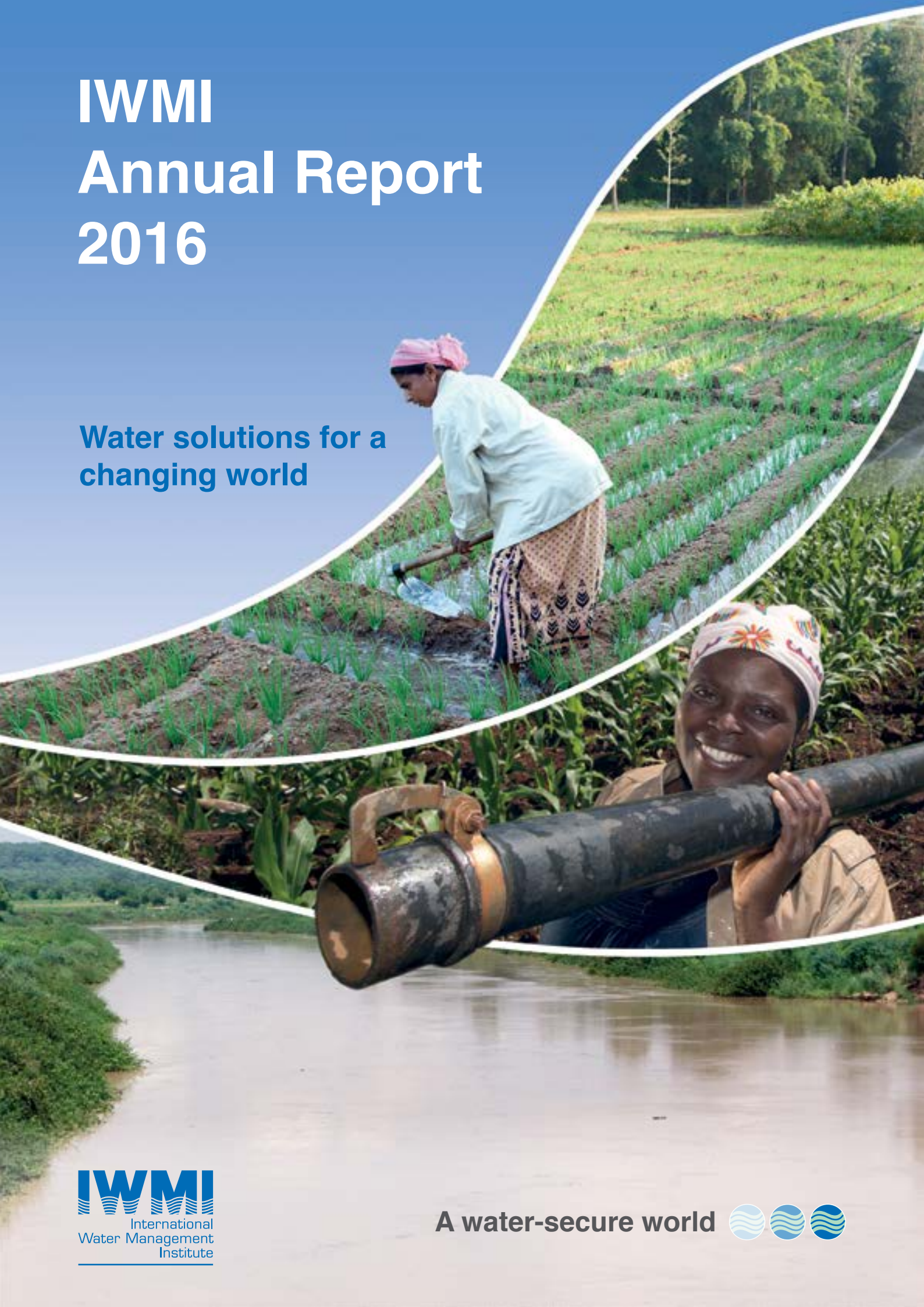
IWMI Annual Report 2016

Water solutions for a changing world



IWMI
International Water Management Institute

A water-secure world

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Drip irrigation in Nepal.

TURNING RESOLVE INTO ACTION

Message from our Board Chair and Director General

The Institute's primary contribution consists of innovative water solutions for a world of rapid social, economic and environmental change.

Pressure on the world's water resources is greater than ever, but so is the resolve of the global development community to do something about it. This is the clear message of the United Nations (UN) Sustainable Development Goals (SDGs), most of the national climate plans prepared for the Climate Conference in Paris, the High Level Panel on Water set up by the UN and World Bank, and a flurry of recent water conferences. Against this background, the International Water Management Institute (IWMI) forged ahead in 2016, delivering research findings that help translate heightened resolve into effective action.

Research momentum

The Institute's primary contribution, as shown in this annual report, consisted of innovative water solutions for a world of rapid social, economic and environmental change. Last December, for example, we launched an index-based flood insurance product in India, which greatly increases the speed and transparency of the process by which farmers receive money for claims (see pages 7 and 9). The product does so by using satellite data for damage assessment together with mobile technology to facilitate all steps in the process. IWMI research also provided new insights on the vital role of "natural" infrastructure (such as wetlands) in Kenya's Tana and West Africa's Volta river basins for achieving food, water and energy security (see page 16).

To keep up the pace of our work, we embarked on new projects and entered into new institutional agreements. For example, building on successful experience in our host country, Sri Lanka, we signed a memorandum of understanding with the UN Office for Project Services to deploy cutting-edge knowledge in South Asia for the recovery of resources from wastewater treatment through business approaches. In addition, together with WaterAid India, we embarked on a new project (supported by the Bill & Melinda Gates Foundation) that will create a viable business model for improved management of fecal sludge in a community along the Yamuna River near New Delhi.

Similarly, in the high-profile setting of World Water Week in Stockholm, we launched the Groundwater Solutions Initiative for Policy and Practice (GRIPP). The chief aims of this global, multi-partner effort are to raise awareness of the pressures on a vital "hidden" water resource, while calling attention to successes in the adoption of practices for sustainable groundwater management. In Stockholm, we were encouraged by the announcement that IWMI will serve as a collaborating partner in World Water Week 2017, the theme of which is "water and waste – reduce and reuse."

Maximum visibility

To gain maximum visibility and high-level support for IWMI's work, we engaged with prominent political and development leaders throughout the year. Mentioned below are just a few of many such instances.

IWMI took part in the first High Level Scientific Consultation Panel and Ministerial Roundtable for the Adaptation of African Agriculture to Climate Change, in Marrakech, Morocco. Its purpose is to secure a key place for agriculture on the climate agenda, thus ensuring that adaptation initiatives are eligible for climate financing.

Donald Blackmore
Chair, Board of Governors

Jeremy Bird
Director General

We were also pleased to accompany Anandiben Patel, Chief Minister of Gujarat, India, at the state's annual agriculture festival. During this event, the world's first solar irrigation cooperative received an award, recognizing a novel approach whereby farmers have the option of selling unused solar power and thus a clear incentive to use groundwater prudently. IWMI developed the approach in collaboration with the Tata Trusts and with the participation of two CGIAR Research Programs: Water, Land and Ecosystems (WLE), which IWMI leads, and Climate Change, Agriculture and Food Security (CCAFS).

IWMI scientists drew attention to key research findings and perspectives through active publishing, increasingly in open-access journals. Totaling 259, our outputs included a major contribution to the *Global Gender and Environment Outlook* (a first-of-its-kind publication from UN Environment).

Focused on development challenges

With the aim of focusing IWMI's research more sharply on high-profile development challenges, in late 2016, we began to reorient our work around three strategic programs and related global challenges: Building Resilience, Sustainable Growth and Rural-Urban Linkages. The programs are supported by various research groups, which provide the knowledge and solutions needed to deliver development outcomes. A key advantage of the new programs is that they will better enable IWMI to bring water management expertise to bear on emerging challenges, such as resource implications of rapid urbanization, new models of economic transformation and the increased vulnerability of rural communities to water-related risks and disasters.

IWMI research accounts for a large part of WLE, which completed its first phase in 2016. The program registered another solid performance this year, synthesizing results from multiple CGIAR research centers and hundreds of partners to achieve notable impact (see page 4). A second phase, starting in early 2017, focuses on equitable development opportunities for women and youth, restoration of degraded soils, reducing risk and building resilience in major agri-food systems through improved water management, and managing the influence of urbanization on rural landscapes.

Like many other international organizations, IWMI faced significant financial challenges this year, resulting from shifts in the global funding environment. The Institute's finances remain sound (see page 30), and our new challenge-oriented program structure and strong regional networks provide a firm foundation for action that can make improved water management a central driving force for sustainable, climate-resilient development.

