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Review of Agricultural Water Management Intervention Impacts at the Watershed Scale: a Synthesis Using the Sustainable Livelihoods Framework

Jennie Barron, Stacey Noel and Monique Mikhail

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ABSTRACT

Agricultural water management (AWM) interventions are increasingly being promoted as a first step to enable positive development, alleviating food insecurity and poverty in the smallholder farming systems that dominate rural sub-Sahara Africa and South Asia. Despite AWM interventions being high on the development agenda, little synthesised experience on intervention impacts is available. This review synthesises the experienced impacts and changes due to AWM interventions in 37 cases using the livelihoods framework. The cases were collected in open source documents (peer review literature, technical reports or personal communications) published after 1989. The cases represent various agro-hydrological conditions in Latin America (two cases), Middle East (one case), sub-Sahara Africa (9 cases) and Asia (25 cases).

In the cases, the most frequently-mentioned constraints for agricultural production and livelihoods were variable rainfall with droughts and dry spells, lack of domestic water and low yields. The most common AWM interventions were change in crop patterns, species a/o varieties (25 per cent of cases), often combined with direct water management interventions such as *in-situ* (soil conservation measures) (20 per cent of cases) and/or adoption of irrigation practises (15 per cent of cases).

The five most listed impacts due to the interventions were positive and related to all five capitals: increase in income (financial capital); on-farm yield output increase (natural capital); building user groups/ governance structure (social capital); improved water infrastructure (physical capital); and increase in skills and/or knowledge (human capital). In addition, cases with five or more AWM interventions had on average 20 per cent more positive changes listed than cases with only 1-2 AWM interventions.

The most negative impacts that were listed related to social in-equity and depletion of natural resources (water and/or land) for other users. However, in general, negative impacts or trade-offs were poorly assessed in the cases, leaving little scope for 'lessons learned'. Monitoring and evaluation of impacts in the individual cases was either poorly done and/or left out of the description.

There are two primary conclusions of this review: first, projects which applied multiple AWM interventions in a single location were associated with more positive impacts. Secondly, to fully acknowledge project impacts, assessment of multiple potential positive and negative changes in natural, social, and human capitals is sorely needed in addition to monitored changes in financial and physical capitals. Inclusions of these capitals both in monitoring and evaluation would improve cost-benefit and investment analyses for AWM interventions' impacts on poverty alleviation and environmental sustainability.

ACKNOWLEDGEMENTS

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We appreciate the contributions from individuals and organisations which helped us in identifying specific cases and providing documentation for this synthesis.

1 INTRODUCTION

Agricultural water management (AWM) interventions are increasingly being promoted as a first step to enable further investments for necessary productivity gains and yield increases in the smallholder farming systems that dominate rural sub-Sahara Africa and South Asia. These AWMs range from *in-situ* soil and water management improvements (conservation tillage, terraces, pitting) to supplemental and full irrigation systems, drawing water from a wide variety of sources in the landscape.

However, re-allocation of water, i.e. changing the spatial and/or temporal flow of water in the landscape, can potentially undermine other uses of the same water, for other livelihood purposes or, indirectly, by reducing availability for support of different ecosystem services (Batchelor *et al*, 2002; Shiferaw *et al*., 2008). In extreme cases, these changes can cause so-called shifts in resource availability, which may not be possible to restore. These changes toward undesirable productivity states have been described elsewhere as undermining social-ecological resilience (cf Gordon *et al*, 2008).

To date, there is little synthesised knowledge regarding how much AWM interventions can improve livelihoods in poverty-dominated rural areas in sub-Sahara Africa and South Asia. Despite the growing number of examples of significant changes in landscape water flows (notably reduced groundwater tables and decreased water quality due to agricultural intensification), thus far little attention has been given to the environmental impacts AWM interventions may have. In addition, despite a growing number of success stories, there is evidence that the impacts of AWM interventions are often evaluated in a one-dimensional way, either from a natural resource or social-human perspective. Much evidence is still based on a limited number of meta-analyses that in themselves point to inconclusive outcomes due to inconsistent or sometimes non-existent monitoring and evaluation of impacts (World Bank, 2007; Joshi et al, 2008; Barron *et al*, 2008; Kerr, 2002; Joshi *et al*, 2005)

This synthesis focuses on capturing the changes in different capitals that AWM interventions may have at the watershed scale (i.e., at meso-scale, 1- 10 000 km^2). The aim is to assess which impacts are predominant, and if these relate to negative or positive impacts. Secondly, this review will suggest parameters needed for inclusion in monitoring and evaluation of AWM interventions in the project pilot watershed areas. These parameters will assist in addressing potential positive and/or negative impacts of AWM from a holistic social-environmental perspective at the landscape scale. These outcomes could further be used to guide potential cost and/or benefit estimates of AWM interventions.

2 MATERIALS AND METHODS

2.1 CRITERIA AND SOURCES OF CASES

In order to focus the source material, a set of criteria were determined for case selection.

AWM Interventions (table 1, extended list in database, appendix): an agricultural water management intervention is an intervention that changes the partitioning of water when reaching the soil surface. Thus, most *in-situ* (including most soil and water conservation technologies) and *ex-situ* water management interventions qualify. The source of water for AWM interventions, which include irrigation, can be rainwater harvesting, groundwater, re-located stream flow or recycled water. Other crop management activities can also directly and/or indirectly alter the water balance partitioning at the field, thus potentially impacting water resources at a landscape scale. Therefore, additional crop systems changes were included. With this definition, most cases entailed crop water management interventions rather than livestock water management interventions.

For each case, there may be multiple AWM interventions. Some AWM interventions are also often combined; for example, development of irrigation is often coupled with changes in cropping systems.

