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10 Years of IWMI Research - An Overview

More Crop Per Drop Revisited

In 1996 David Seckler, then recently appointed Director General of IWMI with a mandate to re-focus the research agenda of the institute, published the first IWMI Research Report (Seckler,1996). This brief note contained many of the basic ideas that have come to characterize what has been coined "the IWMI approach to water for agriculture". It was, in essence, a research agenda around the following three ideas:

1. **Basin focus:** As renewable water resources available for human use become fully committed in a basin, and competition among users increases, the appropriate focus for water management is the basin level, not the field, farm or even the irrigation system level. This concept is closely linked to the idea of open, closing and closed basins – where a basin is defined as 'closed', when there is no usable water leaving the basin;
2. **Recycling:** Many of the water savings achieved at field level may only capture water that would otherwise have been re-used downstream. These are not real water savings, where additional supplies become available ("wet" water savings), but simply a re-allocation of water from downstream to upstream users ("dry" water savings). With this idea comes a focus on the fate of water through recycling and re-use;
3. **Crop water productivity:** Rather than focusing on the potentially misleading idea of increasing irrigation efficiency, the focus should be on increasing water productivity – in essence, the output produced per unit of water consumed. This gave rise to the phrase "more crop per drop".

These ideas, described in more detail below, formed the core of the IWMI research agenda in the 1995-2000 period, culminating in the key publication on water productivity by Kijne et al.,eds (2003).

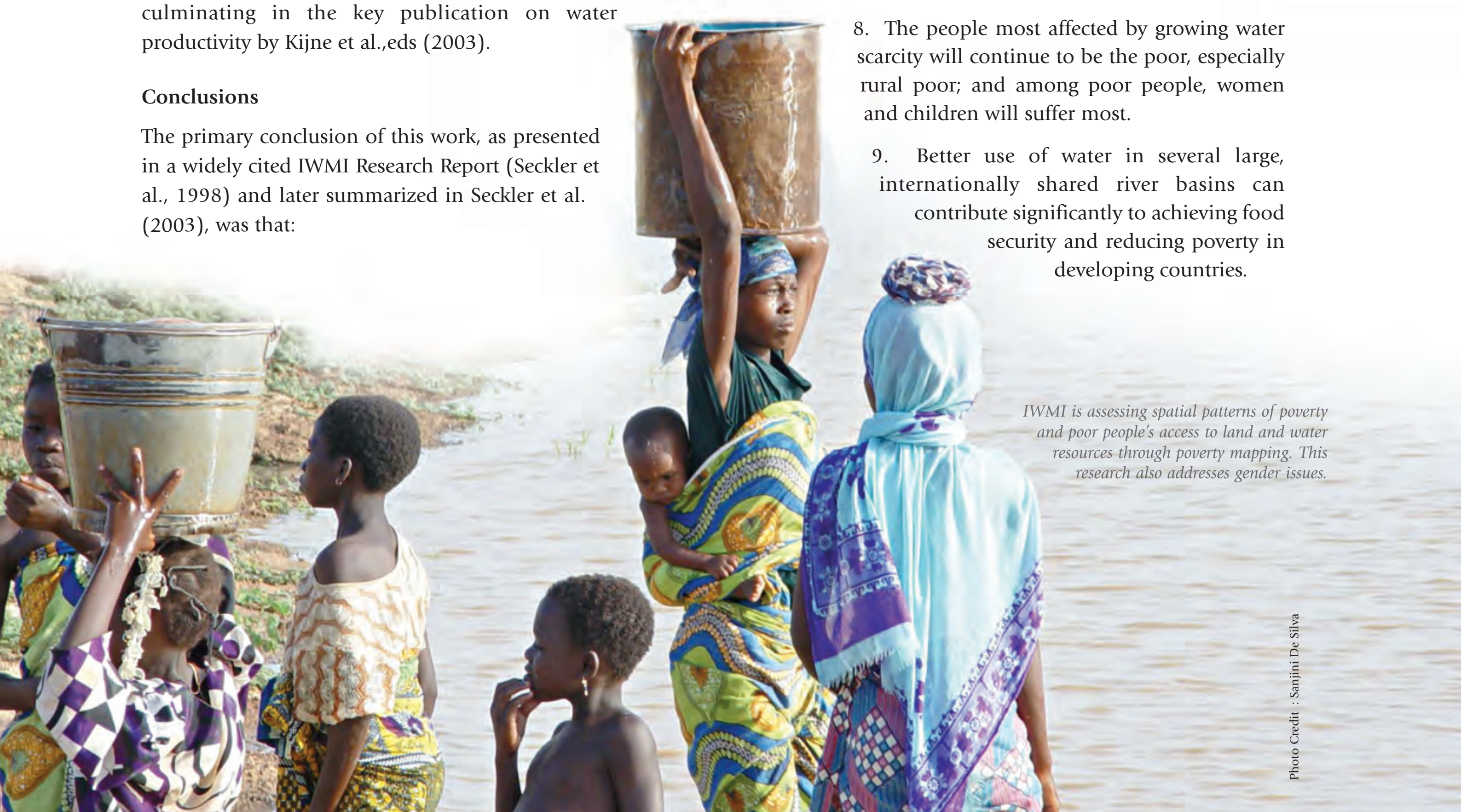
Conclusions

The primary conclusion of this work, as presented in a widely cited IWMI Research Report (Seckler et al., 1998) and later summarized in Seckler et al. (2003), was that:

"...one-third of the population lives in regions that have absolute water scarcity, in the sense that they will not have sufficient water resources to meet their agricultural, domestic, industrial and environmental needs in the year 2025…an additional 500 million people live in regions of severe economic scarcity; they have a sufficient amount of potential water resources to meet their 2025 needs, but they will have to more than double their present utilization of these resources through large, expensive and possibly environmentally destructive development projects…"

The "basic IWMI scenario" was published as the IWMI contribution to the World Water Vision (Cosgrove and Rijsberman, 2000). Its major findings and recommendations were (IWMI 2000):

1. The world's primary water supply will need to increase by 22% to meet the needs of all sectors in 2025.
2. Seventeen percent more irrigation water will be needed for the world to feed itself in 2025.
3. Nearly one-third of the populations of developing countries in 2025, some 2.7 billion people, will live in regions of severe water scarcity.
4. The global community must invest in research to improve crop water productivity (crop per drop).
5. New water infrastructure will have to be developed to meet future food requirements.
6. Groundwater reserves will be increasingly depleted in large areas of the world.
7. Salinization of soils, compounded in many cases by increasingly saline or poisoned groundwater, will seriously affect land that has been highly productive in recent decades.
8. The people most affected by growing water scarcity will continue to be the poor, especially rural poor; and among poor people, women and children will suffer most.
9. Better use of water in several large, internationally shared river basins can contribute significantly to achieving food security and reducing poverty in developing countries.



IWMI is assessing spatial patterns of poverty and poor people's access to land and water resources through poverty mapping. This research also addresses gender issues.

Photo Credit : Sanjini De Silva

Seckler believed that while the solution to water scarcity was to enhance water productivity in irrigated agriculture as much as possible, further development of water supplies for irrigation to meet future food demands was inevitable and would require the widely-cited "17% of additional water for irrigation by 2025". He did not believe there was much potential to improve water productivity in rainfed agriculture. This assumption that the increase in water productivity in rainfed agriculture would be low is a key factor in the relatively high estimate of a 17% growth in irrigation water demands.

Photo Credit : Sanjini De Silva

Poor farmers in urban and peri-urban areas turn to untreated wastewater as an alternative source of irrigation water. Here a farmer in Hyderabad, India tends his crop grown with wastewater.

