such as access to credit (Pagiola 2002), and practices like cost sharing—full subsidy to the cost of adoption, or partial subsidy. Investment subsidies, particularly cost sharing, have been the most frequently applied procedures. However, one study on the Indian experience observed investment subsidies to be the least effective mechanism (Kerr et al. 2007). Experience also suggests that subsidies, if not sustained, do not realize long-term changes in conservation practices. Once the projects end and the subsidies cease, land users have often resumed their previous land uses where they disregard the conservation measures they had adopted, or even actively destroy them (Lutz et al. 1994).

In order to avoid the apparent problems of a "compensation" approach, watershed management programs also resort to a variety of nonfinancial approaches to persuade stakeholders to adopt the recommended conservation practices. While some have recommended to provide alternative income generation activities to compensate for lost income because of conservation practices, some have relied on a hoped-for "demonstration effect"—assuming that conservation practices could eventually demonstrate their usefulness to stakeholders who would approve them of their own accord once their benefits had been established (Pagiola 2002). Others have employed approaches such as awareness generation, moral obligation and regulatory limits and fines. Generally these approaches have not proved effective (Enters 1997; Pagiola 1999). The alternative income-generating activities approach has had mixed results; the demonstration effect has often failed because the assumption that conservation practices were lucrative to upland stakeholders was often not the case. Regulatory approaches are often very difficult to implement and may entail high costs on poor land users by forcing them to adopt land uses that generate lower returns.

Apart from the aforementioned approaches, market-based contracting approaches—payment for environmental services (PES)—have also been used in some cases, particularly in Latin America in small-scale initiatives involving water services. Presently, several countries are already experimenting with such systems (Landell-Mills and Porras 2002). The basic principle behind such approaches is that those who supply environmental services should be compensated for their service and that those who receive the services should pay for their provision. This approach has the added advantage of providing supplementary income sources for upstream poor land users and, thus, helping them in improve their livelihoods. In most cases, although a PES approach is apparently attractive, putting it into practice is far from simple. Application of these approaches requires the presence of several building blocks (Pagiola and Platais

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2007) and systematic evidence and scientific information for designing appropriate policies.

Institutional issues

Harmonising upstream activities with management objectives at the broader watershed level is obviously a major challenge as upstream–downstream linkages are multifaceted and the information essential to understand the interactions has, until recently, proved complicated and costly to accumulate. However, development of dynamic modelling at the basin level coupled with more affordable monitoring tools such as remote sensing, allows for enhanced understanding of watershed properties with better capability to define upstream–downstream relations, functions and management impacts. Moreover, if watershed management is to be justified by its beneficial impact on the downstream environment, institutional arrangements are needed to endorse interaction among micro-watershed groups at the meso-level within large macro-watersheds, and to determine and monitor outcomes and impacts. It could involve specific mechanisms to facilitate the interaction such as new legislation or new arrangements for sharing upstream-downstream costs and benefits. A variety of institutional mechanisms exists, from simply maintaining an information system that identifies externalities, through the formation of platforms for dialogue between upstream and downstream communities, to building higher-level watershed planning institutions. Preferably, the institutional framework should be capable of incorporating the micro-watershed management plans through meso-plans to the broader scale of the watershed as a whole (Reddy et al. 2010). This would involve developing something like a "nested platforms" approach at a macro-watershed scale.

The important question regarding the tradeoff between operating at a hydrological level which is sustainable versus a social level that is perceived to be equitable between key groups and interests is its intractability. In the early days of watershed projects, disregarding the values and functioning of the social unit resulted in failure of the projects as they could not accomplish effective watershed governance. Of late, the pendulum has swung in the opposite direction and now most projects operate at the village level, disregarding hydrological linkages between micro-watersheds. The downstream effect in general, with catchment closure as an extreme manifestation, has appeared in part by overlooking these hydrological linkages, and it illustrates the need to deal with them by working at a broader scale.

Integrating hydrology and livelihoods

Scale issues become even more complicated when the focus shifts from bigger (ultimate) scale to the smaller scale. Technically, the river basin or complete watershed level is the ultimate one where interactions of various systems and impacts can be modelled to a large extent. Importantly, the availability of data at that level is generally not a constraint. At the next (second) level down, there is the sub-basin or sub-watershed level. Some aquifers could be big enough to fit this level. At the third level is the meso or mega watershed level or the aquifer level. The experience of this study clearly shows that no two systems are coterminous at this level, i.e. the boundaries of meso watersheds do not match with aquifer boundaries at this level, and hence it is difficult to assess the surface and sub-surface flows and the trans-boundary problem may need to be considered. Lack of availability of technical data at this level is also often an issue.