Table 1: AWM clusters and principal change in water balance at field scale

AWM clusters	Principal change in field water balance*	AWM code (Appendix 1)	Typical technologies
In-situ on/off farm	Increase infiltration into unsaturated soil (recharge) and reduce surface runoff	1; 4; 14; 15; 18; 21; 22; 25	Incl. conservation tillage, terracing, soil conservation technologies, other rainwater harvesting structures in landscape
Development of storage	Increase residence time of water in specific landscape, and if used as irrigation, reduce surface runoff and potentially increase transpiration a/o field evaporation	3; 5; 29;	Incl. ponds, dams, shallow wells
Development/ adoption of irrigation	Potentially increase transpiration a/o field evaporation, other impacts depend on source of irrigation water	6; 8; 16	Incl. drip/micro, bucket, treadle pump
Develop water supply	Reduced use of water for other purposes , incl. aquatic and/or other ecosystems services	7; 17	Irrigation canal construction a/o rehabilitation
Develop source of water	Potentially increase transpiration a/o field evaporation, other impacts depend on alternative uses of this water source	19; 23; 31	Incl. springs, boreholes
Reclaim/ expansion of crop land	Increase infiltration into unsaturated soil (recharge), more water available from biomass production (transpiration and/or evaporation, recharge groundwater) and reduce surface runoff	10; 24; 26; 28	Incl. rehabilitation of degraded land and gully, live fencing
Increased use organic matter	Increase infiltration into unsaturated soil (recharge), increased water holding capacity, more water available from biomass production (transpiration and/or evaporation), better water uptake by plants (due to improved nutrient availability with OM) and reduce surface runoff	12; 13; 20	Incl. manure, compost, plant residues
Change of crop system	Increased uptake of water for transpiration and evaporation , reduced recharge (if multiple crops, sequential cropping)	9; 11; 27; 30	Incl. crop, variety adoption, tree planting, kitchen garden

* These changes in field water balance are expected a/o documented. The impact at meso-scale may be insignificant or highly significant depending on landscape characteristics beyond the field subject to intervention

Extent of adoption: A case was included in this assessment if the information indicated a substantial area or community adoption.

Location of case: The case was included if it was located in a developing country or newly-industrialised country. Secondly, the intervention was included if it focused on smallholder farming systems in areas and/or countries with high incidence of poverty among this group of farmers. The cases do not include AWM interventions in large-scale commercial farming systems in developing countries.

Age of case description: The documented AWM intervention was included if it was no older than 20 years, i.e., from 1989 to present.

Source of case information: The case description, data and information was included if it was available in the public domain. Four categories of sources were identified:

- journal articles;
- research reports, technical papers, conference papers, books;
- internal report, reviews and project documentation; and,
- personal communication/expert consultation.

Only cases using the first three sources were used in this synthesis.

2.2 THE LIVELIHOODS FRAMEWORK AND CAPITALS

To measure both positive and negative impacts from the AWM interventions, the cases were analysed using the sustainable livelihoods framework (DFID, 1999). This framework categorizes assets in terms of five capitals. They are:

Financial: available monetary assets; for example: income, savings, access to capital and credit;

Human: an individual's skills, knowledge and capabilities; for example: education, training, good health;

Natural: natural resource stocks; for example: plant and animal products, water for irrigation and domestic use;

Physical: infrastructure and producer goods; for example, schools, roads, communications; and,

Social: skills, capabilities and other attributes accruing at the community level; for example: network of organizations, self-help groups, gender equity, empowerment of local organizations to interact with government entities.

This theoretical framework enabled the systematic assessment of multiple dimensions of livelihoods and well-being. In addition, using the five capitals is not spatially limited. Both on-farm/on-site and off-site impacts (so-called externalities) could be assessed, as well as household and community-level impacts.

The absolute change in a subset of a capital was assessed differently in each case depending on project purpose and available resources to monitor and evaluate a particular change. Some of these key absolute changes are included in the database, but will not be addressed further in this report as it is nearly impossible to standardise between the included cases.

2.3 AVAILABILITY OF DATABASES

The database is available in full on the AWM Solutions Project web page (http://awm-solutions.iwmi.org/home.aspx). The web-interface for display of key text and search and extract facilities is available. The references for all cases are available in an Endnote reference database upon request.

3 RESULTS

3.1 DESCRIPTION OF RETRIEVED CASES

A set of 37 cases were identified as meeting the criteria (section 2.1) from various sources. Most cases were located in semi-arid to dry sub-humid climate zones. There were nine in Africa, two in Latin America, one in the Middle East /North Africa and 25 in Asia (figure 1).

Several case studies did not state how large the area affected by AWM intervention(s) was, nor share of total population. In 19 cases, the areas affected by adoption ranged between one km^2 to 1000 km^2, where adopters were mixed with non-adopters. Only 16 cases stated the approximate number of households which have adopted AWM interventions (ranging from 40 households to more than 6,000 households). In the majority of cases it was impossible to retrieve the percentage of total population in the area that were AWM adopters versus non-adopters.

The principal agricultural system in the identified cases was smallholder rainfed where yield or incomes from yields form a substantial part of livelihoods (tables 2a and b). In 75 per cent of cases, smallholder rainfed crops produced the bulk of income and food. In 30 per cent of all cases, supplemental irrigation or full irrigation of some crops formed an important part of the livelihood system, in particular for paddy rice and small-scale gardening.

Initial water-related issues in the case description were explicitly listed as erratic, unreliable rainfall with high incidence of droughts, dry spells and also floods (54 per cent of cases). In addition, 25 per cent of the cases mentioned problems with domestic water supply. Lack of accessible or good quality groundwater, need for irrigation, soil erosion and competition with other users of landscape water resources were all mentioned in 5-14 per cent of cases. In 50 per cent of cases, no explicit water-related issue was mentioned as to why AWM interventions were undertaken, whereas in 43 per cent of cases, two or more water-related issues were stated.