Donald Blackmore
Chair, Board of Governors

Jeremy Bird
Director General

IN THE VANGUARD OF SUSTAINABILITY

CGIAR Research Program on Water, Land and Ecosystems (WLE)

In the 25 years since the Earth Summit first moved sustainability to the center of the global development agenda, to what extent has agriculture succeeded in putting the concept into practice? Given that agriculture remains a major contributor to ongoing degradation of the environment, the answer must be "not enough." Even so, by acknowledging the fundamental importance of achieving food security globally, while protecting the environment, the United Nations Sustainable Development Goals (SDGs) have set the stage for renewed efforts to achieve sustainable intensification of farming.

This is the background against which the first phase of WLE came to a close in 2016. The program has yielded a wide array of outcomes, which reflect scientific excellence and translate into marked changes in attitudes and practices, with significant progress toward impacts in terms of poverty reduction and improved natural resource management. These achievements and the transformative approach that made them possible represent an important contribution to CGIAR's Strategy and Results Framework, and provide a strong foundation for the program's second phase.

Collecting soil solution for testing in Kenya's Tana River Basin.

Numbers that tell a story

Since its start in 2012, **WLE** has **investigated 574 improved technologies** and **field tested 247,** prompting private and public sector partners to **disseminate 40 new options.**

About 330,000 farmers are applying improved technologies or management practices on 2.9 million hectares across the developing world.

WLE has also supported implementation of **six new policies,** dealing with a wide range of issues.

The program has provided **short-term** training for **48,778 people** together with **long-term** capacity strengthening for **1,090, 35%** of them women.

Solar-powered irrigation in India.

Opportunities for sustainable intensification

Water and land resources, if sustainably managed, offer enormous potential to intensify crop production, especially in areas that have yet to see major gains. WLE researchers provided vital evidence and innovative solutions that offer the means to realize this potential.

In West Bengal, India, for example, where groundwater is abundant, WLE facilitated policy changes that expanded electrical connections for tube wells, leading to improved irrigation on 250,000 hectares (ha). Benefits accrued to about 1.3 million farmers, who were able to boost incomes by shifting to high-value crops. In Gujarat, India, the program helped pilot the world's first solar cooperative. Using

In an important contribution to greener economies, WLE produced a suite of business models for waste reuse.

solar-powered pumps to access groundwater, it avoids over-pumping by offering farmers the opportunity to sell back excess solar power to the utility.

With the aim of identifying similar opportunities in Africa, WLE researchers developed maps showing the potential for irrigation with groundwater across the entire continent. The maps suggest that the practice could be expanded from just 2 million hectares (Mha) currently to 40 million Mha, much of this in the semi-arid Sahel and eastern regions stretching from Ethiopia to Zimbabwe.

In an important contribution to greener economies, the program produced a suite of business models for waste reuse and contributed to the development of a co-compost called *Fortifer*™, made from fecal sludge and organic waste (see page 26) in Ghana. In 2016, the product was approved for use and commercial production by the Ghanaian Ministry of Food and Agriculture, and May 2017 saw the launch of a co-composting plant in Tema, Ghana.

Ecosystem action

Enabling individual farmers, whole nations and regions to derive enhanced goods and services from ecosystems requires diverse interventions across scales. WLE has worked successfully at multiple levels to achieve this effect, starting with its influential role in shaping and monitoring indicators for particular SDGs and supporting national implementation plans.

Organic fertilizer pellets produced at the JVL *Fortifer*™ Compost Plant in Ghana.

The program has advanced the sustainability agenda through its work in a wide variety of geographical and institutional settings. Its research in support of water funds in Kenya and Peru, for example, helped secure major financial support for measures aimed at improving land management in upper watersheds, with benefits for rural communities as well as downstream consumers and businesses. WLE research on community-based fisheries in floodplains demonstrated how improved management and governance can sustainably increase fish production to reduce poverty and gender inequality.

WLE introduced an innovative approach – called Underground Taming of Floods for Irrigation – for tackling the dual threat of flooding and groundwater depletion, by which excess water is channeled into aquifers during the wet season. This can both reduce flood damage and boost agricultural productivity by increasing the amount of groundwater available for irrigation. In Rampur District, India, a WLE-supported pilot enabled remuneration of 2,000 people who participated in applying the new system, and the district has now included this in its irrigation plan.

Evidence-based decision making

Accurate data and information are critical for improved decision making on natural resource management, and WLE has developed a variety of innovations for this purpose.

To help governments and investors find opportunities for the restoration of degraded land, WLE prepared the *Soil Best Bets Compendium*, which supports more effective targeting of investments. The program also produced digital soil maps for sub-Saharan Africa, which provide information on soil properties, such as soil organic carbon, pH and nutrient content.

WLE is collaborating with scientists in Ethiopia, Ghana, Nigeria and Tanzania to prepare soil health baselines as part of the Africa Soil Information Service (AfSIS), which covers more than 28,000 soil-sampling locations. The service provides information that is critical for making smart land-use choices.

In collaboration with governments and the private sector, WLE is using advanced technology to provide accurate and timely information in response to extreme weather events. In Bihar, India, for example, the program has trialed a low-cost crop insurance product, which uses remote sensing and modeling to predict assets and potential losses. In 2016, 307,677 ha were covered by flood insurance and USD 34 million provided in compensation for losses. Finally, the South Asia Drought Monitoring System (SADMS), a regional drought-monitoring platform developed and managed by WLE, was used by the Sri Lankan Disaster Management Center to manage responses to severe drought in 2016.

Real-world science

To help communities realize opportunities for improved food security, livelihoods and resilience, WLE supported diverse interventions at the local level. Research on women's empowerment has demonstrated how innovative technologies, finance mechanisms and capacity development can improve women's access to irrigation – for example, through the use of small reservoirs in Ghana.

An experimental game approach has enabled local stakeholders to better understand the opportunities for improving community management of shared resources, such as groundwater. In Andhra Pradesh, India, and in Colombia, experimental game pilots helped water users understand how to solve groundwater challenges by addressing the problems cooperatively.

In the Mekong Delta, WLE mobilized "citizen scientists" to collect data that helps farmers manage the switch between shrimp farming and rice cultivation, depending on the salinity of the water available.

Banking on natural capital

Improvements in natural capital are critical for sustaining the gains that WLE research generates in crop productivity, livelihoods and ecosystem services. To this end, the program contributed substantially to global policies on the management of wetlands and other ecosystems. In support of the Ramsar Convention, for example, researchers promoted a people-centered approach for planning and management of wetlands. Similarly, their assessments prompted the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to put agroecosystems and agricultural biodiversity at the center of its work.

Global policies are only as good as the local efforts undertaken to put them into effect. WLE research in Ethiopia's Yewol watershed, for example, has led to improved productivity, crop diversification, improved water availability downstream and enhanced livelihoods for an estimated 15,000 people. The watershed now serves as a "learning site" for integrated watershed management, catering to extension agents and policy makers. Other work in Ethiopia and Tanzania is targeting areas at risk of land degradation for large-scale restoration.

Much remains to be done before sustainability becomes the norm rather than the exception in agriculture. However, in just 4 years, WLE has demonstrated convincingly that, by working across scales to put in place technological, institutional and policy innovations, it can help communities and societies make great strides in the right direction.

WLE is supported by the **CGIAR Fund** and through bilateral funding agreements.

Interviewing users of a small reservoir in northern Ghana.

LED BY:

IWMI International Water Management Institute

IN PARTNERSHIP WITH:

Bioversity International

CIFOR

CIAT International Center for Tropical Agriculture Since 1967 / Science to cultivate change

CIP International Potato Center A CGIAR RESEARCH CENTER

FAO Fiat Panis

ICARDA Science for Better Livelihoods in Dry Areas

ICRISAT International Crops Research Institute for the Semi-Arid Tropics

IFPRI International Food Policy Research Institute

ILRI International Livestock Research Institute

RUAF Foundation

World Agroforestry Centre

WorldFish

Before disaster strikes

IWMI is finding ways to help farmers whose livelihoods are affected by too little or too much water.

The increasing frequency and severity of droughts and floods is of global concern. IWMI is finding ways to increase countries' resilience to both phenomena, helping farmers whose livelihoods are negatively affected by too little or too much water. Among the Institute's achievements towards these goals in 2016 were: testing of the South Asia Drought Monitoring System (SADMS) and generation of estimates for crop yield forecasts for insurers; creation of an index-based flood insurance product to ensure that affected farmers get compensation for failed crops; and development of a "crop health card" system to verify weather-based insurance claims.

"Many governments have signed global agreements, such as the Sendai Framework for Disaster Risk Reduction and the SDGs," explains Giriraj Amarnath, leader of IWMI's Water Risks research group. "SDGs 1 and 2 are about ending poverty and hunger. If you want to achieve those, you need to increase resilience to disasters first through drought mitigation, flood proofing and making agricultural livelihoods resilient to climate change. We are trying to link our work on droughts and floods to the global sustainable development agenda and the Sendai Framework."