The ideas IWMI developed and promoted–often referred to as the "more crop per drop" paradigm–have been very influential in academic circles, as well as two large scale research programs based on these concepts: the CGIAR system-wide Comprehensive Assessment of Water Management for Agriculture and the CGIAR Challenge Program on Water and Food. Together these programs have engaged the participation of over a thousand scientists–they are the flagship programs for research on water, agriculture and development.

Limitations of the "More Crop Per Drop" Paradigm

The emphasis on "more-crop-per-drop" in IWMI's work, as outlined above, has undoubtedly been influential, but it also has a number of limitations:

1. It underplays the importance of water quality; the emphasis on potential re-use of the fraction of the water that is not consumed appears to suggest that such re-use can take place without a cost. However, virtually all water withdrawal and application leads inevitably to at least some quality degradation (salinization and other pollution) and costs energy. This explains IWMI's preference to measure water demands by their evapotranspiration, while others maintain a preference for water withdrawals as the key indicator.
2. The crop-per-drop concept does not accommodate the non-crop water outputs, fisheries and environmental services to the other multiple values water serves (from domestic water use to livestock watering). The implication is that while at farm or field level, the focus on crop water productivity can often be justified, on larger scales a broader definition of water productivity, which incorporates all values associated with water use, is needed. Only such a broader definition will serve the management of water across the many uses within a basin.
3. The implicit emphasis on irrigation of crops through renewable water resources, i.e., the part of the water cycle that runs off into rivers and recharges groundwater, (also called "blue water"), tends to underestimate the importance of the other 60% of the hydrological cycle that is stored as soil moisture, (the so-called "green water"). Through the growing importance of groundwater irrigation, small scale irrigation, rainwater harvesting and supplemental irrigation, the once sharp boundaries between rainfed and irrigated agriculture have largely disappeared. This requires a new, unified approach that examines the whole hydrological cycle and looks at water management for agriculture across the rainfed-irrigated spectrum.
4. Increasing water productivity is no more than a means to an end. One key objective is the reduction of poverty and hunger. Increasing water (and land) productivity may well be a significant factor in alleviating poverty in communities strongly dependent on access to productive land and water resources. It cannot be said, however, that improving water productivity will by definition have a positive impact on poverty, since access to resources (and the distribution of any net benefits) also plays a determining role in the final analysis.
5. Similarly, another often linked objective is the sustainable use of natural resources, i.e., the arrest or rehabilitation of resource overuse (groundwater depletion) and degradation (soil erosion or salinization). Increasing water productivity is unlikely to halt over-use of water locally. Indeed, it may in fact encourage resource intensification, as it is likely to increase the profitability of the farmer, whose productivity has increased. On a larger scale, assuming that the total demand for a given product or service stays constant, increased productivity in one location ought to displace water use at a lower productivity elsewhere, but not necessarily increase the sustainability of the resource use in the basin or sub-basin, where the productivity is increased.

Addressing the Limitations

In the period 2000-2005, IWMI has addressed a number of the limitations discussed above as follows:

1. The balance between water for food and water for nature has become the core issue on the agenda, and IWMI has

re-focused its research around the so-called water-food-environment nexus (Rijsberman and Molden, 2001; Rijsberman and Mohamed, 2003; Rijsberman and de Silva, 2004).

2. The linkages between water and land, salinization and soil degradation, water and land quality, nutrient cycling, and re-use of wastewater in peri-urban agriculture have become a central focus of IWMI's work (Scott et al. eds., 2004).

3. The improvement of water productivity across the entire blue-green, rainfed-irrigated, surface-groundwater spectrum has become the norm in the institute's work (Noble et al., 2004). This has also led to a re-assessment of the potential to improve water productivity in rainfed agriculture.

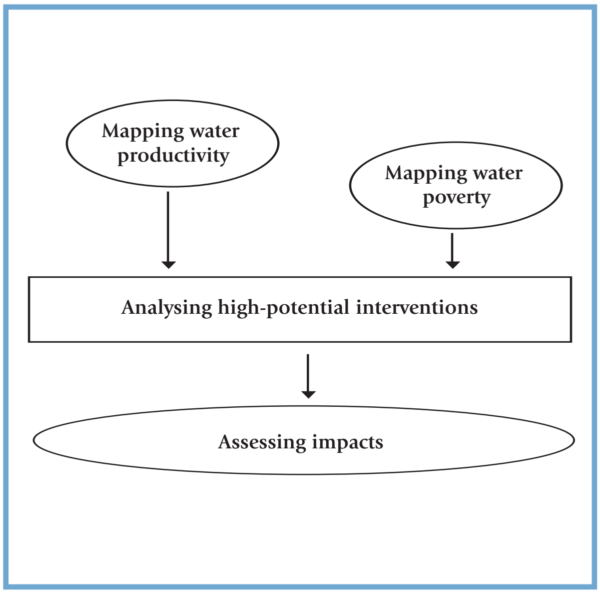
4. Assessing the impact of water productivity on the alleviation of poverty and hunger has become a central theme in IWMI's work as well (e.g., Maria Saleth, 2003).

Five themes were introduced with IWMI's 2000-2005 Strategic Plan:

1. Agricultural Water Management
2. Sustainable Land and Water Management
3. Groundwater Management
4. Water Resources Institutions and Policies
5. Water, Health and Environment

Each of these themes, their focus and research contributions are described in more detail in the following five summary articles.

Figure 1. IWMI Conceptual Framework



Early in 2005, IWMI's thematic structure was further tightened into four themes as follows:

1. Basin Water Management: understanding water productivity;
2. Land, Water and Livelihoods: improving livelihoods for the rural poor;
3. Agriculture, Water and Cities: making an asset out of wastewater;
4. Water Management and Environment: balancing water for food and nature.

Tightening up: the new focus

An external review of IWMI's work, (Wright et al., 2003), and the CGIAR Science Council review of the Challenge Program on Water and Food in 2004, motivated the development of a new, tighter conceptual framework. This is intended to provide a cleaner structure that will allow a sharp focus of the institute's work on its final objectives, i.e., contributing to the Millennium Development Goals related to, primarily, reduction of poverty and hunger and sustainable use of the environment.

Briefly, in this new framework IWMI's work falls into four blocks or activities–see also Figure 1.

1. **Mapping water productivity (WP):** to assess water (and land) productivity at basin level for key crops, (as well as combinations of crops and complementary livestock/fishery outputs, livelihood strategies, and environmental values), spatially disaggregated (to a useful level) across the basin; and to analyse the key variables that explain WP variations, (including soil/land degradation). The key idea is not to suggest that water productivity is a solution, but rather that it provides a valuable framework for understanding productive land and water use.

Photo Credit : IWMI Southeast Asia

Soil degradation affects many rural farmers in Southeast Asia. A discussion on soil remediation measures is led by IWMI and partners in Thailand.

Photo Credit : Sanjini De Silva

Ma Tshepo Khumbane, senior advisor to IWMI in the Water for Food Movement, works with rural women in South Africa, teaching them rain water harvesting, home garden production and food production.

2. **Mapping water poverty (WPv):** to assess spatial patterns of poverty and poor people's access to productive land and water resources throughout the basin. The basic idea is not to presume that increasing water productivity will alleviate poverty, but rather to identify the target group that could benefit from improved access to productive land and water resources.

3. **Analysing high potential interventions:** to identify, assess – and possibly develop – interventions, (technologies or combinations of technologies and institutions/policies, or policies), that can improve water (and land) productivity, as well as the access poor people have to productive water and land resources and the sustainability of natural resource use.