As a consequence of low and erratic rainfall, the agricultural issues mentioned in case studies related to low yield productivity, although only 14 per cent explicitly mentioned lack of irrigation as an issue in agricultural production. Soil fertility and erosion was perceived as a greater issue, mentioned in 35 per cent of cases.

In total, 138 AWM interventions were identified in the 37 cases (figure 2). The most common AWM intervention in the selected cases related to changes in crop patterns, species and/or varieties. This was likely

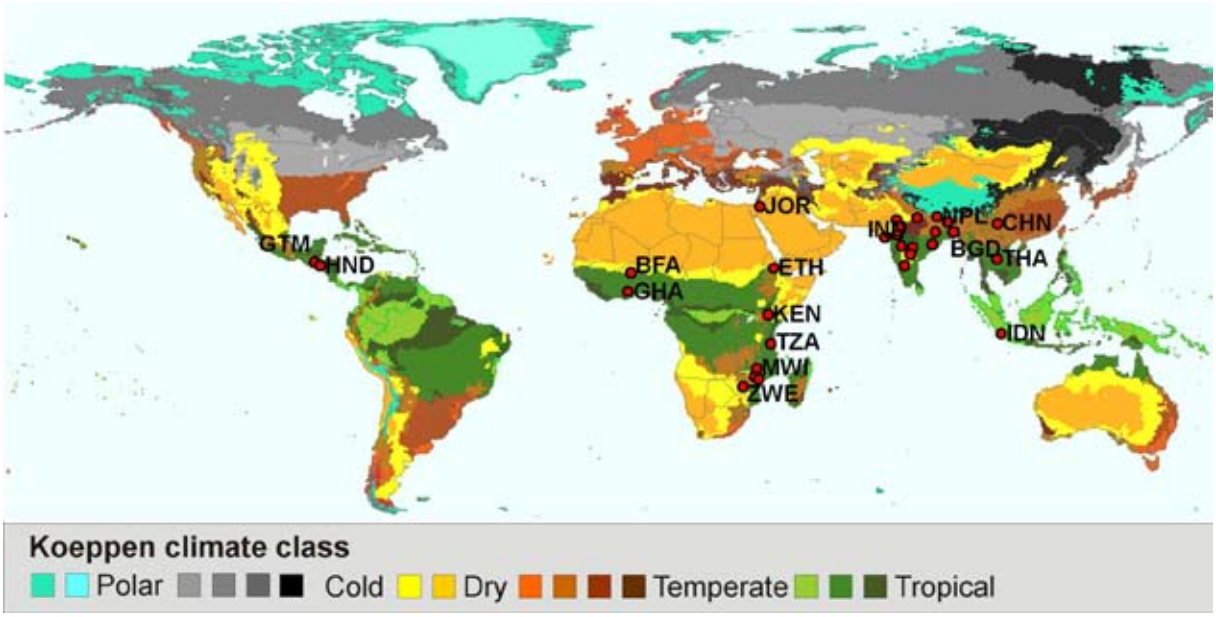

Figure 1: Locations of Agricultural Water Management (AWM) intervention cases included in this synthesis and in the database

Table 2a: Water-related issues explicitly mentioned in cases

Water-related issues	Number of cases
droughts, dry spells, erratic/variable rainfall	20
lack domestic water supply	10
need irrigation	4
soil erosion	8
flooding, water logging	3
lack groundwater	5
competition downstream /alternative water use	3

Table 2b: Agricultural-related issues explicitly mentioned in cases

Agricultural issues	Number of cases
low yields	9
crop water stress/ lack of irrigation	5
soil fertility	7
food shortage/ food insecurity	2
labour	1
market access	1

an effect of the adoption of other AWM interventions, such as *in-situ* technologies and/or combinations of irrigation development (source of supply, storage, and/or irrigation application). The second most common intervention was so-called *in-situ* water management: technologies that increased soil infiltration capacity and thus reduced surface runoff. In the 37 cases, 20 per cent of listed interventions were classed as *in-situ* AWMs, on-farm or off-farm on community land. In addition, several of the other AWM categories were interventions that enhance soil infiltration. These included seven per cent of cases with increased use of organic matter (i.e., long-term building of soil water-holding capacity), and seven per cent AWM interventions of reclaiming degraded land/expansion of land (i.e., a spatial increase of infiltration capacity).

The third principal development of AWMs related to development of storage on-farm or in the landscape, to enable longer growth seasons or a more reliable supply of water for crop production in-season. In several of the cases, the stored water also had multiple benefits for the community, not just supplying water for crops but also for domestic uses and livestock (Mikhail and Yoder, 2008).

Whilst 11 of 37 cases described only one AWM intervention, 13 cases (35 per cent) took a more holistic approach and included 5-11 AWM interventions. Of the 26 cases describing two or more interventions, 18 included at least one AWM intervention addressing *in-situ* on/off farm or development/adoption of irrigation, combined with one AWM intervention that changed crop systems.

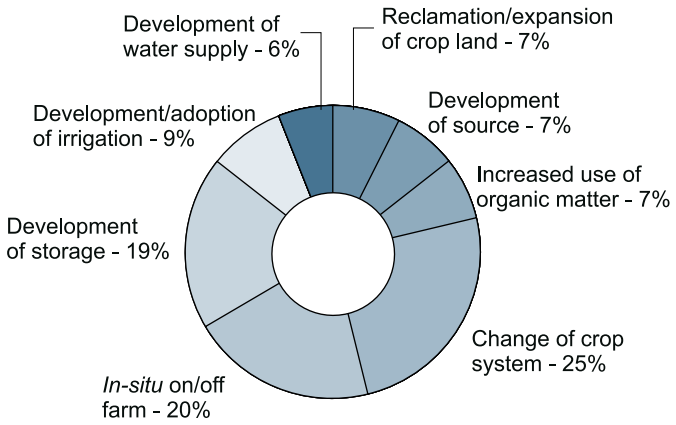

Figure 2: Agricultural Water Management (AWM) interventions in the featured cases (n=37). Many cases involved more than one AWM intervention

3.2 CHANGES IN CAPITALS DUE TO AWM INTERVENTIONS

Natural capital changes

The positive impacts on natural capital from AWM interventions related to a range of ecosystem services in production landscapes, both on-farm and off-farm (for example community/common land). First, the on- and off-farm productivity was often impacted. The highest ranking impact of AWM interventions was increased on-farm output (100 per cent of cases). The third and fourth positively-ranked impacts were related to the first: increase in total biomass and overall positive impacts on natural resources.

