

Advancing Agricultural Productivity in the Face of Increasing Water Insecurity: Innovating for the Future

Policy makers should view water scarcity and insecurity as an accelerating problem that calls for new perspectives on solutions –Growing more food with less water and less impact on fragile resources.

Behind the current causes of water scarcity and insecurity detailed by many international organizations, there is a much more foreboding future, in which current policy options are inadequate. A looming water crisis fueled by demographics and accelerating climate change - demands that current policy options need to go beyond water as the measure of the solution. Along this line, stressing management of water resources amid competing demands among which agriculture is a big piece, will inevitably put more pressure on agriculture at a time when productivity needs to increase.

A key for this policy brief is to share a complementary approach that shifts the current focus of water as a scarce resource that needs to be managed to solutions that apply less is more to address advancing agricultural productivity in the face of increasing water insecurity.

To drive the call for a shift, two ominous overarching trends behind accelerating water scarcity and insecurity that should give all of us pause are demographics and particularly accelerating climate change.

1. Many causes for water scarcity

Increasing water scarcity is a reality, and a myriad of reports have shown multiple causes. The 2006 Human Development Report, “Beyond Scarcity: Power, Poverty and the Global Crisis,” (United Nations Development Programme 2006) considered water scarcity from two points of view: (1) as a crisis arising from a lack of services that provide safe water and (2) as a crisis caused by scarce water resources. It concluded that the

world’s water crisis is not related to the physical availability of water, but to unbalanced power relations, poverty and related inequalities.¹

At the 5th World Water Forum, Istanbul, Turkey, March 17, 2009, the World Bank stated that the global financial crisis comes to a water sector that is chronically under-funded. The Bank continued that how to address the huge needs of financing for water covers much of the same issues such as improving access to water supply and sanitation services, expanding irrigation, improving water security, and promoting environmental protection.²

The Stockholm International Water Institute (SIWI) notes that lack of water in relation to water requirements is another issue that needs to be addressed. This can be caused by increases in demand, droughts, land degradation, population growth, pollution, emerging sectors of additional demand. Insufficient soil water (green water scarcity) can lead to crop failure, hunger, starvation and under-nutrition. As a result, the problems of poverty and hunger tend to be largest in arid regions. SIWI offers the approach that in order to address greater physical water scarcity, governments should adopt a range of demand-management measures before undertaking supply-side solutions. Examples of such management measures would include decreasing water losses in systems (water use

¹ Stockholm International Water Institute (SIWI) 2008, On the Verge of a New Water Scarcity: A call for good governance and human ingenuity. P. 3

² Speech: “The Economic Crisis and the Water Sector: Rising to the Challenge” Katherine Sierra, Vice President, Sustainable Development The World Bank (March 2009).
http://siteresources.worldbank.org/INTWAT/Resources/03132009-RM-Fifth_World_Water_Forum-KS-TPs.pdf

efficiency), reconsidering the volumes of water allocated to agriculture, and reducing water losses from soils.³ This way of thinking has been useful in that it has increased our understanding of the need to manage demand. Key in SIWI's solutions is reconsidering the volumes of water allocated to agriculture, which may be considered as counter to the World Bank calling for expanding irrigation, thus highlighting the pressures of competing sector demands.

As noted by the 2006 Human Development Report, while governance remains a key challenge, there is also a need to better understand the increasing strain being placed on finite, erratically available and vulnerable water resources.

The Food and Agriculture Organization (FAO) affirms that water is a finite resource, and agriculture is the primary user of water by far, claiming almost 70 per cent of the total amount withdrawn globally. It takes a significant amount of water to produce crops, for example under current rice production practice, one to three cubic meters to yield just one kilogram of rice. As population grows, water needs for agriculture can only increase. But supplies are already limited. An FAO study of 93 developing countries indicates that a number of water-scarce nations are already withdrawing water supplies faster than they can be renewed. Ten countries are in a "critical state", meaning that agriculture accounts for more than 40 per cent of total withdrawals of renewable water resources. Another eight are "water stressed" - satisfying the needs of agriculture requires them to withdraw more than 20 per cent of that total⁴.