While it is a challenge to characterize the surface and sub-surface flow processes reasonably well, making generalisations of such outcomes could be more challenging, if not impossible. From a surface-water hydrology perspective, level is not necessarily the primary issue—as processes can be modelled at whatever level is needed. Sometimes there is a need to model at a finer level. This often means that there are not appropriate gauges available for calibrating models, leading to the need to make predictions at ungauged locations. This may be relatively easy if there is a suitable gauge nearby. If not, the uncertainty in the model predictions increases (e.g. Bardossy 2007), and this needs to be allowed for in any output from integrated modelling required for holistic evaluations of WSD.

There is a problem when the social and economic units do not line up with hydrological boundaries. From a hydrological viewpoint, modelling part of a catchment is possible, though it can lead to complications, and increased uncertainty. For example, one of the simplest methods is to add the effective rainfall from each watershed or HRU (hydrological response unit), and then convolve this with the unit hydrograph for the point in the stream network we are trying to model. A more complex method is to route the water through the river network—mostly using a lag-route method. Muskingum-Cunge methods can be used but these introduce some undesirable characteristics. From a groundwater perspective, it is more common than not that only part of an aquifer is modelled, but it relies on having enough information to set the necessary boundary conditions. If the social/economic level matches with the hydrologic divides then more meaningful results can be achieved. It is also argued, at the conceptual level by some hydrologists, that, *all other things being equal*, both micro and meso scales may have the same effect on the gross water balance for the watersheds

A strategic "whole of catchment" approach

Having discussed the scale and level related issues in detail, it would seem that there is scope for using a top down, whole-of-catchment approach for strategically assessing the available water resources and those already reserved for the various anthropogenic uses. The environmental water requirements can then be identified. On the basis of this information, allocation strategies can be

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developed at the sub-catchment level. This, in turn, gives rise to the type of configuration of WSD that may be beneficial at a whole-of-catchment level to encourage the best long-term uptake given that there is unlikely to be enough investment to cover the whole-of-catchment. Once this is done, the significant meso and micro-scale issues can be canvassed.

For example, one conceptual approach to contribute to assessing distributed WSD at a strategic level over a catchment would be a “checkerboard hydrology” approach. Figure 1 shows two mega watersheds side-by-side with contrasting WSD configurations.

In this representation, each cell represents a micro-watershed, with a group of 10 or so equivalent to a meso-level watershed. One of the mega watersheds is treated at the micro-level; the other at the meso-level. The extent of treatment (just 10% in this case) is the same for each; only the distribution of treated areas varies. The key points from the checkerboard are that:

– Treatments at both micro- and meso-level have the same effect on the gross water balance at the mega-watershed level. Both increase local groundwater recharge at the expense of reduced surface-water runoff and surface-water storage, relative to the case of no WSD.
– Upstream and downstream effects occur in both cases; however, for the micro-level they are more distributed and localised, whereas at the meso they are more focused and obvious. In some parts of the system, there is no difference between the two systems (e.g. surface - water storage or head reaches of the watershed).
– WSD attributes such as the extent of storage, the distribution within the treated watershed, effectiveness of performance of treated areas, are as important as if treatment occurs at micro or meso-levels. Other scales not easily represented on the checkerboard, like type and quality of treatment, soil type, soil depth, geology, rainfall pattern, effectiveness of performance of treated areas and so on, are also important.

Regardless of the gross simplicity of the checkerboard approach, it leads to the possibility of assessing desirable levels and distribution of WSD activities at a whole-of-catchment level. While the whole-of-catchment model may have some degree of error it would provide a template for consideration of strategic issues such as potential diffusion of WSD for different configurations as well as transaction costs for required institutions for differing configurations of WSD.

The approach points to the need for integrated tools to aid planners and policy makers to develop robust and more equitable WSD programs. Such tools have been developed in the past (Calder et al. 2008b) for the micro-level. These could be extended to the meso and perhaps macro levels. Potentially, the information obtained from such an analysis could be valuably applied in the context of the general clustering approach suggested by Huchtemann and Frondel (2010).