Second, biodiversity was impacted. In addition to overall 'positive impacts on natural resources' (20 per cent cases), crop diversity was increased in 20 per cent of cases. A related impact was also mentioned as 'positive ecological impacts to aquatic systems'.

Third, a set of positive impacts on the soil resources were noted. Increased soil fertility and improved water holding capacity (20 per cent of cases) and decreased soil erosion (10 per cent cases) were the principal effects mentioned.

An important aspect of AWM interventions was the improved resource use efficiency that they enabled. In particular, water productivity improvements and increased productivity of inputs were mentioned as gains in natural capital.

There were also a set of impacts on natural capitals which could be positive (desired) or negative (undesired) depending on the local context (figure 3). The second highest impact on natural capital changes was stated as increased land area cropped (43 per cent of cases) and, in five cases, expansion into marginal lands. This may be positive, for example if the AWM intervention(s) enabled sequential cropping, multiple harvest or intensification on already-existing crop lands. In some cases, the AWM intervention may have enabled reclamation or restoration of degraded land into an improved production state, which of course is positive and desired. However, if the AWM intervention enabled horizontal expansion of crop land, at the expense of other land uses, this may be undesired for other stakeholders, i.e., a negative externality of the AWM intervention. Horizontal expansion can also affect other ecosystem services which otherwise support livelihoods directly or indirectly.

Similarly, spatial and/or temporal changes in stream flow and groundwater can be desirable or undesirable. Among the cases, 32 per cent had increased groundwater recharge. The changes in stream flow were in the order of 10-13 per cent of cases.

A set of negative (undesired) impacts were also noted in selected cases. These related to loss of soil

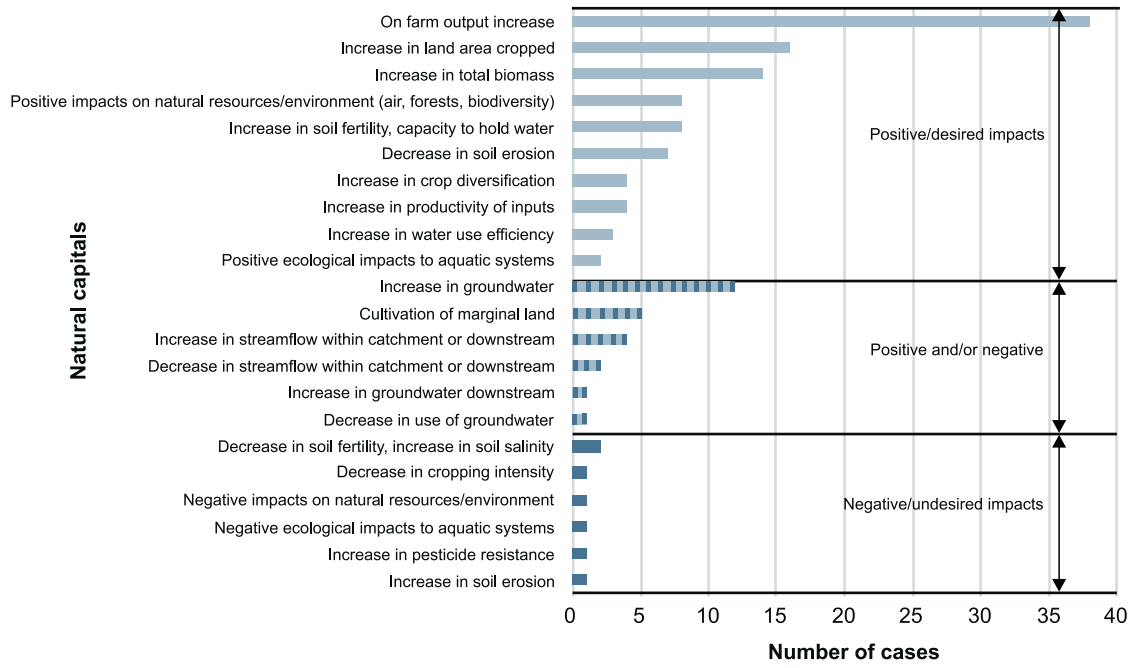

Figure 3: Specified changes in natural capitals due to AWM interventions in the 37 case studies

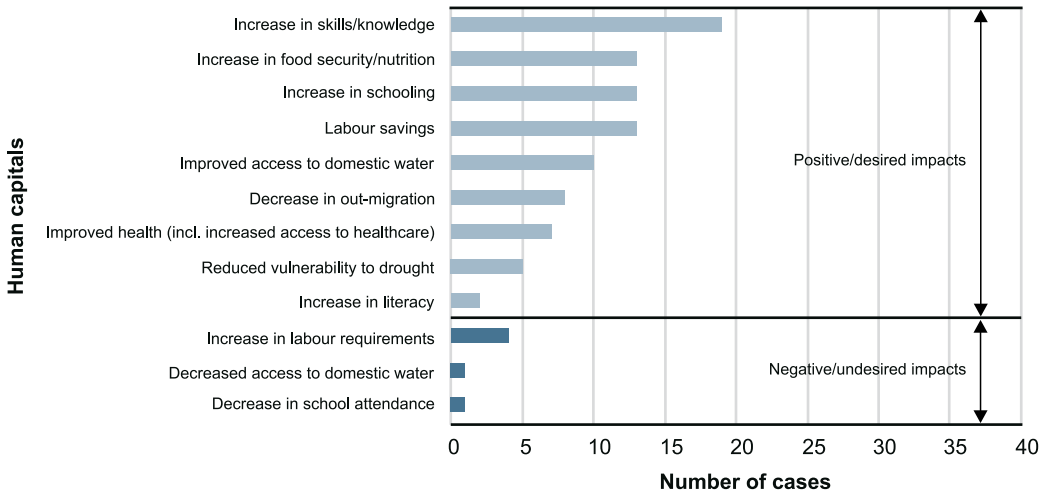

Figure 4: Specified changes in human capitals due to AWM interventions in the 37 case studies