2. Adding to the steps that need to be taken

None of the above policy recommendations will increase agricultural productivity to meet future

³ Stockholm International Water Institute (SIWI) 2008, On the Verge of a New Water Scarcity: A call for good governance and human ingenuity. Pp 3 -4.

⁴ FAO 2002, Water a Precious and Finite Resource, <http://www.fao.org/Ag/Magazine/0210sp1.htm>

needs in the long run. The argument being that even with all of the above policy recommendations from increased water use efficiency, adjusting water allocation, improving irrigation infrastructure, and or calling for new dam development - it will not be near enough and the calls for improved infrastructure fiscally not possible for many countries to undertake.

That said, the basket of policy options and action programmes should not be tossed aside, but coupled with policies that increase agricultural productivity in the face of accelerating water scarcity. The FAO echoing the above, also calls for improved farming techniques to be coupled with greater water use efficiency as the keys to food security for a growing world population.⁵ To drive home the need for increased action, it is critical to visualize what is happening now on our planet with particular attention given to two overarching trends.

3. Two Overarching Trends: First Demographics

Despite the varied critical water scarcity problems that have be borne out thus far in this brief, there are two global trends that are overarching, and are adding to the already enormous pressure being placed on water. The first trend as mentioned by FAO above is demography. Over the past 50 years, as the world's population rose from 3 billion to 6.5 billion, water use roughly tripled. On current estimates, population is likely to rise by a further 2 billion by 2025 and by 3 billion by 2050.⁶ Demand for water will rise accordingly.

With farmers using around 70 per cent of the world's water resources, an article by the Economist posits that both increasing population as well as changing diets will drain the well much more rapidly. Different foods require radically different amounts of water. To grow a kilogram of wheat requires around 1,000 litres. But it takes as much as 15,000 litres of water to produce a kilo of

⁵ Ibid

⁶ Economist.com, Sin aqua non, 8 April, 2009: http://www.economist.com/world/international/displayStory.cfm?STORY_ID=13447271

beef. The meaty diet of Americans and Europeans requires around 5,000 litres of water a day to produce. The vegetarian diets of Africa and Asia use about 2,000 litres a day⁷.

The Economist article argues that the shift from vegetarian diets to diets with more meat on the menu, contributed to the food-price rise of 2007-08, and that this shift has big implications for water. In 1985 China's population consumed, on average, 20kg of meat, and as of 2009, Chinese meat consumption has increased to around 50kg. This difference translates into 390km³ (1km³ is 1 trillion litres) of water, almost as much as total water use in Europe.⁸

The shift of diet will be impossible to reverse since it is a product of rising wealth and urbanisation. In general, "water intensity" in food increases fastest as people begin to climb out of poverty, because that is when they start eating more meat. On top of changing diets, statistical trends indicate that our planet will add 2 billion more people to the world's population between now and 2030. More than 85 per cent of this additional demand will be in the developing countries, as nearly all population growth will be there.⁹ The FAO says that, without changes in efficiency, the world will need as much as 60 per cent more water for agriculture to feed those 2 billion extra mouths. That is roughly 1,500km³ or as much as is currently used for all purposes in the world outside Asia.

4. The Second Overarching Trend: Climate Change

The World Meteorological Organisation (WMO) notes that there is evidence that global warming is speeding up the hydrologic cycle, - the rate at which water evaporates and falls again as rain or snow.¹⁰ It brings longer droughts between more

intense periods of rain.

Climate change has major implications for water use. First, it changes the way plants grow. Trees, for example, react to downpours with a spurt of growth. During the longer droughts that follow, the extra biomass then dries up so that if lightning strikes, forests burn more spectacularly. Similarly crops grow too fast, then wilt.

Second, climate change increases problems of water management. Larger floods overwhelm existing controls. Reservoirs do not store enough to get people or plants through longer droughts. In addition, global warming melts glaciers and causes snow to fall as rain. Since snow and ice are natural regulators, storing water in winter and releasing it in summer, countries are swinging more violently between flood and drought.