4. **Assessing impacts:** to assess the potential impacts of interventions on water (and land) productivity, as well as on water poverty–i.e., what would be the impact of interventions under different adoption scenarios, knowledge sharing models and development in exogenous variables, on water productivity, livelihoods, health and sustainability of resource use–at basin scales.

This new framework will help tighten the focus of IWMI's work in the years to come.

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Dr. Hugh Turral - *Theme Leader*

Research Theme 1 -

Integrated Water Management for Agriculture

"More Crop Per Drop" Moving from "Dry" to "Wet" Water Savings

Historically, water management for agriculture was equated with the development and operation of water systems and structures, largely for irrigation. However, the rapid growth of urban centers and industry has led to increasing competition for water across sectors. Thus, the key challenge now for agricultural water management is achieving "more crop per drop"–an approach that marked a paradigm shift in IWMI's thinking on how to increase food production for a growing population, while simultaneously meeting the water quality and quantity requirements of other economic and environmental sectors.

Irrigation management has been at the core of IWMI's research agenda since the institute's inception in 1984. Research initially focused on the operation, maintenance and efficiency of irrigation systems at the field and system scales. In response to the need for increased food production, the IWMI Theme "Integrated Water Management for Agriculture" changed in the mid-1990s, when strategies to improve the productivity of water for food and livelihoods became the central focus.

IWMI Research Report #1, *The New Era of Water Resources Management from "Dry" to "Wet" Water Savings* (Seckler, 1996) represented a major change in the Institute's overall view of water management: from one previously focused on system level analysis to a more holistic, basin scale approach. IWMI began to place irrigation management into the overall context of river basins and to examine the interlinking hydrologic, socio-economic and environmental aspects of water management at multiple scales.

The overall focus changed from improving water management from the traditional agronomic perspectives of higher yields and higher total production (land productivity) towards water productivity, where the focus is on improving the output from each unit of water used. IWMI's slogan therefore became "more crop per drop". In more recent times, "more crop per drop" has become an essential part of the larger picture in the valuation of water and its use.

Following from this shift, IWMI pioneered the change in thinking from yields per hectare to yields per cubic meter. Further, the concept of water productivity is now widely used in both scientific and popular writings, and measuring water productivity has become a standard when assessing water management performance, be it at field, system or basin level.

IWMI's Basin Paradigm

IWMI's Basin Paradigm, spearheaded by Dr. Seckler, focused on four implications of moving from irrigation system level to basin level

- **The importance of knowing whether basins are "open" or "closed".** In open basins, there are unused or unallocated flows out of the basin, while in a "closed" basin all water is already used for environmental or human consumption, and there are no further utilizable flows out of the basin. The concept of "open" and "closed" basins helped in determining which management strategies were most suitable.
- **The importance of understanding the recycling of water within river basins.** While individual irrigation systems may be "inefficient", recycling along the length of the basin may re-capture losses, leading to high levels of basin efficiency.
- **The effect of scale on the interpretation and importance of water use efficiency.** Finding ways in which water can be managed at all scales can enhance water productivity. IWMI's work helped develop practical tools for implementing and measuring water use efficiency.
- **The need to look at longer term trends in water supply and demand.** Much of the water used by humans is for agriculture. Therefore, water management practices need constant improvements to meet food targets with increasingly stressed water supplies.

The RIPARWIN project in Tanzania studies the balance between irrigation and wetland ecosystems. IWMI develops tools and methods to manage land and water resources to optimize agricultural production, while conserving freshwater systems.

Photo Credit : Hugh Turral

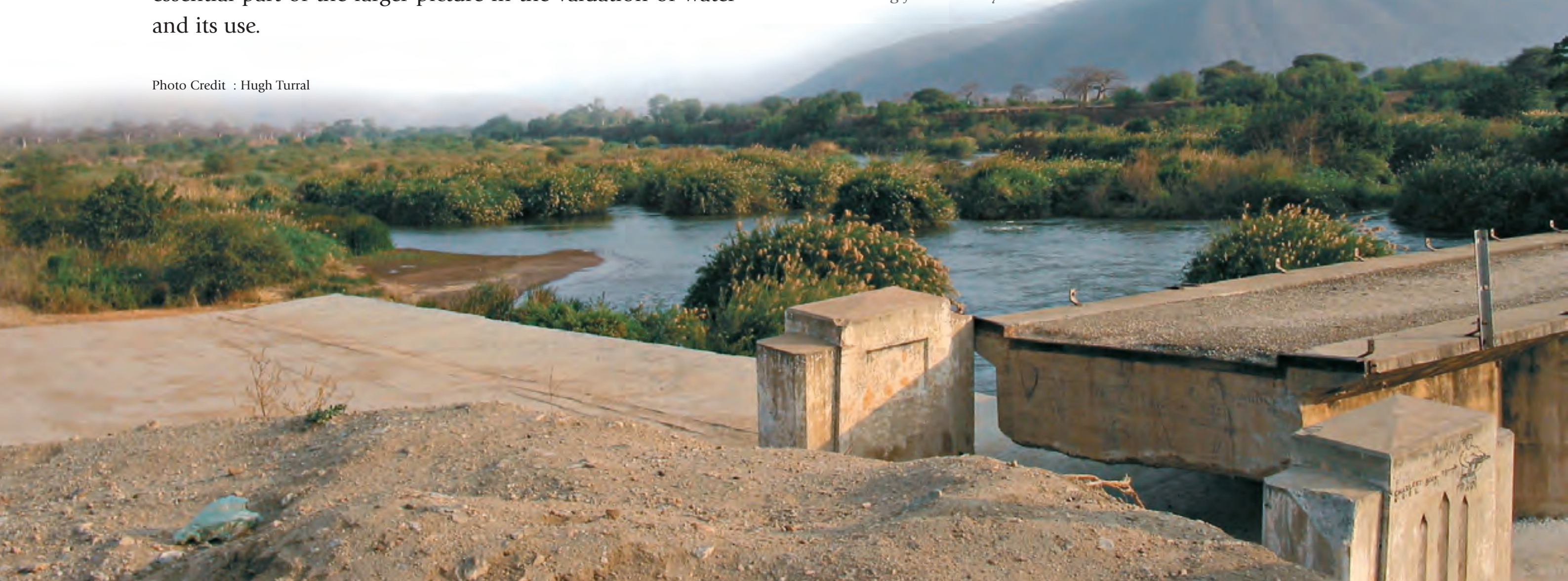

Photo Credit : Hugh Turral

The Pehur High Level Canal in Pakistan, where IWMI is doing work on "Operations Support" for a newly and extensively modernised "down-stream control" canal, supplying 180,000 ha, in NWFP.

Within this broader framework, IWMI's research over the past 10 years focused on 3 key areas:

Water Productivity at Basin Scale

Water productivity is a ratio between crop output and water delivered. Water productivity can be measured with respect to transpiration or water delivered at field, farm-gate or system level and in relation to land productivity. IWMI has made significant contributions to key water management concepts and tools such as water accounting (Molden, 1997) and hydronomic zones (Molden et al., 2001b); water productivity indicators (Molden et al., 2001a) and benchmark values for different crops under different conditions (Hussain et al., 2003); and water saving techniques (e.g., Barker et al., 2001).