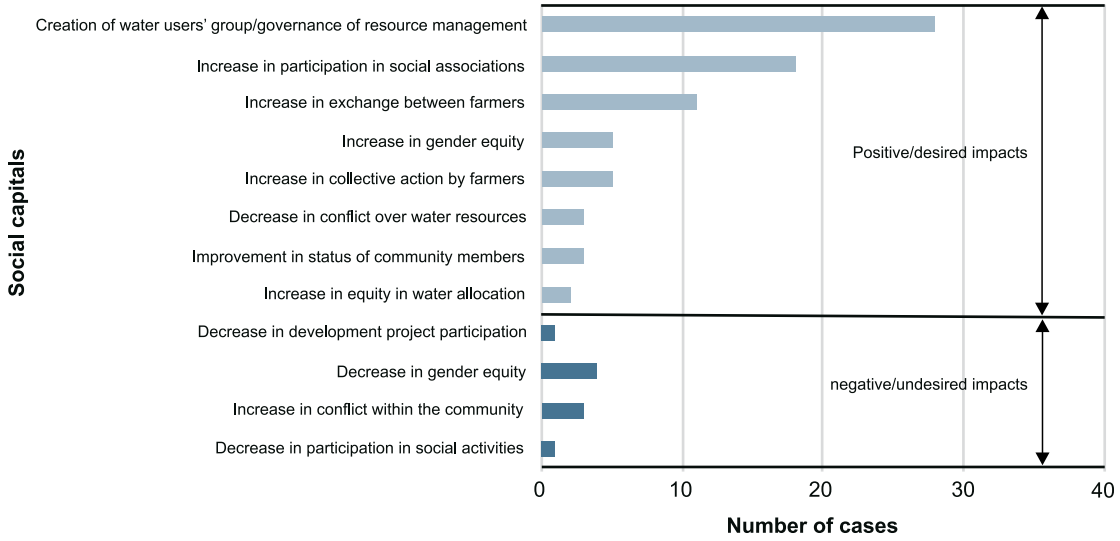

Figure 5: Specified changes in social capitals due to AWM interventions in the 37 case studies

fertility (2 cases) and increase in soil erosion (1 case), decreased crop intensity (1 case), and increased pesticide resistance (1 case). Additionally, a couple of cases mentioned wider ecosystem impacts: one case indicated negative impacts specifically on the aquatic resources, and the other case mentioned a general degradation of the environment.

Human capital changes

In summary, human capital was mentioned as changing due to AWM interventions in 80 per cent of the cases, and mostly was perceived to increase (improve) as AWM interventions were adopted (figure 4).In the selected cases, the human capital changes often directly related to the Millennium Development Goals (MDG).

The highest ranking positive change, mentioned in 50 per cent of the cases, was increased knowledge and skills among the communities or individuals that adopted the AWM interventions. Second highest were changes in human capitals that directly relate to the MDG targets of improved schooling (35 per cent of cases), increased food security (35 per cent of cases) and improved access to domestic water (30 per cent of cases). An additional positive impact mentioned in 30 per cent of cases was a reduction in labour requirements when AWM interventions were introduced. However, in 13 per cent of cases the AWM intervention led instead to an increase in labour requirements. Also, in one case, school attendance fell due to adoption of AWM interventions (Holder, 2006).

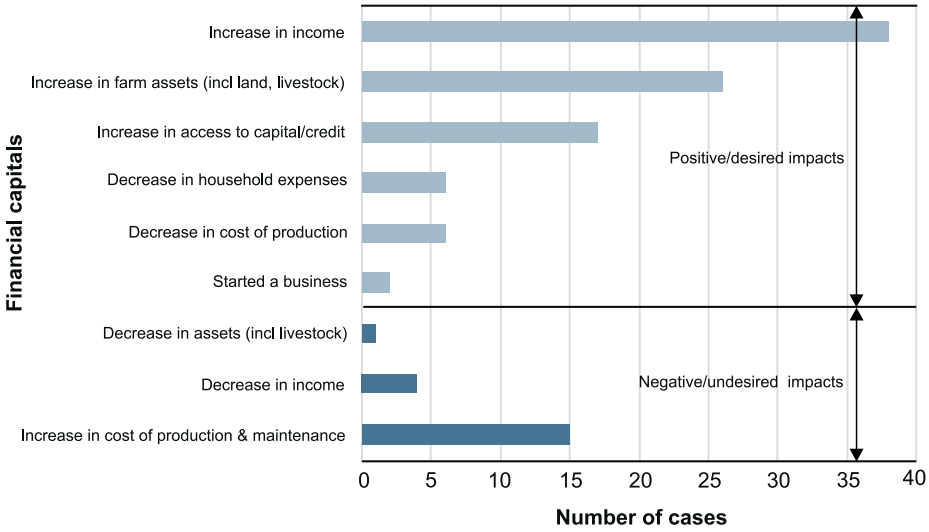

Figure 6: Specified changes in financial capitals due to AWM interventions in the 37 case studies

Social capital changes

It is increasingly being recognised that social capital has high influence on success of adoption of improved AWM interventions (cf Noble *et al*, 2006). Figure 5 shows the social capital changes identified in the analysed cases. Overall, 70 per cent of cases reported various changes in social capital.