Watching out for drought

Conceived in 2014, the SADMS is an international collaboration that seeks to improve resilience and responses to drought. Every eight days, IWMI produces drought severity maps from satellite data, using parameters such as vegetation, soil moisture, temperature and rainfall.

During 2015 and 2016, the Institute worked to test and ground truth the system, at the country and state levels, with the aim of demonstrating its potential value to governments. Researchers also made the system available through an online portal. They were subsequently asked to collaborate on a project with the Indian Council of Agricultural Research (ICAR) to assess the potential of using the drought maps in management plans.

Rice planting after heavy floods in Vaishali District, Bihar, India.

Proof for payment

Many countries are now using index-based weather insurance to compensate farmers if climatic events ruin their crops. In 2016, IWMI launched its Index-Based Flood Insurance (IBFI) product, which is designed to safeguard farmers in locations at high risk of flooding. IBFI combines hydrological and hydraulic modelling with newly available high-resolution satellite images from the European Space Agency. Rainfall data for the relevant catchment are added to the model, which shows how runoff will travel and collect. If a trigger level is reached (calculated using 35 years of hydrological data), satellite images are used to verify the depth and duration of the flood. This accurately identifies the farmers that are eligible for compensation.

IBFI is particularly aimed at regions that suffer from frequent floods caused by rain falling outside their national or state boundaries. In 2017, IWMI will conduct a pilot project involving 1,000 households in 30 villages in the Indian state of Bihar. The plan is to test IBFI during the monsoon season from June to October. A subsidized public-private partnership model will be tested at the micro level, where individual farmers buy the insurance, and also at the meso level, where a group of farmers is insured jointly and receives subsidy support from the government. A similar project is planned for Bangladesh.

IWMI is currently developing an index-based drought insurance product as well. This will use satellite data to show levels of soil moisture in the top 15-30 centimeters of the soil, with farmers being compensated if the moisture level drops below a particular value.

Report cards on crop health

For such products to work, it is important that involved companies have confidence in the science used to underpin the insurance. In the past, some weather-based insurance products relied on low-resolution satellite data, which could not pinpoint affected fields very accurately. Therefore, IWMI developed a crop health card combining satellite images and photos in an easy-to-understand format to demonstrate the accuracy of the IBFI product.

"Using satellite images of fields before and after a flood, it is possible to show by the color of the field whether there were healthy crops that have been destroyed by the flood," says Amarnath. "It can help to ensure eligible farmers are compensated as well as in preventing fraud. Our goal is to encourage governments to invest in insurance by subsidizing schemes before disaster strikes."

This research is being conducted as part of two CGIAR Research Programs: Climate Change, Agriculture and Food Security (CCAFS) and Water, Land and Ecosystems (WLE), supported by the CGIAR Fund. Key partners include Japan's Ministry of Agriculture, Forestry and Fisheries (MAFF), the World Meteorological Organization (WMO) and Bajaj Allianz.

Too little water and too much: The satellite images compare a dry period with flooding around the village of Bihpur in Bhagalpur District, Bihar, India. Heavy rain upstream in the Ganges River Basin has caused major flooding in Bihar.

Growth for people and nature in Ethiopia

The idea is to scale up the lessons learned to other regions of Ethiopia and other countries in the Horn of Africa.

The mountains and forests of Ethiopia's Bale Eco-Region (BER) support a unique and diverse flora and fauna. Incorporating the Bale Mountains National Park, the BER is home to almost half the total population of Ethiopian wolves, along with vast forest areas that yield significant amounts of wild coffee and honey. Moreover, the whole region is a vast carbon store, providing ecosystem services that sustain the environment and people alike.

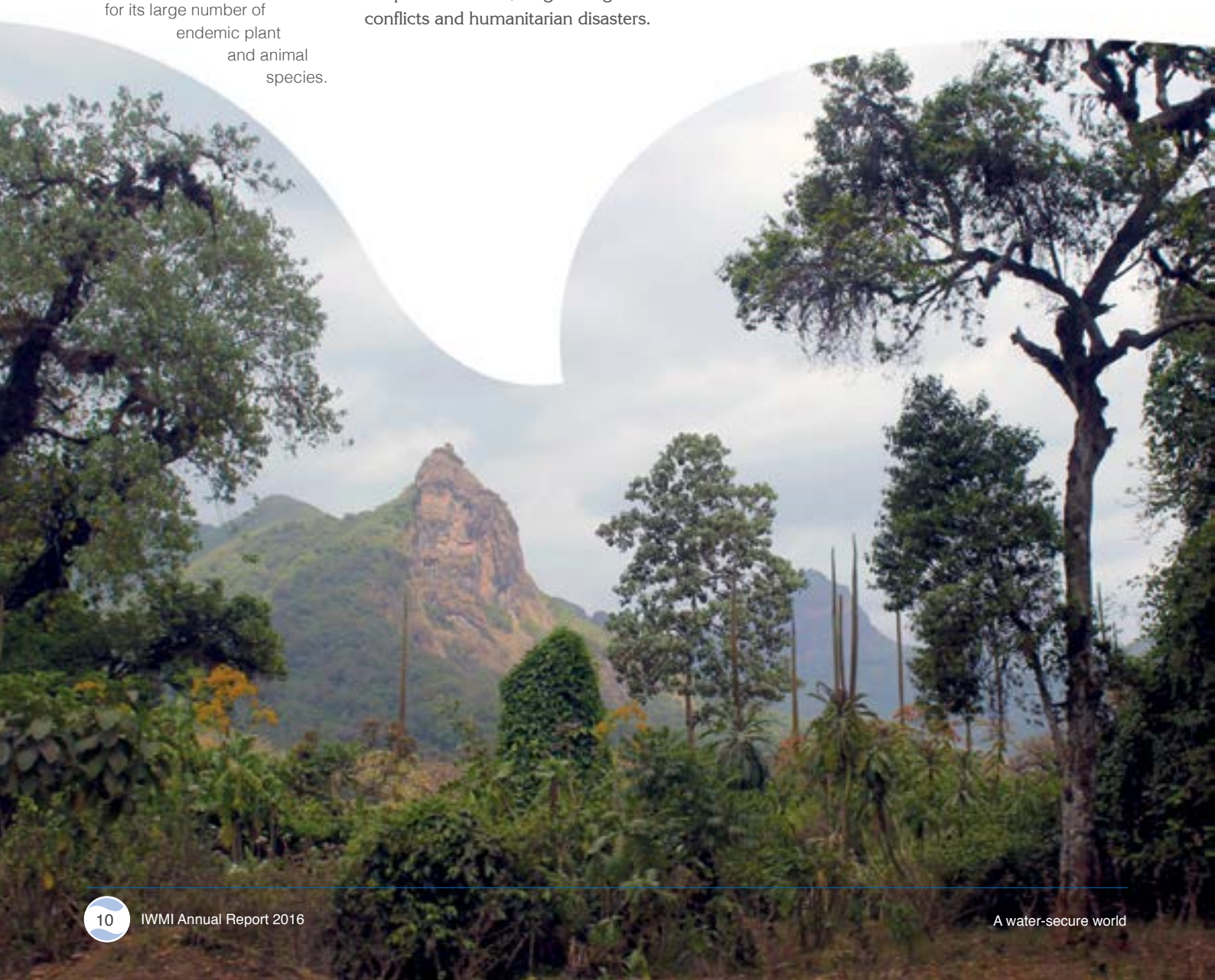
Some 1.6 million people live in the BER, many of them subsistence farmers who depend on the area's natural resources for their livelihoods. Rapid population growth and increasing numbers of cattle are raising competition for natural resources and prompting the unsustainable use of forests, land and water. Climate change makes the problem worse, heightening the risk of conflicts and humanitarian disasters.

Sustainable landscape management

Since 2014, IWMI has collaborated with Farm Africa, SOS Sahel Ethiopia, Frankfurt Zoological Society and Population, Health and Environment Ethiopia Consortium (PHEEC) on the Supporting Horn of Africa Resilience (SHARE) initiative. By working with communities to pilot solutions, the project´s interdisciplinary team aims to help BER's farmers manage resources more sustainably and become more resilient. This should also benefit people living downstream from the area.

"The project is unique in that it's very wide-ranging, addressing aspects from sustainable land use and family planning to water

Bale Mountains National Park, which is recognized internationally for its large number of endemic plant and animal species.



availability and livestock issues," explains Daniel Van Rooijen, SHARE-BER project coordinator for IWMI. "The aim is to enhance sustainable management of the region's natural resources and ecosystem services by building the capacity of local communities and strengthening governance. Before the project ends in 2017, we will produce a set of guidelines for sustainable management of the entire Bale Eco-Region, which can be applied in other regions as well."