Integrated Land and Water Modeling

Complementing IWMI's work on water management concepts and tools has been the development of modeling and analysis tools for improved water management at the basin scale. IWMI has developed an approach to modeling that now enables researchers to study the interactions between different water users within a basin. One high-impact product developed by IWMI is a global water scarcity map, which contributed to the World Water Vision (Cosgrove and Rijsberman, 2000). Further, modeling efforts together with in-house GIS and Remote Sensing expertise have supported the development of a suite of decision support systems for water allocation and management at a variety of scales (see e.g., Bastianssen et al., 1999; Droogers and Kite, 2001).

Operation, Maintenance and Management of Irrigation Systems

Finally, IWMI continues to examine irrigation system management for opportunities to improve performance, flexibility and reliability (e.g., Sakthivadivel et al., 2001). Almost all of IWMI's research on irrigation operation and management has revolved around the issue of level of service. This "level of service " concept accepts that users have a major stake in how water is allocated and delivered and that operation should be structured so that users are satisfied with the performance levels. IWMI's research generally concludes that there are no technical fixes that can overcome the lack of adoption of better service orientation and integrated technical, institutional and governance approaches are required (Research Report 17).

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Dr. Deborah Bossio - *Theme Leader*

Research Theme 2 -

Smallholder Land and Water Management

Putting Smallholders on the Road to Food and Livelihood Security

Despite the benefits of the Green Revolution, more than 1 billion people worldwide suffer from food insecurity. Declines in household food production are commonplace for about 60 percent of the rural population in tropical and sub-tropical countries. Land degradation has resulted in low productivity - partially due to poor land and water management practices and inadequate policies. These improper practices in turn directly impact on smallholders and cause off-site damage to downstream producers and the environment. The UN Millennium Development Goals (MDGs) are an urgent call for action to create a better world. IWMI's research on Smallholder Land and Water Management has focused on addressing three of these goals in particular: 1) eradicating extreme hunger and poverty, 3) ensuring gender equality and the empowerment of women, and 7) ensuring environmental sustainability.

The merger with the International Board for Soil Research and Management (IBSRAM) in 2001 brought issues of soil and land management firmly into IWMI's research agenda. It also served to expand IWMI's perspective from a former focus on large irrigation schemes to a broader view of the spectrum of options—large-scale, small-scale, irrigated, rainfed—available to farmers to enhance food production and livelihoods. Thus, in complement to IWMI's Agricultural Water Management Project, a key focal point of the Smallholder Land and Water Management Theme was to research mechanisms to improve water and land productivity of rainfed and small-scale systems at the catchment scale.

Rainfed lands in developing countries tend to be associated with poor farmers. In Sub-Saharan Africa, for example, rainfed agriculture accounts for 95% of the agricultural land and supports 70% of the rural population. Yields from these systems are low, and fertility management and supplemental irrigation can significantly reduce the chronic low productivity and crop failures that characterize the region. (Rockstrom et al., 2003) Further, recent stagnation in the growth of agricultural production in the green revolution areas in Asia has prompted policy makers to look in the same direction, toward rainfed agriculture, to continue the momentum of productivity growth that will be necessary to feed the growing world population. The negative impacts that unsustainable upland farming practices have on downstream populations and resources, and on biodiversity preservation, is an additional driver for this area of research that has lent increasing urgency to the task.

IWMI's research on Smallholder Land and Water Management has concentrated on the essential link between soil and water productivity in three focus areas: rainfed and small scale irrigation systems, catchment management and rehabilitation of degraded lands. The research was divided into the sub-themes, "Smallholder Productivity", which emphasized adoption, adaptation, and equity issues to increase access and productivity of water for smallholders; "Catchment Management", for integrated natural resource management (INRM) research at the watershed scale that encompassed on and off site impacts of resource management; and "Rehabilitation of Degraded Lands", because degradation of natural resources is so important, and because land and water degradation processes are interlinked.

Productivity of Smallholders

This area, identified in IWMI's Strategic Plan 2000-2005 as a sub-theme, provided a nexus on increasing food production to alleviate hunger and poverty, (First recommendation of the UN Hunger Task Force, 2004) and the emerging major opportunities to achieve significant impacts with water and

IWMI Southeast Asia has been working on the application of low cost bentonite clays, which rejuvenate degraded soil. Research has shown an increase in crop productivity where this technology has been used.

Photo Credit : IWMI Southeast Asia

Photo Credit : Sanjini De Silva

Central Asia suffers severe land degradation and water scarcity problems, which threaten the livelihoods of poor farmers. Here, a farmer cultivates his crop of liquorice trees, which hold the soil together while providing a means of income. Inset : Close –up of a liquorice root.

land (Copenhagen Consensus, Economist, June 3, 2004). The theme has analyzed different water and land management technologies and their opportunities and constraints for improving the livelihoods of smallholder farmers (e.g., Sally et al. 2000; Penning de Vries et al., 2002b). The research focus has been on technologies that can be implemented on an individual basis, by single farmers to upgrade their own farming systems, as this type of option has been very attractive to farmers in Asia, with substantial productivity benefits. The treadle pump and low cost drip irrigation have proven very effective in improving both water supply and water productivity in a range of situations. The primary focus for IWMI research was the integration of these technologies into social, biophysical and economic contexts of the smallholder farmer (Badiger, 2003).

Catchment Management

For farmers living in marginal lands in upper catchments, IWMI made significant headway in understanding the complex inter-linkages between the biophysical and socio-economic process that influences local land use practices and their downstream implications (e.g., Maglinao and Valentin 2003). Basic scientific research on erosion has yielded a new understanding of plot level and catchment level processes that are directly relevant to farming systems for sloping lands. These scientific contributions, particularly in the areas of long term effects of erosion, tillage erosion, weed ecology, and relationships between land use and catchment level sediment yields are embedded in an action research agenda that applies these results directly to farming systems (Maglinao and Valentin, 2003). Best practices and guidelines for sloping land agriculture that were developed have been adopted in national manuals and even in legislation in Southeast Asia, and some outcomes have been adopted in practice, such as Conservation Villages. Significant capacity building has taken place as represented by the numerous scientific publications produced by national scientists and students. All researchers in both IWMI's Asialand and MSEC networks have benefited from cross-country exchange, and their perspectives have gained a higher profile within the international scientific community.

Rehabilitation of Degraded Lands– "Learning from Bright Spots"

Finally, IBSRAM and later IWMI research on land degradation and related policy analyses (e.g., Penning de Vries et al., 2002a) has led to a relatively new area of research on 'bright spots,' where scientists are examining existing smallholder and/or community experiences in rehabilitating degraded agroecosystems and the opportunities for replication at different scales and in different locations (multiple manuscripts in preparation). The degradation of land and water resources which includes salinization, erosion, nutrient mining and pollution reduces the global capacity to produce food. It also reduces water productivity and environmental services. IWMI and colleagues looked at this issue from the angle of integrated soil and water management. IWMI's work focused on 1) assessment work focused on learning from 'Bright' spots 2) farm scale rehabilitation of light textured tropical soils and 3) understanding regional and global processes that contribute to land degradation. Looking systematically into the factors that contribute to the development of "Bright Spots", their impact on land and water and how such successes can be repeated elsewhere has become an important thrust of IWMI's research with significant support from other programs, such as the Comprehensive Assessment.