In the Asia Pacific region climate change acceleration is demonstrated with excerpts from Brookings Asia Third Assessment Report¹¹ as follows:

1. For Asia as well as the world as a whole, new evidence on recent trends, particularly on the increasing tendency in the intensity and frequency of extreme weather events in Asia over the last century and into the 21 century are reported to be more frequent and intense in the past 20 years. Significantly longer heat-wave duration has been observed in many countries of Asia, as indicated by pronounced warming trends and several cases of severe heat-waves. In addition to heat-waves, the frequency of occurrence of more intense rainfall events in many parts of Asia has increased, causing severe floods, landslides, and debris and mud flows, while the number of rainy days and total amount of precipitation has decreased. Also, there are reports that the frequency of extreme rainfall in some countries has exhibited a decreasing tendency.

⁷ Ibid

⁸ Ibid

⁹ FAO 2002, How to feed 2 billion more mouths in 2030? Here are some answers. :

<http://www.fao.org/english/newsroom/news/2002/8280-en.html>

¹⁰ WMO (2000), Our World, Global Climate, Global Warming. :

http://www.wmo.ch/pages/about/wmo50/e/world/climate_pages/global_warming_e.html

¹¹ Brookings Institute, Asia Third Assessment Report p.473: www.brookings.edu/wolfensohncenter

2. Regarding drought, frequency and intensity of droughts in many parts of Asia are largely attributed to rise in temperature, particularly during the summer and normally dryer months and El Nino events. In Mongolia for example, heat-wave duration has increased by 8 to 18 days in the last forty years and cold wave duration has shortened by 13.3 days. In India the frequency of hot days and multiple-day heat-waves have increased in the past century, with an increase in deaths due to heat stress in recent years. For China, an increase in area affected by drought has exceeded 6.7 Mha since 2000 in Beijing, Hebei Province, Shanxi Province, Inner Mongolia and North China, with an increase in dust storm affected area. The trans-boundary Qinghai-Tibetan Plateau shows an increase temperature change of 0.16 and 0.32 degrees Celsius. Warming in China over the last 50 years is more pronounced in winter than summer, with a rate increase more pronounced in minimum than in maximum temperature. In Nepal, 0.09 degrees Celsius per year in the Himalayas is reported. For Bangladesh, an increasing trend of about 1 degree Celsius in May and 0.5 degrees Celsius in November during the 14 year period from 1985 to 1998. All countries in the region show warming in varying degrees. India as well with 0.68 degrees Celsius increase per century, increasing trends in annual mean temperature, warming more pronounced during post-monsoon and winter. And in general for South-East Asia, 0.1 to 0.3 degrees Celsius increase per decade reported between 1951 to 2000.

3. Tropical cyclones originating in the Pacific have also increased in intensity and frequency in the last few decades, while in contrast, cyclones originating from the Bay of Bengal and Arabian Sea have been noted to decrease since 1970 but the intensity has increased. In both cases, the damage caused by intense cyclones has risen significantly in the affected countries.

4. The impacts of the above on agriculture

and food production should be of great concern to the region. Production of rice, maize and wheat in the past few decades has declined in many parts of Asia due to increasing water stress arising partly from increasing temperature, increasing frequency of El Nino and reduction in the number of rainy days. In a study by the International Rice Research Institute (IRRI), the yield of rice was observed to decrease by 10 per cent for every 1 degree Celsius increase in growing season minimum temperature. A decline in potentially good agricultural land in East Asia and substantial increases in suitable areas and production potentials in currently cultivated land in Central Asia have also been reported. Climate change could make it more difficult than it is already to step up agricultural production to meeting growing demands in developing countries in Asia.

5. Regarding hydrology and water resources in dryer parts of Asia, melting of glaciers account for over 10 per cent of freshwater supplies and melting is faster in recent years, particularly glaciers around the Qinghai-Tibetan Plateau. In parts of China, the rise in temperature and decreases in precipitation, along with increasing water use have caused water shortages that led to drying up of lakes and rivers. In India, Pakistan, Nepal and Bangladesh, water shortages attributed to rapid urbanization and industrialization, population growth and inefficient water use aggravated by climate change are having adverse impacts on demand, supply and water quality. In arid Central and West Asia, changes in climate and its variability continue to challenge the ability of countries in the arid and semi-arid region to meet growing demands for water particularly for agriculture.