There are three agro-ecological zones in the BER: uplands, supporting mixed crop and livestock farming; mid-altitude forests, from which farmers harvest wild coffee and honey; and lowlands, where pastoralism dominates. Biodiversity loss, soil erosion, erratic rainfall, seasonal flooding, droughts and groundwater depletion make life increasingly difficult for BER's farmers. Meanwhile, unsustainable farming practices, such as cultivating on steep slopes and overgrazing pastures, make matters worse.

Mobilizing students for research

IWMI is coordinating research associated with SHARE-BER in collaboration with the International Livestock Research Institute (ILRI) and Ethiopia's Water and Land Resource Centre (WLRC). The research encompasses hydrology and hydrometeorological monitoring; socio-economic aspects of BER; trade-offs and the optimal allocation of development assistance; payment for ecosystem services; and access to and demand for family planning versus natural resource management and livelihood planning.

Nine master's degree students from Addis Adaba, Arba Minch, Hawassa and Madda Walabu Universities have received financial support from the project, along with supervision from IWMI and review of their theses in 2016. With data in short supply in Ethiopia, hydrological and hydro-meteorological monitoring has been fundamental to the project. For this purpose, IWMI and WLRC installed a weather station and cross-section in each of the three agro-ecological zones in the BER. Scientists from the Institute, assisted by the master's degree students, are now monitoring weather patterns, water flow and sediment load.

Maps that make a difference

The Institute is also working with WLRC to produce watershed development maps, indicating where pastures might be better fenced off and left to grow, which areas would benefit from being forested and where it might be beneficial for farmers to grow, in particular, climate-smart crops.

Project partners take these maps to communities to discuss potential actions they can take to enhance the environment. The hope is that, as farmers learn to adopt more sustainable farming practices and forest degradation is reversed, IWMI will detect a corresponding fall in sediment loads, a rise in dry-season flows and an attenuation of peak flows in the wet season, reflecting the positive change in practices.

With the 40 springs and five major transboundary rivers that emerge in the BER providing water to an estimated 12 million people in Ethiopia, northern Kenya and the Republic of Somalia, even small improvements could have a big impact. "SHARE-BER is a pilot project, and the idea is to scale up the lessons learned from the BER to other regions of Ethiopia and other countries in the Horn of Africa," says Van Rooijen.

The SHARE Bale Eco-Region project is part of the European Union-funded Supporting Horn of Africa Resilience (SHARE) program. It also contributes to the CGIAR Research Program on Water, Land and Ecosystems (WLE).

Weather station managed by a local community in the heart of the Bale Ecoregion.

India's irrigation reforms

The government has taken up IWMI recommendations and is developing a new USD 4.61 billion scheme to expand small-scale irrigation.

Unpredictable and variable rainfall makes farming in India a precarious livelihood. Across much of the country, rainfall is concentrated during the monsoon, from July to September, with the other months being dry. Farmers without irrigation struggle to grow more than one crop a year. Although much money has been invested in irrigation over the years, poor governance means these schemes have not always been as effective as they should have been.

Water to every farm

While campaigning for election in 2014, India's governing party promised *har khet ko pani* (water to every farm). Once in power, Narendra Modi's government committed USD 7.75 billion to this ambitious task under an irrigation scheme named Pradhan Mantri (Prime Minister) Krishi Sinchayee Yojana (PMKSY). The IWMI-Tata Water Policy Research Program (a longstanding collaboration between IWMI and the Tata Trusts) analyzed recent irrigation reform in several Indian states, using data from various public sources. Its aims were to suggest the best pathway for implementing PMKSY and to highlight successes the scheme could emulate.

"Our findings showed that there are two low-hanging fruits that India can use to progress towards *har khet ko pani*," says Tushaar Shah, senior fellow at IWMI. "The first is to strengthen irrigation governance, with the aim of bridging the widening gap between the irrigation potential that has been created and the potential that is actually used. The second is to invest in expanding groundwater irrigation where its development has previously been limited, with emphasis on minor irrigation and with improved policies for renewable energy to counteract depletion.

The IWMI-Tata Program published its findings in a special policy paper titled *Har Khet Ko Pani*? (Water to Every Farm?) Rethinking Pradhan Mantri Krishi Sinchai Yojana. The paper identifies the 112 districts that are most deprived of irrigation and which should therefore be the primary focus of PMKSY. It further argues that recent irrigation reforms in Madhya Pradesh and Gujarat set a good example for the scheme to follow, as opposed to those undertaken in Maharashtra, Andhra Pradesh and other states.

A holistic approach

"The bulk of the 40 million hectares (Mha) of newly irrigated area post-1990 depends on wells, tube wells and private small-scale lift irrigation," says Shah. "Farmers prefer this type of irrigation, because it can be implemented quickly and cost-effectively, permitting on-farm water control all year round, in contrast with

Groundwater for irrigation in India.

large canal irrigation systems. From 2000-01 to 2012-13, Maharashtra and Andhra Pradesh made massive investments in large public irrigation projects, but the index graph of irrigated area remained flat or declined. By comparison, the same graphs drawn for Madhya Pradesh and Gujarat revealed a strong upward trend, despite more modest financing."

The expansion of irrigation in Madhya Pradesh came about after it swept away a culture of mismanagement and adopted a holistic approach to water management. A program of regular maintenance of canal systems was introduced, with stringent deadlines set for repairs and timetabled checks on progress. Also, a "tail-end first" policy was adopted. This guaranteed water to farmers located at the end of canals, provided they could prove their fields were water-ready.

Water scheduling was improved, so farmers knew exactly what they were getting and when. The irrigation department began using digital technology to improve communications. Regular video conferences kept canal managers informed, while the chief engineer kept in touch with 4,000 farmers by mobile phone.

The energy-irrigation-food nexus

IWMI's earlier research in Gujarat had put into bold relief the beneficial impact on irrigation of restricted but high-quality farm power supply under the *Jyotigram Yojana* ("lighted village") scheme. Madhya Pradesh also improved how farmers use groundwater by introducing temporary, 90-day power connections, which guarantee farmers a high-quality power supply against advance payments. This has enabled smallholders to produce more winter (*Rabi*) wheat. Remote sensing images prepared by IWMI indicate that, as a result of the combined canal and groundwater irrigation reforms, Madhya Pradesh's cropped area has expanded by 1.90 Mha (an area around the size of Israel).

In May 2016, IWMI held a policy consultation at the India Habitat Centre, New Delhi, to present an alternative formulation for PMKSY that prioritized the 112 districts that are most deprived of irrigation. It drew on the experience of states including Madhya Pradesh and Gujarat (which had achieved an agricultural growth rate of 9% during 2000-08 after making similar reforms, on IWMI's advice).

"Spending billions of rupees on grand irrigation projects is risky," says Shah. "But some Indian states have managed to invest effectively in irrigation improvements, and it is important that those lessons are incorporated into the design of PMKSY." The government has taken up key IWMI recommendations and is developing a new USD 4.61 billion scheme to accelerate the development of small-scale irrigation, focusing on 97 of the 112 high-priority districts identified in the report by the IWMI-Tata Program.

IWMI's research on irrigation reform in India derives from a large body of policy research undertaken since 2011 as part of two CGIAR Research Programs – Water, Land and Ecosystems (WLE), which IWMI leads, and Climate Change, Agriculture and Food Security (CCAFS) – and with financial support from the Tata Trusts.

In India, 112 districts have low access to irrigation and high levels of untapped groundwater.

Getting a GRIPP on groundwater

Enabling more farmers to pump groundwater can boost production and rural incomes, while making communities more resilient to climate shocks.

Enabling more farmers to pump groundwater can boost agricultural production and rural incomes, while making communities more resilient to climate shocks. Sustaining these benefits, however, requires informed approaches for farmers and resource managers.

At present, groundwater supplies around 40% of the world's irrigated land, so there is potentially room for many more farmers to tap into this subterranean resource – especially in areas of limited irrigation development, such as sub-Saharan Africa. However, as much as a fifth of the food currently produced with groundwater globally relies on unsustainable extraction. Depletion of groundwater is greatest in South and East Asia; the countries of the Organisation for Economic Co-operation and Development (OECD), especially the USA; and the Near East and North Africa. Overexploitation results in falling water tables, deteriorating water quality, environmental degradation, increased pumping costs and lower crop yields.

How to manage a hidden resource

During the 2016 World Water Week in Stockholm, Sweden, IWMI launched the Groundwater Solutions Initiative for Policy and Practice (GRIPP), with the aim of helping developing economies use their groundwater resources sustainably. GRIPP unites 30 international partners (research organizations, associations, networks, universities, geological surveys, NGOs, private companies, and international donors) – including the International Groundwater Resources Assessment Centre (IGRAC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). Their shared aim is to advance the agenda of sustainable groundwater management globally toward achievement of the UN Sustainable Development Goals.