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Dr. Tushaar Shah - *Theme Leader*

Research Theme 3 -

Sustainable Groundwater Management

Unfolding the "Big Picture" on the Groundwater Economy

The use of groundwater revolutionized irrigation in many parts of the world, impacting the lives of millions of rural farmers in South Asia and North China, where over a relatively short period of time, it has become the mainstay of agriculture. In India, groundwater accounts for nearly 60% of the country's irrigated land, overtaking surface water in terms of total area irrigated. In Africa too, groundwater plays an important role within certain farming systems. The rapid growth in groundwater irrigation has brought many benefits to the rural poor. However, the intensification of groundwater irrigation is also threatening the resource together with the lives, livelihoods and ecosystems dependent upon it. IWMI's pioneering work on Sustainable Groundwater Management (SGM) has attempted to uncover the "big picture" of the groundwater economy and helped to fuse resource, user and institutional perspectives towards a better understanding of the groundwater socio-ecology. It has also mainstreamed key policy issues and built a network of local partners, while disseminating policy-relevant research results.

IWMI's groundwater work has been driven by the premise that groundwater management is not possible unless certain questions are asked and answered. What is the size of the national or regional groundwater economy? How much groundwater is diverted for irrigation? What is its opportunity value? Who benefits from it, and who loses from it? What is the technological configuration of the groundwater economy? These questions, seldom asked by either researchers or practitioners, have shaped the scope and direction of IWMI's groundwater research which attempted to expand the groundwater irrigation discourse from one dominated primarily by ecological concerns, to one that incorporates the huge impact of groundwater on livelihoods, incomes, poverty and productivity.

With close links to IWMI's other themes, IWMI's research on SGM, has focused on "the challenge of the balance", i.e., achieving sustainable use and management of groundwater in ways that promote food and livelihood security for poor women and men in Asia and Africa. IWMI's broader overview of the groundwater economy began with an IWMI discussion paper on the "Global Groundwater Situation", which served as a basis for stimulating discussions at the 2nd World Water Forum in the Hague (Shah et al., 2001.). Subsequently, a new body of IWMI literature on groundwater socio-ecology-virtually unparalleled in South Asia—was generated to add more substance and nuance to the emerging "big picture", as summarized in a paper for the 3rd World Water Forum in Kyoto (IWMI, 2003). More recently, IWMI's research on the groundwater socio-ecology has extended to the North China Plains, where groundwater irrigation has become a major factor, as well as to Africa, where the groundwater economy is thought to be evolving rapidly with little knowledge of its current use or management.

Apart from revealing the broader picture of groundwater irrigation, the SGM theme also focused on practical solutions to protect the massive welfare gains that groundwater irrigation has created, particularly in Asia, while minimizing the costs associated with its intensive use in agriculture. (Shah, 2003). This has included bringing the issues of promoting productivity, equity and environmental sustainability in groundwater use to the forefront of global, national and regional discussions. IWMI has also explored alternative institutional and policy approaches to sustainable groundwater management through comparative studies. Research results in all of these areas are summarized below.

Regional assessments of groundwater potential and impacts

IWMI's big picture analysis examined the factors that drove the spread of groundwater irrigation (Shah et al, 2000). For example, in South Asia, research showed that tubewell density closely followed population density and population pressure on agriculture. Research also drew attention to the environmentally unsustainable effects of groundwater irrigation which was dependent only on natural recharge from rainfall and limited surface run-off. Studies showed that the intensification of groundwater use in agriculture produced many beneficial impacts in terms of agricultural productivity, food security and poverty reduction at both macro and micro levels.(Debroy et al., 2003) However, because groundwater irrigation occurred through an informal market driven process, if left to itself, it also produced adverse effects which reduced the net social benefits.

Photo Credit : Courtesy IWMI- Tata Program

Rural woman with her treadle pump. In India, groundwater accounts for nearly 60 % of the country's irrigated land. IWMI is working towards fusing resource, user and institutional perspectives to establish a better understanding of the groundwater socio-ecology.

Photo Credit : Courtesy IWMI- Tata Program

IWMI's groundwater research has extended to the North China Plain, where groundwater irrigation is rapidly expanding. Here a woman "water lord" pumps water from a tubewell.

Groundwater and Public Health

IWMI groundwater research has also raised awareness of the links between groundwater quality and public health. For example, research carried out in Bangladesh revealed that groundwater supplies in 61 out of 64 districts in Bangladesh were contaminated with arsenic and an estimated 35 million people were at risk of being exposed to arsenic poisoning. IWMI initiated some work on this crisis in 1999 by carrying out a literature review based on situation analysis. Two other focal areas included 1) assessing the scale of present and likely future loss of human welfare on account of arsenic contamination and 2) identifying approaches that could be mobilized to eliminate or minimize such welfare losses. The Institute also assessed the prevalence of dental and skeletal fluorosis as a result of fluoride contaminated groundwater in North Gujarat and Southern Rajasthan.

Sustainable groundwater technologies and institutions.

Research on demand and supply management has focused on the range of policies and technologies available to promote more sustainable groundwater irrigation. In India, IWMI's research focused on the efficacy of several approaches including the promotion of micro-irrigation technologies, conjunctive use of surface and groundwater, market-based systems, and decentralized groundwater recharge. IWMI's research on groundwater recharge, for example, showed that earthen irrigation systems can be transformed into highly productive, region-wide groundwater recharge systems at very little cost and that groundwater recharge can ensure crop security and adequate water in times of drought. IWMI has also looked extensively into the water-energy nexus and the opportunities for jointly managing the two resources through indirect supply and pricing policies (Shah et al., 2003). IWMI's cross-country comparisons, however, suggests that appropriate solutions for groundwater management depend on a constellation of factors, and these differences have decisive impact on whether an approach that has worked in one country will work in another with a different context.

Translating Research into Action

The design of institutional interventions is an area where SGM has contributed at both national and regional level. Under the IWMI-Tata Program (ITP), built around a partnership between IWMI and the Sir Ratan Tata Trust Fund, SGM has worked with around 50 NGOs and local research institutions in India and organized over 20 consultations and workshops for researchers and policy makers. Much of the peer reviewed research has been translated into Water Policy Briefs, which are widely distributed among policy makers, researchers, donors and NGOs. At the grassroots level too, ITP's close collaboration with NGOs has made significant inroads in translating research findings into actionable recommendations on the ground.

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Dr. Madar Samad - *Theme Leader*

Research Theme 4 -

Water Resources, Institutions and Policy

Developing Frameworks and Tools for Good Governance and Management of Water Resources

Water scarcity is a growing threat to food security, human health and the sustainability of natural ecosystems. Research shows that by the year 2025, about one third of the population in developing countries will live in regions of severe water scarcity (IWMI, 2000). Irrigation water, which accounts for about 70 % of freshwater supplies in developing countries, is being increasingly diverted for domestic and industrial purposes. Yet, irrigated agriculture will continue to remain in the foreseeable future a principal means for producing enough food for a growing population and improving the livelihoods of poor men and women. The challenges faced by the water sector are exacerbated by distorted economic and non-economic incentives that have perverse consequences and highly fragmented institutions that are ineffective for allocating water across purpose.

Research on institutions and policies has occupied a prominent place in IWMI's research agenda since the inception of the institute. In the early years, the focus was primarily on two specific sets of activities: a) improving the performance of public organizations managing irrigation systems through improved designs and operational procedures and b) understanding institutional arrangements and management practices of indigenous farmer managed irrigation systems, and analyzing the external and internal stresses that constrain their performance levels. IWMI has done extensive work on these topics, and research reports published by the institute have been frequently used by specialists in designing new strategies for effective water management programs.