5. Drastic changes taking place at Asia's "Water Tank"

The Qinghai-Tibetan (Qingzang) Plateau is a vast, elevated plateau covering most of the Tibet Autonomous Region and Qinghai Province of the

People's Republic of China and Ladakh in Kashmir. It occupies an area of around 1,000 by 2,500 kilometers, and has an average elevation of over 4,500 meters. Sometimes called "the roof of the world, and Asia's water tank" it is the highest and largest plateau on earth, with an area of 2.5 million square kilometers. The plateau has the historic capacity to store more freshwater than any place on earth, except the North and South Poles.

Currently the plateau is undergoing transformation due to climate change, rising temperatures, deficiency and changes in precipitation that will have adverse impacts on agriculture, food security and livelihoods. Glaciers and wetlands on the plateau serve as head waters for several important rivers in Asia and play pivotal roles in agricultural productivity, water donation, and storage.

The Intergovernmental Panel on Climate Change (IPCC) reports that Himalayan glaciers are receding rapidly and that many could melt entirely by 2035. If the giant Gangotri Glacier that supplies 70 per cent of India's Ganges river flow during the dry season disappears, the Ganges could become a seasonal river, flowing during the rainy season but not during the summer dry season when irrigation for agricultural needs are greatest. This would have serious consequences for over 200 million living in the Indo-gangetic plain in India and Bangladesh.

The use of groundwater has been put forth as an alternative source for many rivers in the region. However, in the case of the Yangtze, Yellow river, and the Ganges, groundwater in the areas along all has been excessively pumped, resulting in cracks in aquifers and leading to land-surface depression as the ground sinks to fill the void left by underground aquifer water loss resulting in pronounced economic damage.

The population in either the Yangtze or Gangetic river basin is larger than that of any country other than China or India. And the ongoing shrinkage of underground water supplies and the prospective shrinkage of river water supplies are occurring against a startling demographic backdrop: by 2050 India is projected to add 490 million people and

China 80 million¹².

Compounded by climate and demographic changes in the region, agriculture is just one of many users of water, accounting for the largest withdrawals in developing countries (with South Asia, close to 90 per cent of all water withdrawals for agriculture), and water for agricultural use is considered the main obstacle when water supplies cannot satisfy all demands.

All of the above facts mean that the region faces gravely serious impacts on agricultural productivity due to climate change and demographics. To overcome this, substantive policies and action programmes will need to be in place to advance agricultural productivity in the face of increasing water scarcity and competing demands. It is clear that agriculture will need to:

- Produce more with fewer natural resources particularly water while reducing pressure on already strained natural resources.
- Reduce agriculture's negative contributions to climate change and;
- Ensure that agriculture can co-exist with and contribute to bio-diversity conservation.

To address the above, countries in the region will require private-public partnerships, South-South cooperation and private sector involvement to promote, advocate, and manage environmentally sustainable agricultural techniques and practices. Also, countries in the region need international support and technical coordination. This "call to arms" already has produced an innovative solution as follows:

6. Less is more: less water, fewer plants, more rice - the SRI revolution

The System of Rice Intensification (SRI), pioneered in Madagascar in the early 1980s by the French Jesuit priest, Father Henri de Laulanié, has now been validated in 34 other countries, including by the rice research institutes of China,

¹² Earth Policy Institute: Lester Brown,. Earth Policy Institute Melting Mountain Glaciers Will Shrink Grain Harvests in China and India

India and Indonesia, which together produce 60 per cent of the world's rice¹³. It is a civil society innovation originating not from research stations or laboratories¹⁴. The System of Rice Intensification (SRI) is an unusual innovation in several ways in that its methods can raise, concurrently, the productivity of the land, labor, water, and capital invested in irrigated rice production. There are costs involved with SRI adoption, particularly increased labor from farmers during their initial learning phase; and there are some conditions where the methods will be inappropriate or impractical, e.g., where there is little water control and flooding creates anaerobic soil conditions. With some initial local trial and error, SRI can become labor-saving over time, saving water (by 25-50 per cent) and seed (by 80-90 per cent), reducing costs (by 10-20 per cent), and raising paddy output at least 25-50 per cent, and often 50-100 per cent and sometimes even more¹⁵.