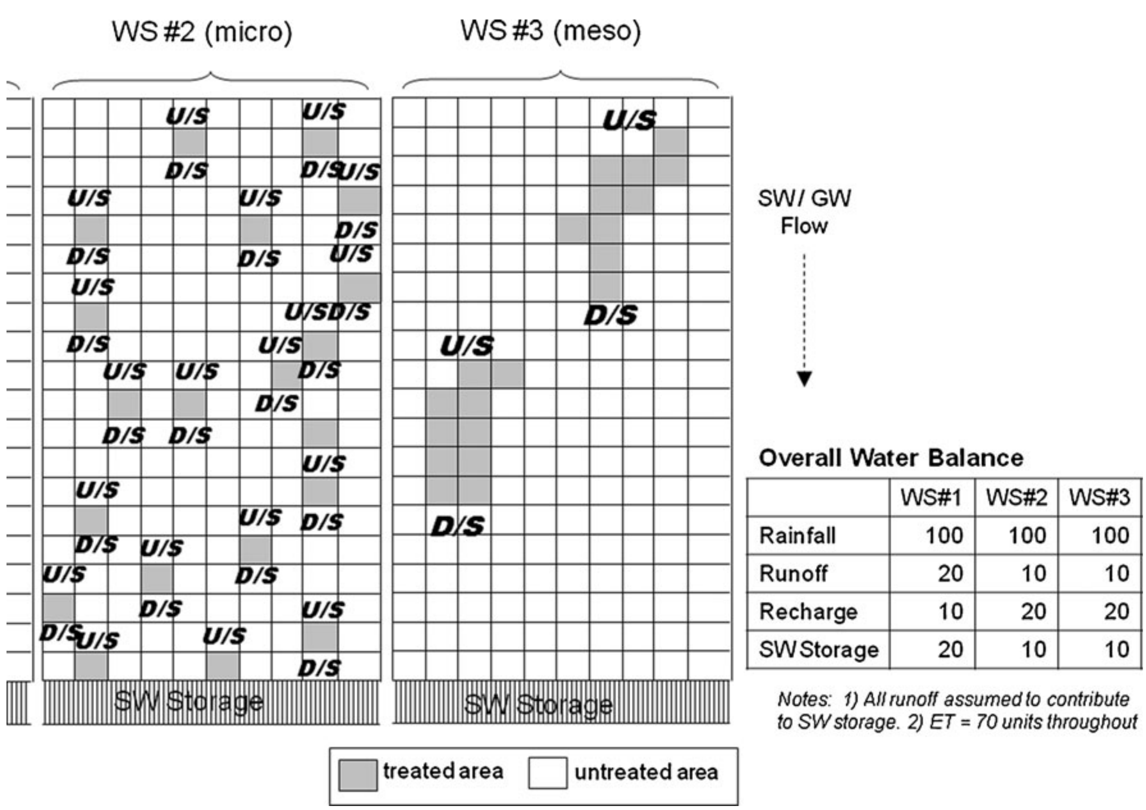

Fig. 1 A checkerboard approach to distributing WSD activities on a catchment. This illustrates three mega-watersheds: one without any WSD, one treated with WSD at micro-level, and the other equally treated at the meso-scale. Overall, water-balance values are expressed in percentage terms

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Incorporating the wider socio-economic catchment context

Managing a meso-level watershed brings up socio-economic issues of a different nature than those faced at micro-watershed levels. While farmers are aware of the role of politically dominant groups upstream in influencing water availability downstream, such iniquitous interventions are mostly assigned to fate and ignored at a micro-level approach. Managing meso-level water sheds from a top down perspective presents the opportunity to rectify some of these inequities through external interventions and, more importantly, presents scope for examining alternative institutional arrangements amongst upstream and downstream water users. Another social benefit of a meso-level approach is the opportunity to evaluate presence of persistent patterns of inferior livelihoods amongst the backward groups of the society that cut across smaller village-level boundaries.

Economic implications of management interventions also differ when applied at meso and micro- levels. First, meso-level interventions are better able to harmonize sustainability of rural livelihood with that of groundwater sustainability. At a micro-level, village level heterogeneities may disguise wider patterns present across a much larger level. For instance, presence of significant seasonal migration and concomitant remittances in a water-starved village might present a picture of a sustainable livelihood, whereas in reality, depleting groundwater and the vagaries of urban demand for rural labor could actually be increasing the vulnerability of such villages on a longer time frame (or level). Secondly, it is much easier to direct social development efforts such as formation of cooperative societies, through economic incentives in drought prone villages, once their increased vulnerability has been identified in the larger watershed region. This, however, does not imply that micro-level interventions are any less desirable. In the absence of any distortions, efficiency in allocation of resources at a household level is achieved best when individuals act in their self interest, maximizing profits. However, the common property nature of groundwater resources requires inducement towards collective actions so that challenge of a lack of well-defined property rights is mitigated. The issue of scale in watershed management, in light of the aforementioned, should not be perceived as one of the contradictions between micro and meso-levels, but rather as an opportunity to exploit the best outcome through their simultaneous management.

Discussion and conclusions

In the attempts to evaluate the potential effects of differing scales and levels, it was concluded that the geographical “scale (or level) issue” in WSD is reflected by the variation in drivers associated with level outcomes, not the scale or levels themselves. The hydrological scale issue relates to where and how much of the water in the system is intercepted, as well as the interaction between groundwater and surface water, e.g. at what point does the extraction of groundwater unduly affect surface-water flows (again, level is not the driver, it is just correlated with the driver). Similarly, other factors such as land use, social and institutional commitment to WSD and the maintenance of water-retention works also influence this.