The highest ranking gains in social capital mostly related to the creation and strengthening of social organisations (75 per cent of cases), including increased participation (50 per cent of cases) and increased collective action (14 per cent of cases).

A second set of social capital changes related to equity. The AWM interventions were stated as increasing gender equity in 14 per cent of cases, and in equally as many cases, gender equity was decreased due to adoption of AWM interventions. On the positive side, two cases of 37 stated that the AWM interventions had improved equity of water in the community. However, the same number of cases stated that the AWM adoption had increased conflict in the community over water resources.

Financial capital changes

As a direct effect of the changes in natural capital (i.e. increased yields and/or increased value of yield due to change of crops), incomes and financial capital were affected. In 100 per cent of cases, income was reported to have increased for at least part of the households adopting the respective AWM intervention (figure 6). Due to the wide variety of assessments of the income increases, as well as the different contexts, no attempts were made to normalise the value of income increases for different cases.

The second highest impact on financial capital was the increase in assets among AWM adopters, including increased land value and increased number of livestock[1]. And thirdly, the cases indicated that AWM adopters had greater access to credit facilities as a result of AWM adoption, many through the establishment of savings organisations.

Physical capital changes

Investment in physical capital is often part of AWM project implementation. In addition, when incomes rise, these gains are often invested in physical capital. In the reported cases, three sets of physical capital gains were identified (figure 7): a total of 60 per cent of cases had improved infrastructure for water supply and storage. Secondly, personal gains in physical capital were identified in 40 per cent of cases, including improved housing and investments in consumer durables such as radios, televisions, vehicles or bicycles by individuals who adopted AWM interventions. In one case, the AWM intervention was stated to affect physical capital negatively, through a decrease in water infrastructure efficiency.

1 This may be disputable, as other research has shown that adopters of new technology in these systems often are the better situated households, and thus the adopters here having better assets may be inherent effect due to being better off to begin. Unfortunately, baseline data in individual cases have not been able to disentangle these effects satisfactorily.

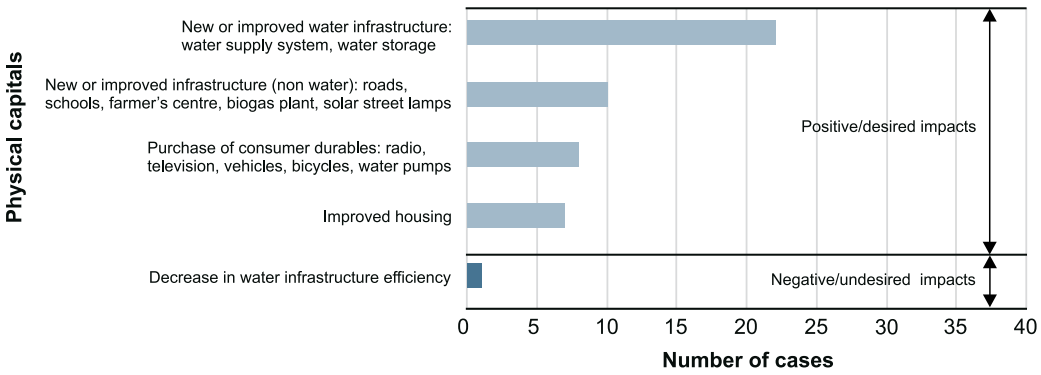

Figure 7: Specified changes in physical capitals due to AWM interventions in the 37 case studies

3.3 AWM INTERVENTIONS AND CO-VARIATION OF MULTIPLE CAPITAL CHANGES

Summarizing the AWM interventions and the impacts on different capitals, it can be seen that cases with five or more AWM interventions appear to have more positive impacts than cases with 1-2 AWM interventions. Cases with 1-2 AWM interventions (n=18) had on average a share of 82 per cent (STD=18) positive listed capitals, and on average 18 per cent negative or negative/positive listed capitals (figure 8). The cases with five or more AWM interventions per case (n=13) had on average 92 per cent (STD=5) positive changes, and only eight per cent statements on negative or negative/positive impacts per case. Although the difference between cases with 1-2 AWM interventions and five or more is not statistically significant at $p<0.05$, the results of the synthesis strongly suggest that multiple AWM interventions can have more positive and more diverse impacts on several key dimensions of smallholder semi-subsistence farming systems.

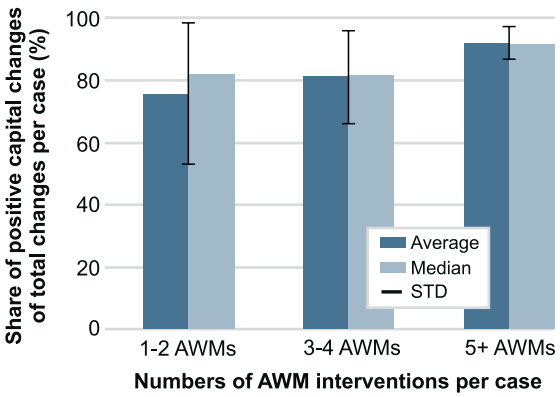

Figure 8: Average and median share (%) of registered positive changes in capitals for cases with 1-2 AWM interventions, 3-4 AWM interventions and five or more AWM interventions.