In China, the faculty of Nanjing Agricultural University did the first trials with SRI methods outside of Madagascar, the yields obtained in these trials in 1999 with three different spacings, ranged from 9.2 to 10.5 tonnes per hectare (t/ha). That these could be obtained with about half as much water as usually used is perhaps of more interest than the yield level, given China's growing scarcity of water for agricultural purposes¹⁶.

In SRI, rice plants are transplanted early, after just 8-12 days in an unflooded nursery, and they are planted singly, rather than in clumps. Planting is a precision task, done in a square pattern with relatively wide spacing: 25-30 cm between plants. This increases the sunlight each receives and gives roots more room to grow. Fields are ideally kept

damp rather than completely flooded, creating a more aerated environment, which promotes root development and diversity of soil organisms. This also allows more weed growth, but this problem is addressed by using conical weeders - rotating, spiky drums which are rolled between the rows of plants, burying the weeds and aerating the soil. Because SRI seedlings are planted in a square grid, weeding along and across the rows is possible, also giving better soil aeration. This regular weeding has boosted plant vigor, eliminating competition from weeds and encouraging the infiltration of moisture and nutrients into the root zone.

With SRI, fertilization is done before planting, using compost or well-decomposed livestock manure spread on the fields prior to ploughing. Using crop residues, for example, may remove the need for chemical fertilizers completely.

Yield in rice is closely linked to the number of tillers, the shoots that produce grain-bearing panicles, and grains per panicle. Trials in Afghanistan, have seen rice yields reaching an average of 10.2 tonnes/ha in SRI plots, compared to 5.7 tonnes in control plots. In Tripura state, northeast India, where less than 1,000 farmers used SRI methods in 2005-6, there are now over 162,000 farmers using the technique, with strong backing from the state government. In Ha Tay province of Viet Nam, some 3,000 hectares were under SRI in 2007. This rose to 35,000 hectares in 2008 thanks to a campaign by the Ministry of Agriculture and Rural Development¹⁷. Twenty other provinces of Viet Nam introduced SRI demonstration programmes in 2008 as part of this campaign.

In addition, farmers report and researchers have verified that SRI crops are more resistant to most pests and diseases, and better able to tolerate adverse climatic influences such as drought, storms, hot spells or cold snaps. The length of the crop cycle (time to maturity) is also reduced, with higher yields. Resistance to biotic and abiotic stresses will become more important in the

¹³ New Agriculturalist: Less water, fewer plants, more rice - the SRI revolution (March 2009)

<http://www.new-ag.info/09/02/develop/dev4.php>

¹⁴ Norman Uphoff (2008), The System of Rice Intensification (SRI) as a System of Agricultural Innovation p. 2

http://www.future-agricultures.org/farmerfirst/files/T1c_Uphoff.pdf

¹⁵ Ibid, p. 1

¹⁶ Cornell International Institute for Food, Agriculture, and Development (CIIFAD), Rice Intensification (2002), p. 98
<http://ciifad.cornell.edu/sri/sriar.pdf>

¹⁷ Ibid

coming decades as farmers around the world have to cope with the effects of climate change and the growing frequency of “extreme weather events.” The resistance of SRI rice plants to lodging caused by wind and/or rain, given their larger root systems and stronger stalks, can be quite dramatic. Research has also found that the best SRI results come from improved rice varieties. In general, SRI methods have shown to reduce the agronomic and economic risks that farmers face¹⁸.

7. SRI Farmer Innovation: Brief Country Examples

A paper titled: *Farmer Innovations Improving the System of Rice Intensification (SRI)*¹⁹ shares several country examples of which two are shared here. In the Philippines, some farmers are growing SRI seedlings in sand, since seedlings get most of their initial nutrients from the seed rather than the soil. Farmers have noted that it is very easy to separate seedlings grown this way, and it is gaining favor among SRI farmers in the area.