It was also concluded that the meso-level is reflective of the tensions between macro-level and micro-level. There are no definitive stand alone “meso” measures currently available. Hydrology can be used at a macro level to provide a plausible plan for the distribution of WSD, whether at the micro or meso. It can also identify the potential influence of that distribution on water availability and the likelihood of dissemination of WSD given that the whole catchment is unlikely to be covered.

Social and economic data are either collected at the macro-summary level or typically through interviews with individuals at a micro-level and then aggregated for meso interpretation. Thus meso-level WSD will be evaluated with a combination of macro and micro-level data. As such, the research challenge that this study originally set itself, of using the meso-level evaluation to recommend the “best” level of WSD implementation, is unlikely to provide a precise answer.

Not only extent of area for WSD but also the quality delivery of the program will also be important factors. It must be acknowledged, however, that geographic area or level may have a significant impact on the ability to deliver, if there are insufficient resources or inappropriate institutional structures for that level. It is unlikely that meso-level intervention will sit seamlessly on overlapping ground and surface-water catchments, especially if WSD is designed to coordinate with administrative boundaries for efficiency. In this case, the institutional scale and level become highly significant in governing WSD outcomes. Research has also shown that above micro-level economic incentives or voluntary action may have many challenges. Regardless, without adequate consideration of the hydrology, an “institutions only” approach is unlikely to be successful.

The time scale and level is also important from the social and ecological point of view as the treated areas are expected (if managed well) to provide sustainable impacts over the longer term. How long would it take meso-level WSD (in a normal situation) to mitigate any negative effects of WSD structures and under what conditions (e.g. quantity of rainfall)? For example, studies have shown that impacts, including externalities, are more in the regions with above 700 mm rainfall. Water tables may rise if rates of recharge exceed extraction, which over a period of time could result in higher flows downstream.

It was also found that the social-science scale without hydrological input is not enough for a definitive evaluation. Often specific hydrological conditions will tend to influence social perceptions of equity or improved livelihoods. With research efforts usually limited to the collection of survey data from relatively few villages, errors in interpretation can occur if simple *WSD* versus *no WSD* comparisons are made to demonstrate the effectiveness of WSD. The issue of selecting a control *no WSD* village is also problematic in that it is hard to pick similar villages at a meso-level that are hydrologically, agriculturally and socially compatible.

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When considering the relative equity of different levels of WSD, it is also important to recognise that there is a tendency in India for people to more readily accept that water resources are unevenly distributed; that upstream and downstream areas are not naturally endowed equally in hydrological terms. Therefore there is a need to interpret WSD outcomes along with other programs that recognize this point and promote more equitable socio-economic outcomes. This is likely to be more evident with larger land areas and populations. As has been stated: "integrated water resources management is not integrated unless water related policy is integrated with wider socio-political contexts" (Skogen 2003).

This discussion has also demonstrated that changing the geographical area of WSD may benefit from evaluation against a strategic whole-of-catchment model to provide general guidance in regard to the investment of essentially limited funds. This could provide an assessment on the basis of broad hydrological data and an estimate of the hydrological efficiency of differing patterns and intensities of WSD at a catchment level. These patterns/intensities can then be assessed in a preliminary fashion from economic and social perspectives. The social evaluation will need to include consideration of the relative diffusion and resilience provided by alternative WSD spatial models. It must be noted though that the feasibility of doing this at this level is dependent upon basic factors such as rainfall, soil type and the non-linear effects of areas covered by WSD. For example, twice the geographical coverage may have more than twice the adoption impact for WSD practices. Diffusion of knowledge is likely to be compounded by greater visibility of WSD outcomes through media reporting and the perception by landholders that something "substantial" is happening, which could result in the activation of alternate and substantially wider communication networks.

From an integrated methodology perspective perhaps the hierarchical approach adopted by the European Union for river management may ensure that each of the levels have some conceptual linkage—see Vreudenhil et al. (2010) who use five levels for a river varying from river basin to eco-element to show how each fits into a discipline's natural level of thinking and how linkages may be created between each functional level. For the meso-WSD problem in India, one could adopt four levels (basin, sub-basin, meso and micro). Research on each scale (e.g. hydrology, land use, institutions, and equity issues) would be at its appropriate level, which would ensure that level gaps did not occur for each scale and that there was a perspective from each scale at each level. This may go some way to answering more definitively the issue of what scales or levels are "best" for what purpose. In using such a methodology, however, it must be noted that any re-scaling in WSD will require careful thought in terms of the actors involved and their changed power relationships and the requirements for fresh community-based institutions (Young 2002). In short, the "transaction" costs of change may become a major consideration (Birner and Wittmer 2004).

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