"Groundwater is a hidden resource that many people rely on, especially in arid and semi-arid areas and during droughts, but few countries actively manage it," says Karen Villholth, GRIPP coordinator and leader of IWMI's Groundwater research group. "In some locations, the resource has been severely depleted and degraded by indiscriminate pumping and unwise land use within only one generation and with detrimental impacts on societies and the environment. We need concerted efforts and global-to-local alliances for better management of a resource that is often ignored."

The novelty of GRIPP is that it applies multidisciplinary expertise from a diverse set of international organizations to sustainable groundwater management – through joint project development, international advocacy

and dissemination of lessons learned, including the GRIPP website (http://gripp.iwmi.org/) and a series of Groundwater Case Profiles from around the world.

The overexploitation of groundwater has reached critical levels in parts of the Middle East and North Africa. Governments across the region have developed a wide array of policies in an attempt to tackle the problem. The Groundwater Governance in the Middle East and North Africa project sought to identify the most successful of these initiatives for transfer elsewhere. Among the more effective measures considered for the region were using smart meters to ensure that groundwater is used equitably and managed aquifer recharge, which tops up groundwater with wastewater or rainwater during rainy seasons for use in dry periods.

"Tunisia has been using managed aquifer recharge since the 1970s as a means to improve groundwater quality and quantity," explains IWMI researcher Alvar Closas. "Today, wastewater in Tunisia still causes pollution, and the country continues to expand aquifer recharge with wastewater. At present, 4% of aquifer recharge originates from treated wastewater, helping aquifers to recover and preventing the salinization of coastal aquifers caused by intruding seawater – a side effect of groundwater overabstraction."

Aquifer exploration

One challenge with using groundwater sustainably is uncertainty about the size of the available resource. Traditional survey techniques, such as drilling boreholes to create subsurface maps, are time- and labor-intensive, often requiring access to remote areas. In recent years, Danish technologists have developed a new system with the potential to revolutionize groundwater management. Called SkyTEM, it involves using a helicopter-borne transmitter and receiver to record variations in electrical resistivity. These measurements reflect the underlying soil and rock types, enabling a three-dimensional geological model to be created. From this, the water-bearing capacity and potential areas for groundwater exploration can be assessed with reasonable accuracy.

With the help of the US water exploration company XRI Blue, SkyTEM and Savannah Helicopters, IWMI scientists used the technique in 2016 to produce the first-ever three-dimensional maps of the transboundary Ramotswa Aquifer shared between Botswana and South Africa, which is one of the most important groundwater resources in the Limpopo Basin. The data were gathered through the IWMI-led Potential Role of the Transboundary Ramotswa Aquifer project, which is part of the Resilience in the Limpopo River Basin program. The project aims to develop a strategic action plan for the aquifer, so that the water needs of ecosystems, and rural and urban populations can be met in a sustainable manner.

"A better understanding of this groundwater resource will contribute significantly to overcoming water insecurity in the face of rapid climatic, demographic and socio-economic change in the border region," says Villholth.

GRIPP forms part of the CGIAR Research Program on Water, Land and Ecosystems (WLE), supported by the CGIAR Fund. The United States Agency for International Development (USAID) has provided funding for the Groundwater Governance in the Middle East and North Africa project and the Potential Role of the Transboundary Ramotswa Aquifer project.

Irrigating with groundwater in Zambia (opposite) and in Laos.

Striking a balance between nature and development

The aim is to gain insights into how we can combine built infrastructure with "natural infrastructure" for the benefit of all.

Globally, investment in reservoirs, dams, irrigation channels and other built infrastructure has increased enormously in recent decades and is set to expand in the near future. Although such investment contributes importantly to economic growth, it typically also comes at a cost to the environment and to people, often the poorest, who depend on natural resources for their livelihoods.

Since the mid-1990s, we have gained a better understanding of ecosystems and the critical services they provide – from reducing floods to underpinning fisheries and supporting healthy soils. However, population growth and rapid development in many countries are placing more demands than ever on natural resources. Balancing the need for water, energy and food security, while preserving ecosystems and their benefits, is increasingly a challenge.

Nature-based solutions

To help respond, over the last three years, IWMI has been a partner in the Water Infrastructure Solutions from Ecosystem Services Underpinning Climate Resilient Policies and Programmes (WISE-UP to Climate) project. It seeks to demonstrate how ecosystems can provide "nature-based solutions" that contribute to climate change adaptation and sustainable development. The aim is to gain insights into how we can combine built infrastructure with "natural infrastructure," such as wetlands, floodplains and watersheds, for the benefit of all.

In this collaborative effort, IWMI is working with the Basque Centre for Climate Change and the University of Manchester in the UK on analysis of investment in ecosystem infrastructure. The UK's Overseas Development Institute (ODI) is examining the political economy of water infrastructure decision making and governance. The organization leading the project, the International Union for Conservation of Nature (IUCN), is overseeing "action learning," aimed at strengthening the use of evidence and tools in policy making, decision making around infrastructure, and consensus building. The

Near the Akosombo Dam on the Volta River.

African Collaborative Centre for Earth Science Systems (ACCESS), in Kenya, and Ghana's Council for Scientific and Industrial Research - Water Research Institute (CSIR – WRI) are engaged in the project's case studies, with a focus on capacity building and communications.

The project covers two major river basins: the Tana in Kenya and the Volta in West Africa. Both have considerable built infrastructure with plans for constructing more dams and reservoirs. "One future trajectory is to simply carry on building large infrastructure, particularly big dams," says Matthew McCartney, leader of IWMI's Water Futures research group. "However, we're trying to demonstrate how investing in natural infrastructure will assist with adaptation to climate change impacts."

Tackling trade-offs

IWMI's first role was to define "benefit functions" – essentially quantifying the relationships between river flow and ecosystem services. Examples of useful ecosystem services in the Tana and Volta basins are floodplain fisheries, flood-recession agriculture, reservoir fisheries, estuary fisheries, cattle grazing on the floodplain and sediment transport out into the ocean (the latter is beneficial in the case of Tana, as it helps maintain beaches that are valuable to Kenya's tourism industry). IWMI scientists then modeled flow levels under different climate change scenarios to assess potential impacts on ecosystems and their benefits.

"For each ecosystem service, we looked at the link between flow and the magnitude of the service provided," says McCartney. "That information was fed into an optimization model run by the University of Manchester. They ran thousands of scenarios, incorporating the built infrastructure and its operation, and extracting the benefits and trade-offs in each case. This enabled them to, for example, assess trade-offs between hydropower and floodplain fisheries for a wide range of possible futures."

Action learning

One important lesson learned from the project is that relationships are not always easy to predict in such complex systems and can sometimes be counterintuitive. In the Tana Basin, for example, investing in upstream nature-based infrastructure, such as soil conservation measures, will reduce the sediment entering the river and thereby reduce reservoir siltation. However, if the local hydropower company uses the additional reservoir storage gained to simply maximize hydropower production, this will reduce the water available for downstream ecosystem services, such as floodplain fisheries.

Thus, planning and management need to be comprehensive, factoring in the full range of benefits and the intricate trade-offs between them. By including analysis of how decisions are made across the basins and by holding regular "action learning" events to share and discuss findings with stakeholders, project researchers hope to motivate power companies, governments and other decision makers to consider alternatives for basin and national development that make use of natural infrastructure.

"Dams and other built infrastructure are essential for socio-economic development," says McCartney. Through the WISE-UP to Climate and other projects, IWMI can influence future planning and investment in ways that continue to facilitate economic growth but are more equitable and sustainable.

The WISE-UP to Climate project is led by the International Union for Conservation of Nature (IUCN). This project is part of the International Climate Initiative – Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Germany. IWMI's participation forms part of the CGIAR Research Program on Water, Land and Ecosystems (WLE), supported by the CGIAR Fund.

Terracing for erosion control in the Tana River Basin.

A collective farming comeback

Access to irrigation and better knowledge has enabled one group to grow three crops a year – a 300% increase in cropping intensity.

Across Asia, farmers struggle to cultivate very small and marginal parcels of land. Many are tenant farmers, who are expected to hand over half of what they produce to their landlord. Knowing that they will not benefit fully from any investments they make, farmers have little incentive to purchase fertilizer, irrigation equipment or high-quality seeds. This stifles production and encourages farmers to reject agriculture in favor of finding work in far-off cities. Those left behind, who are often women, struggle to continue cultivation due to shortages of labor.

Farmers join forces

Since 2014, IWMI has been working on a project in India and Nepal that aims to overcome such challenges by encouraging farmers to join forces. The Institute is jointly leading the project (Improving Dry Season Irrigation for Marginal and Tenant Farmers in the Eastern Gangetic Plains) with the University of Southern Queensland, Australia; additional support comes from the Indian Council for Agricultural Research (ICAR), Nepal's Department of Irrigation, North Bengal Agricultural University and local nongovernmental organizations (NGOs). Five farming groups have been established in the Indian state of Bihar; a further six are up and running in West Bengal; and six have been set up in Nepal.