3.4 THE MONITORING AND EVALUATION OF IMPACTS IN EXISTING CASES

The assessed 37 cases had varying degrees of monitoring and evaluation (M&E) applied. Only eight of the cases mentioned any monitoring and evaluation activities relating to the described AWM interventions. The case of Jharkand, India (Honore and Pandey, 2002) reviewed a project that was implemented to expand monitoring of previous watershed development projects beyond hydrologic monitoring. From this work came a comparative evaluation of three watersheds (one participatory approach, one top-down approach, and one control). The project developed procedures and protocols for monitoring and evaluation of AWM schemes and their findings form an appropriate backdrop for the small amount of monitoring and evaluation that was actually explicitly mentioned in the reviewed cases. Overall, they found that in general, too little importance is given to monitoring and evaluation in the AWM projects. Largely, only physical and financial impacts were catalogued, without inclusion of other components such as 'quality of activities, ecological regeneration, livelihoods of people, gender parity and sustainability' (Honore and Pandey, 2002). Also timing of monitoring and evaluation activities has impacts on overall AWM project outcomes. Projects that had pre-, during and post-implementation evaluations were better able to conduct mid-term corrections. Other lessons learned related to how to do M&E. The projects that compared participant and non-participant households could more confidently assess impact and change due to AWM interventions. And participatory monitoring and evaluation where communities were part of the process of defining project indicators instead

of indicators being defined solely by implementing and/or funding agencies were strongly advocated.

The two projects of Bundi, Rajasthan (Kakade *et al*., 2003) and Karnataka (Kakade *et al*., 2003) mentioned doing a baseline participatory rural appraisal including village transect, social mapping, and resource mapping to identify strategies for AWM interventions. This data was complemented with satellite imagery, topographical and geological surveys, and socio-economic data. One case also included collection of information on hygiene practices and water and energy consumption.

Five of the cases described the monitoring that was conducted. In the Karnataka case (Kakade *et al*. 2003), changes in the local environment, availability of water, agricultural production and land use and economic status were monitored. In the Amhara, Ethiopia case (Liu *et al*., 2006), Community Watershed Management Organizations that were established conducted their own annual project evaluations prior to the preparation for the next year's workplan. Farmers identified technologies that performed well and should be scaled up whilst discontinuing ones that had poor performance. Monitoring in the Tafila, Jordan case (PLAN-NET Ltd., 2004) included regular visits to households to monitor project progress, including data collection from installed meters, monthly soil and water sample testing by the communities, and incorporation of feedback into system design. The Mphate, Malawi case (Tewolde, 2009) described the M&E framework as focused on intermediate results, outputs, and activities in relation to food security. Performance indicators were used to track progress, although it was explicitly mentioned that they did not measure impacts but focused only on whether they were achieving investment goals. Thus, they stated, 'the framework is adequate for monitoring and evaluation of the interventions in relation to food security but less so on measuring the impacts on livelihood sources'.

The case of Tafila, Jordan (PLAN-NET Ltd, 2009) explained a detailed post-project evaluation conducted by an external organization. It included an impact assessment, field surveys and questionnaires, an environmental and socio-economic impact evaluation and analysis of soil and water samples. The evaluation was done to determine how well the project objectives were achieved, the technical effectiveness of implemented systems, the socio-economic impacts of the project, the viability of the systems to wider application in the country and recommendations for improvement of the second phase of the project.

Three of the cases included a cost-benefit analysis. In two of the cases (Kakade *et al*., 2003; PLAN-NET Ltd, 2009), however, the specifics were not described. In the case of Gujarat, India (Chaturvedi, 2004) eight watershed development projects were reviewed, two each from four different districts and implementing organizations. Purposive sampling was used to select watershed villages while stratified proportionate sampling was used to select respondents. The three categories of marginal, small and large farmers were also analysed. Questionnaires and focus group discussions were used with direct and indirect beneficiaries as well as those with and without AWMs. Only one other case, the one in Karnataka, India (Kakade *et al*., 2003) mentioned dealing with the issue of attribution through obtaining comparative data from non-project neighbouring villages. None of the cases included in the current database described post-project evaluation.

4 DISCUSSION

Relevance of results and usefulness

The synthesis of cases of AWM interventions suggest that the majority of cases had multiple impacts affecting different dimensions of the livelihood capitals. The top five listed changes were from all five types of capitals: natural capital (increased yield), financial (increased income), social (increased social organisations), physical (improved water supply, irrigation system a/o water storage) and human (increased skills and knowledge). Thus, we conclude that AWM interventions need to be monitored and evaluated for the multiple dimensions that may be impacted, well beyond yield levels and farmer household income. Cost and benefit analyses should also attempt to capture the social, human and environmental gains and losses that this synthesis suggests follow from the AWM interventions.

Monitoring and evaluation programmes typically consider on-farm/on-site impacts and miss changes at higher spatial scales that are external to the area subject to AWM interventions. However, the results from the 37 cases of AWM adoption suggest that it is important to assess beyond the household level for a range of dimensions in order to capture both positive and negative impacts. The case studies included here did not specifically address emerging externalities of local interventions, although the case analysis included them. Although these emerging externalities can be positive or negative some negative impacts were identified in the reviewed cases, mostly relating to natural and social capital changes. It is also worth noting that only one case referred to long-term impacts (Lam and Ostrom, 2009). It would be desirable for other cases to differentiate between the short- and long-term changes in capitals. Inclusion of the long-term would help indicate the sustainability of interventions as well as impacts.

While each individual case may have only registered impacts on biophysical changes to the exclusion of socioeconomic impacts, or vice versa, the current study demonstrates that a holistic approach must be taken to fully capture the spectrum of costs and benefits associated with AWM interventions.

Methodology

This study elected to employ the livelihood capitals framework to ensure multiple aspects of impacts were captured, including benefits (and costs) that accrued at the household level as well as at the community level. In addition, secondary and indirect impacts were also examined, including those affecting MDG attainment, such as gains in food security, health and schooling. Similarly, the framework was flexible in terms of considering both on-site and off-site biophysical changes as a result of the interventions, meaning watershed-level impacts could be assessed. As a result, using this theoretical framework assisted in moving beyond evaluations that focus primarily on judging success in terms of increases in income and yield, thus offering a more nuanced picture of the impacts of AWM interventions.