With the growing recognition of the importance of policy and institutional issues in irrigation management, a separate research program titled Policy Institutions and Management Program (PIM) was established in 1999 for carrying out research on policy options for optimizing water productivity and issues relating to institutions, poverty, food security, gender and inter-sectoral competition for water (Merrey, 1997). The present theme on Water Resource Institutions and Policy (WRIP) evolved as a logical succession to the PIM program. The primary aim of WRIP was to produce knowledge-based guidelines for best practices in policies, governance frameworks and organizational designs to improve land and water productivity for enhanced food security, livelihoods and environmental sustainability. The second aim was to engage in capacity building of national partners and collaborators to facilitate better research and development, policy formulation and the implementation of interventions for sustainable management of water and land resources.

Over the period 1995 to 2002, IWMI's research on policies and institutions was focused on the following broad areas:

Irrigation Management Reform

Irrigation Management Transfer (IMT) served as the cornerstone of the International Water Management Institute (IWMI) research agenda for nearly a decade. This focus resulted from growing evidence of under-performance of publicly owned irrigation schemes and widespread belief that the transfer of management responsibilities to farmer organizations could improve the management of irrigation systems and make irrigated agriculture more productive and sustainable. IWMI contributions to the topic included literature reviews and analyses of experiences and impacts of past IMT processes, advice to policy makers in planning and implementing IMT, and development of generic IMT guidelines and technical support for governments implementing IMT programs. The results of IWMI's research and related policy and operational recommendations have guided national policies relating to irrigation management in several developing countries. Further, guidelines on Irrigation Management Transfer prepared by IWMI and FAO have served as a reference tool to assist policy makers, planners and technical assistance experts and other stakeholders to design and implement irrigation management transfer programs (Vermillion and Sargadoy, 1999). More specific guidelines on Water User Associations have been developed for use in Central Asia.

River Basin Institutions

As IWMI's research focus evolved from irrigation management to water resources in the river basin context, a key practical outcome of the Institute's studies was that it helped create a greater awareness among stakeholders in the countries in which IWMI worked. New methodologies and

Most irrigated agricultural systems are still home to a large number of poor people. IWMI's research clearly shows that the provision of irrigation is indeed an effective instrument for poverty alleviation and is further enhanced when access to land, markets, education and other social capital are provided.

Photo Credit : Sanjini De Silva

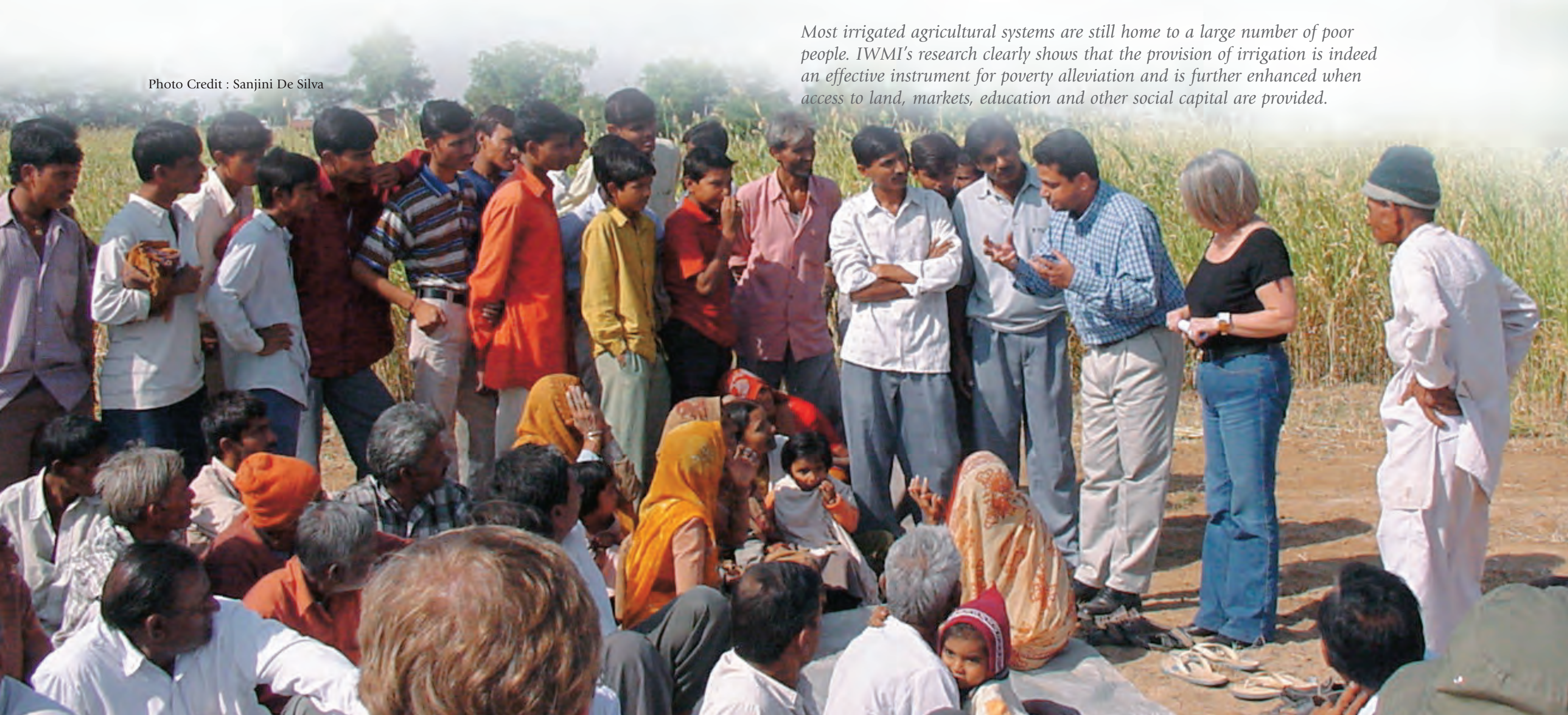

Photo Credit : Iskandar Abdullaev

IWMI is working with partners in the Ferghana Valley and other parts of Central Asia to strengthen Water User Associations and canal management institutions. Photo shows a WUA meeting in progress.

tools developed by IWMI such as "water accounting" (Molden and Sakthivadivel, 1998) and hydro-institutional mapping (Molden, Sakthivadivel and Samad, 2001) and a framework for institutional analysis for water resources management in a river basin context (Bandaragoda, 2000). IWMI's research has shown that there is no single organizational model of water policy and water resources management that applied universally. A country's ability to adopt new policies and institutions is highly contextual and is dependent upon the overall state of the economy, political system, legal system, cultural background and its physical resource base would circumscribe the policies and actions in the water sector. These parameters would also contribute towards determining the style and content of water resources management in any river basin (Bandaragoda, 2005). A Policy Dialogue on River Basin Management in May 2003 brought together senior policy makers and cabinet ministers from 10 countries, which led to the ministers unanimously adopting a declaration stressing the need for effective river basin management.

Mainstreaming Gender Issues

IWMI's research under this theme also addressed gender and water related research issues. A key outcome on gender issues was that research raised awareness and sensitized irrigation managers and policy makers about the needs and concerns of women irrigators in the planning of water allocation. To help translate positive intentions into concrete actions, IWMI pioneered the Gender Performance Indicator for Irrigation (Van Koppen, 2002). This sociological tool diagnoses the gendered organization of farming and gender-based inclusion or exclusion in irrigation institutions. It informs irrigation agencies as to what they can do to support effective change, if necessary. The tool also identifies gender issues beyond a strict mandate of irrigation water provision. The Indicator has been applied and tested by IWMI in nine case studies in Africa and Asia, and serves as one of the few gender studies that offer a practical tool to guide the interventions of policy makers, NGOs and senior irrigation managers wishing to achieve greater gender equity in their development projects.