"We're piloting different models, so some groups are pure collectives, which means that all the labor and profits are shared," explains Fraser Sugden, a senior researcher with IWMI. "Others are cooperating, in that they're leasing the same piece of land, but they're cultivating it individually. IWMI has supported each group by providing irrigation technology and training. The groups have learned about using surface water and groundwater, different kinds of drip systems, more efficient ways of distributing water and the best kinds of crops to grow given their specific conditions."

The groups in Bihar and Nepal mostly comprise women farmers and are women-led, while those in West Bengal are more mixed. Before the project, most farmers were only producing one crop of paddy rice a year. However, in addition to monsoon paddy, they

Introducing solar-powered irrigation at Kanakpatti village in Nepal's lowland Saptari District.

now cultivate wheat, pulses and vegetables in the dry season. Having access to irrigation and better knowledge of what crops to grow has enabled one of the West Bengal groups to grow three crops a year – a 300% increase in cropping intensity.

Building a business case

The year 2016 was a turning point for the project, as it was the first full year of production for the groups. IWMI is monitoring crop yields, the use of fertilizers and pesticides, productivity, water use, water-use efficiency, income per household, functioning of the groups and resolution of conflicts. The idea is that, by monitoring the groups and resolving any issues that arise, researchers can develop a business case for establishing successful farming groups and collectives elsewhere.

"One thing we've learned is that it's better if the groups are completely homogenous," says Sugden. "Originally, one of the groups was a mixture of landless farmers and land-owners. The farmers with land were voluntarily giving it to the group. Although they were all farming it together, there was a definite feeling of inequity between those who had land and those who didn't. We're trying to set up a separate group for landless farmers. More positively, one of the main things the farmers bring up is that they're using labor more efficiently through the collectives."

Irrigation with a difference

Sugden and his colleagues are exploring ways to ensure the groups are sustained after the project ends in 2018. One possibility is to set up a federation through which the farmers can remain in contact with each other and share their experiences. The hope in the long term is to scale up the project, using the lessons learned on which kinds of groups function best.

Collective farming has often been written off as irrelevant in the 21st century. However, this project shows that it may still have the potential to empower women and revolutionize smallholder farming on the Gangetic Plains and elsewhere. "This is the first project that explicitly combines collective farming with a strong irrigation component," says Sugden. "In some other collectives in south Bihar, farmers are working together, but otherwise they're largely carrying on agriculture as they did before. What's different about this project is that we're using the collectives as a development tool to increase the use of irrigation and boost cropping intensity."

The Improving Dry Season Irrigation for Marginal and Tenant Farmers in the Eastern Gangetic Plains project is funded by the Australian Centre for International Agricultural Research (ACIAR). IWMI's participation forms part of the CGIAR Research Program on Water, Land and Ecosystems (WLE), supported by the CGIAR Fund.

Focus group discussion with farmers in Nepal.

First holistic take on the Ganges River Basin

> Sometimes the contributors' views and perspectives were quite different, but I think that helps to set the book apart from other publications.

The Ganges is the most populous river basin in the world, supporting more than 500 million inhabitants. Well known for its cultural and spiritual significance (to Hindus, the Ganges is a goddess), it spans 1 million square kilometers (km^2) across China, Nepal, India and Bangladesh. Over the years, many authors have written books, papers and reports discussing specific aspects of the river. However, no single book has examined the basin holistically. In 2016, IWMI responded to the need for a broader perspective by producing *The Ganges River Basin,* a comprehensive interdisciplinary overview of the key issues and challenges facing the region.

"We wanted to cover the river from different sectoral perspectives, including water use, pollution, socio-economics and biophysical aspects," explains one of the book's editors, Luna Bharati, a principle researcher at IWMI. "But we also wanted to include regional perspectives, so we invited authors from each of the main countries through which the Ganges flows – Nepal, India and Bangladesh – to cover each topic together. If we couldn't locate an author on a particular topic, we employed an IWMI expert who had been working on that topic in the country."

Ebb and flow

Published in collaboration with Routledge as part of its Earthscan Series on Major River Basins of the World, the book has 18 chapters arranged in three sections: Resources and Uses; Environment; and Governance and Livelihoods. The chapters assess the status of the Ganges surface water and groundwater resources, encompassing topics such as climate change; managing floods and droughts; implications for intensifying agriculture sustainably; hydropower; environmental flows, ecosystem services; water quality; institutions and policies; and poverty, inequalities and vulnerability. "The book is aimed at anyone who is interested in water management in the Ganges River Basin and South Asia," says Bharati.

On the Ganges River at Varanasi in Uttar Pradesh, India.

The book clearly highlights some of the major issues facing the Ganges today. Variability is one major concern. Around 80% of the rainwater that sustains the Ganges falls in July, when the monsoon comes. There can also be as much as a 50% difference in the volume of water falling in consecutive years. Often, there is a mismatch between where water is available and where it is needed. Climate change is forecast to increase variability in the basin in the future, so water resource management needs to focus on managing variability. "Forecasts indicate that the monsoon will become stronger and more intense," says Bharati.

One chapter highlights work undertaken to establish the Ganges "environmental flow." This is the minimum volume of water needed to maintain freshwater ecosystems. An environmental flow assessment of the Ganges conducted by IWMI, which considered the water requirements of aquatic biodiversity and cultural ceremonies at three sites, found that the minimum flow requirement was being met, except during a couple of months of the year. IWMI scientists concluded that increasing irrigation efficiency from its current level of 40% could achieve the required flow.

A shining example of cooperation

The volume of water flowing through the Ganges Basin is less of an issue than the fact that there is little transboundary cooperation or data sharing between the countries using the river's resources. Generally, trust is lacking between countries, states and sectors, and there is no basin authority to oversee water management. "There is a lot of water in the basin (600 billion cubic meters of flow), but the inability of neighboring countries to work together has hindered development, says Bharati. "For example, there is less than 2% hydropower development in Nepal."

While the Ganges-sharing countries may struggle to work together to manage their water resources, *The Ganges River Basin* book is a shining example of regional cooperation. With the diverse authors all selected for their high level of experience and expertise, there were some disputes during the book's production, but these were resolved relatively easily. "The book represents the cumulative knowledge of individuals and institutions going back several decades." says Bharati. "Sometimes the contributors' views and perspectives were quite different, but I think that helps to set the book apart from other publications."

The Ganges River Basin was developed in connection with the CGIAR Research Program on Water, Land and Ecosystems (WLE), supported by the CGIAR Fund.

Water quality testing on the Ganges River.

Science for surface irrigation

Increasing the precision with which water is used has the potential to increase farm outputs and improve farmers' livelihoods.

Farmers in West India and Pakistan face a conundrum. The decades-old *warabandi* (fixed turns) surface irrigation system, which supplies set amounts of water at pre-determined times, does not always provide water when crops need it most. However, pumping groundwater, which offers farmers more control over when and how they irrigate, is expensive. IWMI is using laser and computer modeling technology to help farmers make more effective use of the water resources available to them.

"When you use more high-tech sprinkler or drip irrigation systems, you use pipes to convey water to the crops, and you apply it in a way that the soil is used to store water like a sponge," says Arif Anwar, leader of IWMI's Agricultural Water research group. "With surface irrigation, you use the field to both transport the water and store it. Trying to apply a constant depth of water over an area akin to a football pitch that is sloping and uneven, is the challenge many farmers face."

The application of science and mathematics to make surface irrigation water more precise has been going on for decades; the stumbling block has been making it simple enough to project it out of academia and into practical use. There has been some success with using laser-guided land-leveling technology to improve the efficiency of water use in rice paddies irrigated with groundwater. However, less research has gone into applying similar technologies to gently sloping lands using gravity-fed surface irrigation methods, especially those constrained by the *warabandi* irrigation management.

High tech made easy

For several years, Anwar and his colleagues have researched how existing *warabandi* irrigation management in the Indus Basin might be used with the same precision as more high-tech irrigation methods. In a 2016 paper, they concluded that it would be relatively easy to achieve an improvement in irrigation performance, within current irrigation services, by smoothing soil surfaces and making changes to field layouts.

Laser-guided land levelling at Ali Pur village in Pakistan's Punjab Province.

The researchers first used laser-guided grading to remove undulations from fields, while retaining their natural topographic slopes. They then entered field variables into the computer model WinSRFR, developed by the United States Department of Agriculture. These included field length, width and slope; properties of the soil, including the ease with which water could penetrate it; and the volume of water provided by the *warabandi* system, for how long and how often. The model then presented options on how farmers could control particular variables to optimize water use, for example, by increasing or decreasing the number of border strips or furrows.