A weakness of this synthesis is the sources of cases, most likely representing biased positive impacts due to AWM interventions. The analysis relied on the impacts reported within the cases, and in many of the cases there was no explanation of how these impacts were measured. In the 37 cases, only one case (Chilasco, Guatemala, Holder, 2006) critically reviewed a failing AWM intervention. Studying and assessing 'failings' in AWM interventions would better equip implementers with 'lessons learned', and create a more realistic picture of project impacts than is currently being seen.

There is also a need for better quantification as well as qualitative assessments of stated impacts, whether social, biophysical or other. The included cases were weak in terms of capturing essential baseline information, such as even the number of adopters or number of households with improved livelihoods due to AWM interventions. Far fewer assessments are on so-called externalities which emerge due to AWM interventions. A growing number of cases raise the issue of externalities, especially relating to ground water depletion, as AWM interventions are adopted in India (for example, The Economist, 12 Sep 2009; Batchelor *et al*, 2002; Shiferaw *et al*., 2008). In increasingly water-stressed areas, these externalities can be expected to increase as well, unless promotion and adoption of AWM interventions specifically address potential impacts from the beginning of the intervention.

Future areas of research

This database, which uses the livelihood framework to assess cases with AWM interventions, shows some initial unique results, pointing towards the multiple positive gains that can be achieved through addressing poverty with water and land management in smallholder farming systems. The addition of more cases will solidify the outcomes of the initial results presented here. Our intention is to use statistical multi-variant methods to analyse the database further.

A related, and some might argue equally important, analysis would be to review the 'software' components of the projects that also constitute AWM, for example, increasing community capacity on water resource management. Many of the cases reviewed contained these components, although they were not always as explicitly delineated as were the physical components. Additionally, those that were explained more clearly often regarded only agricultural production training and not organizational development, conflict mitigation, or design and implementation of management rules. Yet, Lam and Ostrom (2009) indicate that it is these very 'software' components (or soft components) that may be most important for long-term sustainability of AWM interventions. A review of these other legitimate, but less tangible, aspects of AWM interventions would create an even more nuanced picture of AWM interventions and impacts.

This analysis pointed towards '*what*' AWM interventions aspects of livelihoods and environment may be impacted, based on documented public domain cases at the household, community, and watershed levels. There is still a gap in knowledge relating to *'how'* and *'how much'* the AWM interventions impact livelihood gains/poverty alleviation, the environment, and long-term sustainability. In addition, the investment costs and benefits in relation to the actual AWM intervention change are also lacking, despite a few examples focused specifically on cost-benefit analysis. The synthesised lessons of this analysis can enhance future investments in AWM interventions, particularly for the multiple goals of poverty alleviation, sound environmental management and sustainable development pathways.

5 CONCLUSIONS

Based on the synthesised outcomes of the 37 meso-scale cases with various AWM interventions, and using the five capitals of the livelihood framework, we conclude that:

- The five most mentioned impacts due to AWM interventions were positive and related to all five capitals: increase in income (financial capital); on-farm yield output increase (natural capital), building user groups/governance structure (social capital); improved water infrastructure (physical capital), and increase in skills and/or knowledge (human capital).

- The most mentioned negative impacts due to AWM interventions were increase in cost of production (financial capital); increased labour requirement (human capital) and gender inequity (social capital).

- A set of natural capital changes were registered but not assessed for being positive or negative, as information in each case was too poor. These changes related to principal hydrological and land-use impacts, in particular groundwater changes, discharge changes downstream, and increased use of marginal lands /crop land expansion.

- Cases with five or more AWM interventions had on average 20 per cent more positive changes listed than cases with only 1-2 AWM interventions.

- Cases with multiple AWM interventions often combined water management (water harvesting/ soil conservation and/or irrigation) measures with changes in crop patterns, crop species and/ or fertiliser use.

- Although individual cases mention the degree of impact (quantified change in different capitals), the data collection and sampling was often poorly described.

- The results with diverse and multiple impacts on different forms of capitals suggest that monitoring and evaluation of AWM interventions needs to address multiple dimensions of social, agro-ecological and human systems to assess actual positive and negative impacts at the household, community, and watershed levels.

- Improved and more systematic monitoring and evaluation is needed in AWM interventions to better inform cost-benefit analyses, taking into account both positive and negative impacts beyond the actual financial capitals used in economic investment plans.

- The ‘soft’ components of AWM interventions, while often less explicitly explained, were integral to the projects. Further exploration of the impacts from these components is needed.

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APPENDIX: AGRICULTURAL WATER MANAGEMENT INTERVENTIONS AS LISTED IN DATABASE

AWM1	in situ on farm, soil and water conservation (SWC)
AWM2	conservation tillage (CT)
AWM3	shallow wells
AWM4	in situ off farm / soil conservation (SWC)
AWM5	ponds, dams, other storage
AWM6	drip / micro irrigation
AWM7	irrigation canal
AWM8	treadle pump adoption
AWM9	change of cropping system
AWM10	reclaim wastelands
AWM11	tree planting
AWM12	use of compost, vermicompost, manure, etc.
AWM13	use of organic repellants
AWM14	double dug beds
AWM15	raised beds
AWM16	bucket irrigation
AWM17	improvement of canals (i.e. lining etc.)
AWM18	terracing
AWM19	greywater treatment and reuse
AWM20	plant residues for soil cover
AWM21	zero tillage
AWM22	provision for drainage water back into river
AWM23	developed springs
AWM24	gully rehabilitation
AWM25	water harvesting structures
AWM26	field bunding with vegetative support
AWM27	introduction of improved seed varieties
AWM28	hedge fencing
AWM29	check dams
AWM30	kitchen garden development
AWM31	boreholes

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