Water Security for the Poor

Although irrigation has played a central role in poverty reduction, most irrigated agricultural systems are still home to a large number of poor people. Over the past few years , IWMI has implemented programs to analyze the link between water and poverty. An ADB funded project on pro-poor interventions in irrigated agriculture in Asia generated new knowledge and focused on issues that have been identified for further research. IWMI's research clearly showed that provision of irrigation is indeed an effective instrument for poverty alleviation. Poverty-reducing impacts of irrigation are enhanced when other complementary factors such as access to land, markets, education and other social capital are in place (Hussain, 2005).

IWMI was a founding partner of the Water and Poverty Initiative also spearheaded by the ADB and also a key contributor to the development of the Water Poverty Index formulated by HR Wallingford.

Water as a Free Good or Economic Commodity

IWMI's research has argued that water should be defined as both an economic good as well as a social good (Perry at al., 1997) IWMI has pushed for a blend of values and facts in the proper formulation of water policy. This called for a more in-depth and integrated analysis that recognized the fact that the value of water varies substantially over time and space. Recent studies have also addressed conceptual issues related to the economics of water productivity. Finally, IWMI research has examined how economic tools such as pricing, cost sharing and water markets should be designed and applied for the efficient use and conservation of water resources without disadvantaging the poor.

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Dr. Felix Amerasinghe - *Theme Leader*

Research Theme 5 -
Water, Health and Environment

Dr Amerasinghe passed away on the 7th of June 2005, after a year long battle with cancer. We wish to acknowledge the immense contribution he made to IWMI's research on water, health and environment issues.

Balancing Water for Livelihoods, Health and Ecosystems

Water-related diseases kill an estimated 4-6 million people every year but water is also a critical resource that provides food and livelihoods to countless millions. With increased food production and economic development, the human and environmental costs of using water have received inadequate attention. IWMI is committed to alleviating rural poverty and has recognised the vital contribution of agricultural systems to rural communities worldwide. Yet, if agriculture is to thrive, human and environmental health must be protected. It is this recognition that drove the Water Health and Environment (WHE) theme, which has identified ways and means of protecting human and environmental health through multi-disciplinary research. IWMI's research has looked at how irrigation water can be managed in ways beneficial to human health. It has identified opportunities to optimize the use of urban wastewater to improve livelihoods without the associated health risks. Finally, IWMI has also tested interventions to reduce mosquito breeding in streambeds and rivers.

The theme began with an IWMI hosted workshop focusing on the linkages between irrigation and vector-borne diseases in the mid-1980s. By 1987, continued interest in this area led to IWMI being elected as an official collaborating centre of the Panel of Experts on Environmental Management (PEEM). In 1994, through support from DANIDA, health research staff were seconded to IWMI, but not until 1997 was the human health aspect formally included in the mainstream of IWMI research under the 'Health and Environment' banner. Research at this point treated interactions between irrigation and human health and ecosystems independently, and it was only after the formation of the WHE theme that a truly holistic approach was adopted.

Today health and environment issues are well integrated in IWMI's theme research. Staffed by multi-disciplinary researchers cutting across the agricultural engineering, health and environmental divide, WHE since 1994 has concentrated on the sub-themes, of malaria and agriculture, wastewater and agriculture, multiple uses of water, pesticides, and ecosystems. These sub-themes while offering wide coverage, also directly relate to the Millennium Development Goals of combating malaria and other diseases, promoting environmental sustainability and forging global partnerships for development.

Malaria and Agriculture

Initially limited to Asia and to studying irrigation and its links to malaria (Amerasinghe et al., 1999) this sub-theme has evolved into a broad-based project that studies the interactions between water, land and people and has extended to cover Africa as well. IWMI has investigated the water-agriculture-livelihoods dimensions of the disease. This has generated new knowledge on the ecology of malaria vectors, the risk factors for the disease and feasibility of environmental management interventions to reduce the burden of malaria. For example, research in the Mwea irrigation scheme in Kenya experimented with the use of alternate wet and dry irrigation as a way to reduce malaria vector breeding in rice-growing areas.(Mutero et al., 2000) In the Yan Oya watershed in Sri Lanka, research demonstrated that regulating irrigation water releases could control mosquito breeding.(Matsuno et al., 1999). In Punjab, Pakistan, several studies focused on the problems of water logging and malaria and substantiated the importance of land use changes in the changing malaria patterns. The sub-theme has produced an extensive collection of publications on malaria research, educational audio-visual materials and established numerous links with local NGOs, universities, research institutes and health organizations. For example ,IWMI's GIS based malaria risk mapping initiative has helped personnel engaged in malaria control in Sri Lanka. The CGIAR recognised IWMI's contribution to malaria research by inviting the institution to lead the System Wide Initiative on Malaria in Agriculture (SIMA) in 2001.

Wastewater and Agriculture

Using untreated wastewater for irrigation, though hazardous, is a practical reality for poor urban farming communities worldwide, unable to afford expensive treatment options. Recognising this practice, the Wastewater and Agriculture sub-theme promoted a flexible approach to this practice where potential benefits are greater than the risks. The real extent of wastewater use is unknown and IWMI has been carrying out ground surveys in several countries as well as a global assessment. Based on research in Mexico, Pakistan, India, Ghana and Vietnam, IWMI studies showed that nutrient-rich wastewater gave a significant economic advantage to poor farmers. (Keraita et al., 2002) The

Photo Credit : Sanjini De Silva

Increasing water shortages cause competition among users and human health and environmental problems, which all contribute to reduce the benefits of irrigated agriculture.

Photo Credit : Courtesy IWMI South Africa

Wetlands are important ecosystems central to the lives of many people in rural communities of Southern Africa, who depend on them for their food and livelihoods. Here a woman cultivates her vegetable plot in the Limpopo River Basin.

"Hyderabad Declaration on Wastewater Use in Agriculture" was a key achievement resulting from an IWMI-IDRC conference in 2001. Recent USEPA guideline revisions have included the Declaration and data on the economic benefits of wastewater use provided by IWMI. Finally, Wastewater Use in Irrigated Agriculture, a joint publication by IWMI, CABI and IDRC, which critically evaluated worldwide experience of wastewater use, was a key IWMI output.

Multiple Uses of Water

Apart from water for crops, irrigation systems intentionally or otherwise provide water for domestic consumption, home gardens, livestock and also support other productive uses such as fishing, brick making and a host of other enterprises. However, the fact that irrigation water serves many stakeholders is not adequately recognized by water managers. In a situation of increasing water shortages and competition, this lack of understanding results in increasing conflicts among stakeholders, and in human health and environmental problems, all of which contribute to reduce the benefits of irrigated agriculture. For instance, when the agricultural sector takes measures to diminish water losses, access to water for domestic purposes may be greatly reduced and community health may be adversely affected. (van der Hoek et al., 2001) IWMI research in Kirindi Oya in Sri Lanka has established a framework for examining statutory and customary water rights for multiple users of water and also identified that irrigation water was utilised by a large number of non-farming groups. Research also showed that in areas with saline or brackish groundwater—like the Basse Moulouya irrigation scheme, Morocco or in southern Punjab, Pakistan—irrigation water was the only viable option for domestic use. IWMI's pioneering research in multiple uses of water has helped the issue gain international recognition and demonstrated the institute's strength in carrying out cross-disciplinary research.