"If you apply 50 millimeters of water, depending on crop type and weather, the crop will use it in 5 to 10 days; the farmer will need to replenish it after that," says Anwar. "If you have lots of undulations or you don't have the right slope, or the soil and geometry don't match up, they'll end up applying something like 150 millimeters of water to obtain the required minimum of 50 millimeters. So, they end up applying much more water, because it gets stuck in ponds and doesn't travel. That's what precision irrigation overcomes."

More with less

Where farmers are relying solely on surface irrigation, using more of their allocation on one field means they have to leave more land fallow, thereby growing fewer crops than they otherwise could. Meanwhile, those using groundwater end up spending considerably more money than they need to on diesel to run their pumps. So, increasing the precision with which water is used has the potential to increase farm outputs and improve farmers' livelihoods.

Laser levelling and grading equipment is widely available in Asia and can be hired relatively cheaply. Anwar and colleagues subsequently undertook research into the longevity of each grading action and concluded that the surface would remain smooth for 3 to 4 years before returning to its original condition. "The approach is very generic and can be applied in any place where surface irrigation prevails," says Anwar. "But it is particularly appropriate for West India and Pakistan because of the inflexible nature of water supply under *warabandi* irrigation management."

IWMI's research on surface irrgation in Pakistan, supported by the Netherlands government and United Nations University, forms part of the CGIAR Research Program on Water, Land and Ecosystems (WLE), supported by the CGIAR Fund.

Laser-levelled wheat field in Punjab, Pakistan.

How to get money from muck

Many municipalities are interested in waste-to-resource processes that can contribute to circular economies.

It seems like a no-brainer. Take human waste that is unfortunately far too often buried in landfills or dumped in waterways in the developing world, extract nutrients from it for fertilizer or process it into fuel, and sell the resulting products. Not only would this reduce our reliance on fossil resources, it would also help to clean up the environment and boost local economies. So why has this not happened yet?

Working on the business side

Many municipalities are interested in waste-to-resource processes that can contribute to circular economies, but they often lack the money to co-fund reuse and recycling. To achieve self-sustaining solutions requires a robust business plan, based on detailed feasibility studies and accurate forecasts of supply and demand. However, there is a large knowledge gap when it comes to the business side of waste reuse. "Very often, the technology exists but not the business case for using it," says Pay Drechsel, leader of IWMI's Rural-Urban Linkages strategic program.

A pioneer in the field of resource recovery and reuse, IWMI has spent the past few years seeking answers to this challenge and practical ways forward. Following the publication of the book *Wastewater: Economic Asset in an Urbanizing World* in 2015, the Institute published the report *Business Models for Fecal Sludge Management* in 2016, outlining institutional and business solutions for managing fecal waste. The report forms part of a series on resource recovery and reuse, published by the CGIAR Research Program on Water, Land and Ecosystems (WLE).

"Five years ago, we undertook a review of the reuse of organic waste and wastewater, and the sanitation value chain [the process from waste production to reuse]," explains Drechsel. "We found many papers on technical solutions but hardly anything implemented and then only if highly subsidized. We identified a big knowledge gap linking the sanitation sector, which manages waste, and the farmers or authorities who might benefit from products derived from it." In short, there was a significant lack of business models and plans.

Human waste value chains

IWMI subsequently investigated how to bridge this gap. In the developing world, on-site sanitation involving the use of pit latrines or septic tanks has potential to provide a

Fecal sludge removal service in Accra, Ghana.

valuable source of organic matter, nutrients and energy. This is unlike human waste in the sewered systems of the developed world, which is often mixed with industrial contaminants.

The new report on business models draws on 44 case studies from Asia, Africa and Latin America. These cover either part or all of the fecal sludge value chain, which encompasses: access to toilets; emptying and transport; treatment; and disposal or reuse. Highlighting opportunities as well as bottlenecks, the report elaborates on the institutional matchmaking required to ensure the fecal sludge service chain works.

With fecal sludge rich in organic carbon and nutrients, the best ways to reuse it are to extract energy from it or process it to make fertilizer. Energy can be recovered in the form of gas (and eventually electricity) using anaerobic digestion, where microorganisms break down biodegradeable material in the absence of oxygen. Alternatively, briquettes can be made from dried sanitized sludge for cooking or industrial use. Producing fertilizers and soil improvers requires sludge to be sanitized through anaerobic digestion or aerobic composting; the resulting material is capable of boosting plant growth and enhancing soil health (see page 26).

Policy influence

IWMI is applying its newfound knowledge on business models for using waste materials in its host country of Sri Lanka, advising the government on how best to incorporate fecal sludge management into the national sanitation policy. In its original draft, the policy did not pay much attention to on-site sanitation systems. Based on its research, IWMI facilitated a revision of the policy to incorporate sound fecal sludge management as an option that complements sewered systems, helping prevent environmental damage from illegally dumped human waste, while supporting resource recovery and reuse.

To determine the capacity of treatment and composting stations or energy-generating plants requires detailed statistics on the number of households, the volume of waste produced, the sizes of septic tanks and pit latrines, and the number of vehicles needed to transport the waste. However, with 2.7 billion people globally relying on on-site sanitation, the raw material supply need not be a bottleneck, and neither is the potential value of the compost or energy produced in question. The challenge is to balance supply and demand.

"Our target is to assist urban settlements with decision support on institutional and financing options to make fecal sludge management viable in different contexts and at different scales," says Drechsel. "While resource recovery can support cost recovery, there is nothing wrong with public subsidies, as these are justifiable because of the health and environmental benefits of sound fecal sludge management. Every vacuum truck dumping sludge indiscriminately is equivalent to the open defecation of 5,000 people."

Regular monitoring of dried fecal sludge mixed with organic food waste for "co-composting."

Closing the nutrient loop

The first large-scale plant in West Africa to produce organic fertilizer pellets from market and human waste began operating in Ghana.

In Ghana, more than 90% of human waste is discharged into the environment, contaminating coastal areas, waterways and the irrigated farms that draw water from them. As part of its effort to create productive synergies between rural and urban areas, IWMI is investigating practical ways to help municipalities in this and other countries develop closed-loop processes that turn waste into useful products for farming communities.

From feces to fertilizer

One approach is to collect and process market waste along with "fecal sludge" – human waste produced by households and pre-treated in on-site pit latrines or septic tanks – into a fertilizer. At the end of 2016, the first large-scale plant in West Africa to produce such organic fertilizer in pellet form began operating in Ghana. It officially opened as a commercial venture in May 2017.

The new plant will help to reduce the environmental impacts by safely converting human waste into *Fortifer*™, a trademarked fertilizer developed by IWMI and partners. In a process called co-composting, the nutrient-rich fecal sludge is sanitized together with carbon-rich food waste to produce high-quality compost. At full operation, the plant will annually process 12,600 cubic meters (m^3) of human waste collected from local latrines into 500 metric tonnes of fertilizer powder and pellets for the agriculture sector.

The plant is a public-private partnership between the Ghanaian municipality, Tema Metropolitan Assembly, and Jekora Ventures Ltd. The municipality contributed the one-hectare site on which the plant now stands, valued at around USD 75,000, while Jekora Ventures committed USD 90,000 to cover operational, maintenance and marketing costs during the estimated three-year business start-up period. IWMI initiated and supported the process with market analysis, technology development and transfer. In trials, the performance of *Fortifer*™ was shown to match that of other fertilizers costing the same price, while its real value as an organic soil improver will last longer than its fertilizing effect.

Testing crop performance with compost derived from fecal sludge.

Partnerships in the making

In mid-2016, Ghana's Ministry of Food and Agriculture (MoFA) approved the commercial production of *Fortifer*™ and agreed on its eligibility for subsidies, enabling it to be produced more competitively. The Ministry commended IWMI for initiatives undertaken to ensure the availability of high-quality compost in the country. To support the production of *Fortifer*™, Ghana's Ministry of Local Government and Rural Development committed USD 155,889 towards capital investment in the plant.

"It makes us proud to know that we were able to support the Ghanaian government in its decision to include waste-based composts in its fertilizer subsidy program, which normally only includes chemical fertilizers," says Olufunke O. Cofie, head of IWMI's West Africa Office in Ghana. "After the successful facilitation of a public-private partnership for *Fortifer*™ production in Greater Accra, another three such partnerships are now in progress: involving two plants to transform fecal sludge into *Fortifer*™ and dry fuel, respectively, and another to exploit the nutrient value of wastewater for fish farming."

South-South exchange

Based on its experience in Ghana, IWMI is also promoting *Fortifer*™ as a means to make good use of municipal solid waste in Sri Lanka. Its government has set up more than 115 composting stations, which help to reduce local waste volumes by half. However, most stations do not have the marketing capacity to sell the compost produced. Over the last 3 years, IWMI has signed memoranda of understanding with the Central Environmental Authority (CEA) and the ministries in charge of sanitation and agriculture. The aim is to help the country make its composting stations more viable, based on the production of *Fortifer*™ and related market assessments.