A more detailed example shared is from China, where an SRI farmer has adapted SRI to raised-bed/zero-tillage cultivation in Sichuan province, getting a yield calculated by the Provincial Department of Agriculture to be 13.4 t/ha. Mr. Liu Zhibin developed a ‘triangular’ method of transplanting SRI seedlings, where there are three plants per hill but in half as many hills (more widely spaced), and with 8-10 cm between the three plants in a triangular shape. This way the benefits of wide spacing are maintained while plant population is increased by 50 per cent over conventional square-planted SRI²⁰.

¹⁸ Uphoff, Norman., (2008a), The System of Rice Intensification (SRI) as a System of Agricultural Innovation p. 2 http://www.future-agricultures.org/farmerfirst/files/T1c_Uphoff.pdf

¹⁹ Uphoff Norman., (2008b), Farmer Innovations Improving the System of Rice Intensification (SRI), p. 4

²⁰ This report is from a paper presented by Prof. Yuan Long Ping, director-general of the China National Hybrid Rice Research and Development Center, "A Scientist's Perspective on Experience with SRI for Raising the Yields of Super Hybrid Rice in China," presented to an International Conference on the System of Rice Intensification, Sanya, China, April 1-4, 2002, reproduced in the conference proceedings.

8. SRI methods for other crops

The principle of planting less to get more may not just apply to rice, however. These methods have worked with other crops, including wheat, sugar cane and finger millet in India. It should be stressed that SRI focuses on crop management rather than genetic improvement, and the importance of breeding better rice varieties is not the issue²¹.

With the impressive results of SRI in rice, farmers around the globe are now applying SRI to other crops and reporting increases in their yields. Examples from *Farmer Innovations Improving the System of Rice Intensification (SRI)*²² include the following examples:

- Sugar Cane: A number of farmers in southern India, some working with NGO or university collaborators, have begun adapting SRI concepts and practices to the production of sugar cane (also a gramineae or grass-family plant species like rice). Farmers have reported doubling and even tripling their cane yields with adaptations of SRI.
- Finger millet: This crop, known in India as ragi, is one of the most important cereals crops for the poor, not very high-yielding but very drought-resistant. This system which farmers have developed resembles SRI in many ways. In Haveri district of Karnataka state, it gives yields 2-3 times higher than with 15 conventional methods²³; and

²¹ Research has also found that the best SRI results come from improved rice varieties. The New Agriculturalist article stresses that traditional varieties which are tasty and have good storage and nutrition qualities, respond very well to these methods as well. By making traditional varieties more productive as well as more profitable, SRI also supports rice biodiversity, and is a viable solution that countries can develop and promote.

²² Uphoff Norman., (2008b), Farmer Innovations Improving the System of Rice Intensification (SRI)

²³ (see <http://www.greenconserve.com/Guli%20Ragi%20Method.htm>; and also pages 26-29 of field report <http://ciifad.cornell.edu/SRI/countries/india/inntutrep1006.pdf>).

- **Wheat:** In 2007, an Indian NGO based in Dehradun, did its own ‘SWI’ trials, with a 28-40 per cent increase in grain yield and 18 per cent more straw yield.

The paper outlines other crops that are undergoing trials as well. In short, SRI demonstrates that solutions are at hand that can help farmers negotiate a future of increased water scarcity, and erratic weather events while still being able to increase yields.

This brief also demonstrates that not all solutions have to have additional costs or rely on new research. South – South cooperation could reveal many more practices in which more food is produced with less resources and be environmentally friendly.

SRI shows that its application will aid governments by reducing pressure on water management. It should not however free governments of their responsibility to manage water resources more efficiently. As shown earlier in this paper, climate change research now show that there is no silver-lining in which some countries will benefit with more water.

There is a window of opportunity to be pro-active and the time to take action is now. As time marches on, the margin for error rapidly dwindles leaving our responses less likely to bridge gaps created by our own lack of inaction. The result being a crisis affecting not only people, but the planet’s ability to ever rebound enough to feed the populations in which our earth supports.

Staff of the Indian NGO PRADAN working with farmers in Jharkhand and other eastern Indian states have developed what they call the System of Finger Millet Intensification (SFMI), producing large differences in phenotype.