Pesticides in irrigated agriculture

Pesticide use and abuse is indirectly influenced by water management decisions and is a serious problem within farming communities. IWMI researched this problem in Sri Lanka and Pakistan with an early-IWMI report making an important contribution to a Presidential Task Force on pesticide abuse in Sri Lanka. More recent IWMI research focusing on six hospitals in the southern region of Sri Lanka found that one third of all deaths in hospitals were a result of acute pesticide poisoning. IWMI has focused its policy work on pesticide poisoning on the regulatory framework aimed at reducing the availability and use of the most toxic pesticides at household level. Also, the possible role of integrated pest management as a means to reduce use in irrigated areas has been studied (Konradsen et al., 2003). National workshops in the two countries provided a forum for health and water management officials to meet and discuss the issue. The Sri Lankan workshop resulted in a publication, which is now a country resource handbook. IWMI in partnership with other international researchers has also provided momentum for policy recommendations like 'minimum pesticide lists', which limit the availability of toxic chemicals internationally.

Agriculture and Ecosystems

IWMI has looked at developing tools and methods to manage land and water resources in a way that optimises agricultural production, while conserving freshwater-dependent ecosystems and their biodiversity. Ongoing research has achieved a number of impacts. IWMI's eco-agriculture project in Sri Lanka has convinced authorities to conserve biodiversity hotspots within irrigation development areas. The hydrological model developed for the Karagan lagoon in southern Sri Lanka revealed risk of flooding due to upstream irrigation developments and resulted in the irrigation agency modifying the design. An ongoing study on environmental flows (Smakhtin et al., 2003) has generated international interest and shows promise of developing river basin scale assessment tools. In Africa, an inland wetlands initiative has looked at improving livelihoods without the usual ecological fallout associated with development. IWMI is now represented on key international bodies like RAMSAR and the Eco-agriculture Secretariat, with the institute's research in this area poised for robust growth and further impact.

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Dr. David Molden - *Theme Leader*

The Comprehensive Assessment of Water Management in Agriculture

Investing in Water for Food, Ecosystems and Livelihoods

The role of water in food and livelihood security is a major issue of concern in the context of continued environmental degradation and persistent poverty throughout the developing world. Using more water for agriculture threatens important food production systems and ecosystem services such as fisheries. On the other, hand less water for agriculture could lead to increased malnutrition and food insecurity. The stakes are high, the problems are complex, and there is contention about the best ways of managing and investing in water for agriculture. Assessments are a way to bridge science and policy, and to address complex questions. The Comprehensive Assessment of Water Management in Agriculture has been a major multi-institute initiative—filling gaps in the existing knowledge base to develop consensus on appropriate investment and management strategies to meet food and environmental security objectives in the near future and over the next 25 years.

The Consultative Group on International Agricultural Research (CGIAR) launched the System Wide Initiative on Water Management (SWIM) in 1995 as a major program dealing with broader water management and agriculture issues. In 2000 the initiative, convened by IWMI, was remodeled to bring CGIAR centers, together with a range of partners, to focus entirely on building the Comprehensive Assessment of Water Management in Agriculture (CA). The CA or SWIM-2 expanded the scope of SWIM by focusing on issues of global concern like hunger, poverty, and environment.

The CA critically evaluates the benefits, costs, and impacts of the past 50 years of water development and challenges to water management currently facing communities. It assesses innovative responses and explores the consequences of potential investment and management decisions. The results of the assessment will enable farming communities, governments, and donors to make better investment and management decisions. Ninety institutes worldwide are currently working on the Assessment research through over 40 different projects.

The first phase of the CA concentrated on knowledge gap-filling research and assessment tool development. The CA research agenda closely complements that of IWMI, with many IWMI projects contributing to and receiving support from the CA in the areas of water productivity, integrated water resources management, rainfed agriculture, land and water degradation, groundwater governance, irrigation impacts, and sustainable wetland management. The research agenda is further augmented by the wealth of expertise and projects carried out by CA's partner organizations.

The CA is now in its final phase: developing the Assessment report. Multi-disciplinary, international research teams are synthesizing the results of this massive research effort into the final Assessment report. The Assessment will have 15 chapters, including 8 thematic chapters on Rainfed Agriculture, Irrigation, Groundwater, Low-Quality Water, Fish, Rice, Land, and Basins and 4 cross-cutting chapters addressing water productivity, policies and institutions, ecosystems, and poverty. In addition, the Assessment will include a section on future scenarios and a summary for policy makers. The report will be formally launched in mid-2006 at the Stockholm Water Week and through a number of other forums.

The Comprehensive Assessment is filling in the knowledge gaps on how to address both human and environmental water needs in the face of persistent poverty and environmental degradation throughout the developing world.

Photo Credit : Courtesy the Comprehensive Assessment of Water Management in Agriculture

Assessing the Options

SWIM 2 researchers have been assessing several options put forward to change the "more food=more water" equation through options such as:

- Encouraging water savings and preventing the polluting of rivers and groundwater, reducing waterlogging and salinization and saving water.
- Increasing water productivity to gain more food or more value from the same amount of water.

According to a recent CA global study of environmental water requirements, over 1.4 billion people live in river basins, where high water use levels threaten freshwater ecosystems.

Photo Credit : Courtesy the Comprehensive Assessment of Water Management in Agriculture

- Upgrading rainfed systems by growing more on rainfed land, sometimes with the addition of supplemental irrigation, has the potential to increase water productivity and fight rural poverty.
- Reducing agricultural water consumption by influencing diets. Meat-based diets from grain-fed cattle deplete as much as 5,000 litres per capita per day, while vegetarian diets deplete less than half that amount of water.
- Encouraging trade in virtual water by allowing countries lacking water resources to import staple food from water-abundant countries, thereby saving their scarce water resources for higher value uses.

Of these options, research suggests that increasing water productivity in irrigated and rainfed systems, through innovative techniques and system upgrades offers the greatest potential for immediate, widespread application.

Photo Credit : Courtesy the Comprehensive Assessment of Water Management in Agriculture

Improving the productivity of water in rainfed and irrigated agriculture will leave more water for nature, communities, industrial and farming uses.

Research on Irrigation and Poverty

The CA has already generated a set of refereed research reports and nearly 50 peer-reviewed articles and book chapters. CA research on irrigation and poverty in Asia has demonstrated that while poverty remains an issue in canal systems due to inequitable benefit sharing and poor irrigation performance, irrigated areas tend to have higher productivity and wage rates than rainfed areas (Hussain et al., 2003). Further, research suggests a range of direct and indirect socio-economic costs and benefits accompanying irrigated agriculture not previously documented (Matsuno et al., 2002; Boisvert et al., 2003).

Environmental Impacts of Irrigated Agriculture

The CA has also made important contributions to understanding the environmental consequences of irrigated agriculture through the development of a global framework for assessing environmental flow requirements (Smakhtin et al., 2004) and analyzing the negative and positive externalities associated with an irrigated landscape (Galbraith et al., 2003). According to a recent CA global study of environmental water requirements, over 1.4 billion people live in river basins where high water-use levels threaten freshwater ecosystems (Smakhtin et al., 2004). This first view of environmental water scarcity shows that many countries are already having to make serious environmental tradeoffs to grow food, and that many more will be facing the same dilemma in the next 25 years.

Workshops and Conferences

The CA has played an important role in delivering key water, food, livelihood and environment messages at important workshops and meetings. It played a major role at the Stockholm Water Symposium in 2004, where the Blue Paper on Investing in Water for Food, Ecosystems and Livelihoods was presented. It reviewed several policy and water investment options-along with their livelihood and environmental implications. These preliminary findings were shared to raise awareness that water in agriculture is a pressing issue, that business as usual is not an option, and that there are potential solutions, but they are not necessarily the ones that have received the most attention (Blue Paper, 2004).

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