A large array of field trials are under way to test crop responses for the purpose of developing *Fortifer*™ application guidelines. The government is very supportive of organic fertilizers, as many Sri Lankans suffer from kidney disease, which some have blamed on agricultural chemicals. To encourage planners and policymakers in other developing countries to also embrace the benefits of co-composting, WLE published the report *Co-Composting of Solid Waste and Fecal Sludge for Nutrient and Organic Matter Recovery* as part of its series on resource recovery and reuse.

Research on resource recovery and reuse forms part of the CGIAR Research Program on Water, Land and Ecosystems (WLE), with support from the CGIAR Fund. The launch of the new composting plant in Ghana resulted from more than a decade of research, which received support through grants from various partners in France, Switzerland and other countries, including most recently the Bill & Melinda Gates Foundation and the governments of Canada, the UK and Ghana.

From dried fecal sludge to organic fertilizer pellets.

ABOUT IWMI

Mission

Provide evidence-based solutions to sustainably manage water and land resources for food security, people's livelihoods and the environment.

The International Water Management Institute (IWMI) strives to fulfill its mission through three strategic programs (listed below) whose purpose is to build an evidence base for new approaches that address key water-related development challenges. Our researchers work across sectors and disciplines through eight research groups (as indicated in the drawing) to deliver new knowledge, policy advice and capacity development.

Building Resilience

Sustainable Growth

Rural-Urban Linkages

Headquartered in Colombo, Sri Lanka, with offices across Asia and Africa, IWMI works in partnership with national and local government bodies, academic institutions, community-based groups, international organizations and the private sector, with emphasis on strengthening capacity.

IWMI is a CGIAR center focused on research for development. CGIAR is a global research partnership for a food-secure future. Its work is carried out by 15 centers in close collaboration with hundreds of partners across the globe.
As of January 2017, IWMI is contributing to these second-phase CGIAR Research Programs: leading Water, Land and Ecosystems (WLE) and playing an active role in Climate Change, Agriculture and Food Security (CCAFS); Policies, Institutions and Markets (PIM); Fish; and Livestock.

CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

CGIAR Climate Change, Agriculture and Food Security CCAFS

CGIAR RESEARCH PROGRAM ON Policies, Institutions, and Markets

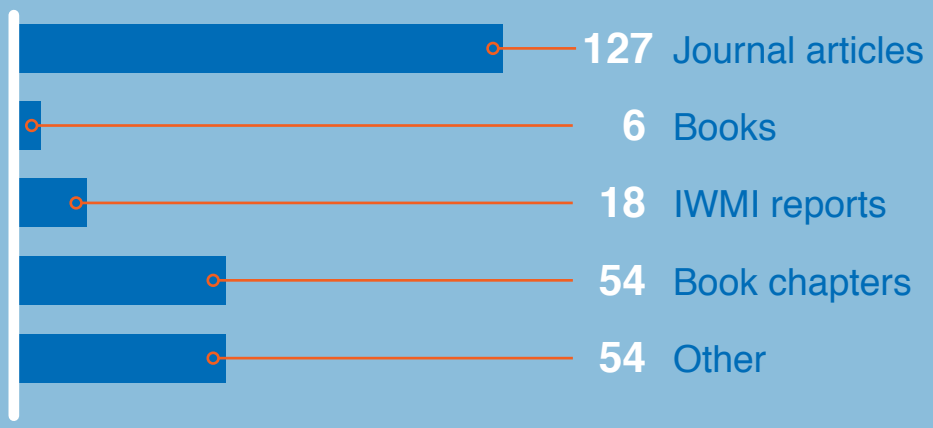
CGIAR RESEARCH PROGRAM ON Fish

CGIAR RESEARCH PROGRAM ON Livestock

STAFF NUMBERS

Researchers	Support staff	Total
91	156	247

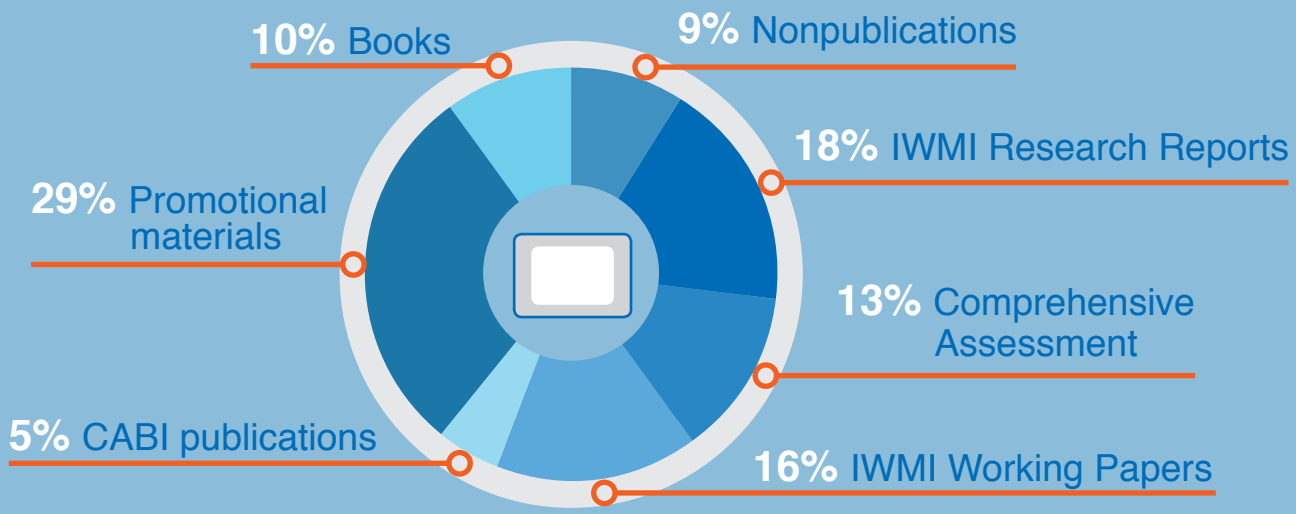
PUBLICATIONS IN 2016



Total **259**

An average of **0.9 million documents** are **downloaded monthly** from IWMI´s publications repository.

IWMI WEBSITE DOWNLOADS



In early **2017**, we adopted a more thorough approach for monitoring document downloads from our website, registering **1.25 million downloads** in the period **March-June 2017.**

Finance and administration

IWMI continued to improve financial controls and efficiency in operations to provide more value for money to donors and other stakeholders. We also met requirements for increased reporting. The volatility of CGIAR funding affected our bottom line, but steps taken to enhance efficiency helped improve the Institute´s financial outlook in 2016. We started implementing International Financial Reporting Standards (IFRS) and expect to be fully compliant by the end of the fiscal year 2017. IWMI contributed to a total of six CGIAR Research Programs and managed 108 bilateral projects.

The 2017 budget approved by IWMI's Board of Governors includes a revenue of USD 26.338 million. The Institute is in the process of upgrading its enterprise resource planning (ERP) platform to fully meet increased donor requirements. Implementation is expected to be complete by the end of the fiscal year 2017. We are also implementing improved human resources compensation systems, which should be in place by the end of 2017.

Statement of Activity

As of December 31, 2016 and 2015
(expressed in thousands of U.S. dollars)

	2016	2015
Windows 1 & 2	20,005	25,063
Window 3	3,972	4,138
Bilateral	10,971	9,115
Total grant revenue	**34,948**	**38,316**
Other revenue and gains	454	444
Total revenue and gains	**35,402**	**38,760**
Research expenses	33,764	38,823
General and administration expenses	3,811	4,797
Total operating expenses	**37,575**	**43,620**
Financial income/expenditure	**(506)**	**(404)**
Surplus (deficit) for the year	**(1,667)**	**(4,456)**

Statement of Financial Position

As of December 31, 2016 and 2015
(expressed in thousands of U.S. dollars)

	2016	2015
Current assets	34,233	37,815
Non-current assets	2,380	2,808
Total assets	**36,613**	**40,623**
Current liabilities	19,490	21,639
Non-current liabilities	3,371	3,565
Total liabilities	**22,861**	**25,204**
Undesignated net assets	11,372	12,611
Designated net assets	2,380	2,808
Total net assets	**13,752**	**15,419**
Total liabilities and net assets	**36,613**	**40,623**

Expenses by Function
As of December 31, 2016 and 2015
(expressed in thousands of U.S. dollars)

	2016	2015
Personnel	15,278	17,882
CGIAR collaboration	7,636	9,557
Non-CGIAR collaboration	6,339	7,436
Supplies and services	6,064	6,171
Travel	1,277	1,592
Depreciation	752	923
Cost sharing percentage	229	59
Total operating expenses	**37,575**	**43,620**

Principal investment partners

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- African Development Bank (AfDB)
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