

# **SUSTAINABLE INTENSIFICATION THROUGH IMPROVED SOIL HEALTH IN SMALLHOLDER AGRICULTURE**

**William D. Dar and Suhas P. Wani**

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT),  
Patancheru-502324, Telangana, India

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*William Dollente Dar* holds a PhD in Horticulture from the University of the Philippines Los Baños. Dr Dar served as Presidential Adviser for Rural Development, Secretary of Agriculture in the Philippines, Executive Director of the Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development (PCARRD) and Director of the Bureau of Agricultural Research (BAR) of the Philippine Department of Agriculture (DA). Currently he is the Director General of ICRISAT since January 2000.

# ABSTRACT

The dryland areas in Asia and Africa are hot-spots of poverty, malnutrition, and food insecurity, largely attributed to the nexus between land degradation, as well as water depletion and water quality deterioration, and the quality of life of the people in these resource-poor and marginalized areas. There is an urgent need to address the issues of land degradation by developing sustainable agricultural systems through science-based interventions. Many forms of land degradation are largely due to soil erosion (wind and water erosion), nutrient depletion, imbalanced use of fertilizers and inappropriate methods used for growing crops including irrigation methods and use of poor quality water in agriculture following depletion of groundwater as a result of its over extraction.


ICRISAT and its partners have developed innovative farmer-centric and holistic watershed (catchment) management approach along the whole value chain (from farm to table), adopting a partnership strategy that involves consortium, convergence, collective action and capacity building. The use of knowledge-based entry point in promoting collective action has demonstrated on-site impacts, primarily through rainwater conservation, soil conservation, productivity enhancement measures along with income generating activities for women and landless people in the catchment. A number of model watersheds in Asia (India, Thailand, Vietnam and China) have demonstrated the power of integrated water resource management in unlocking the potential of dryland agriculture through improved livelihoods of smallholder farmers. The holistic approach has been internalized and adopted by the Government of India in its integrated watershed management programs. Soil mapping for all plant nutrients and other fertility parameters has revealed widespread deficiency of zinc, boron and sulphur along with that of nitrogen (60-100%) in most of the states in India as well as in benchmark watersheds in China, Thailand, Vietnam and the Philippines.

Using the scaling-up approach since 2009, the mission mode program “Bhoochetana” in Karnataka state, India has used soil health mapping as an entry point, and has demonstrated the power of science-based interventions by increasing crop productivity on 3.75 million ha of land by 20-66% in 2009-2012, benefiting 4.3 million smallholder farm families. The benefit cost ratio for various crops in the 30 districts of the state for individual farmers varied from 2 to 14:1; and the total benefit accrued in terms of gross value of increased crop production reached about Rs. 1267 crores (US\$ 230 million). These results highlight the need to scale-up science-based interventions to sustainably intensify dryland agriculture to achieve a second green revolution in Asia, and to meet the goals of food and nutritional security and improved livelihoods through an Inclusive Market-Oriented Development (IMOD) strategy to benefit smallholder farmers.

## KEYWORDS

Sustainable intensification, land degradation, soil health mapping, integrated watershed management, Bhoochetana

## Sustainable Intensification in Smallhold Agriculture



William D Dar, Director General, ICRISAT  
and  
Suhas P Wani, Director, ICRISAT Development Center

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## The Big Threat: A Looming Perfect Storm



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## Feeding the Forgotten Poor




- How do we feed the projected 9.2 B people by 2050 sustainably?
- Not just a need, but a moral imperative
- 1.4 B people in the developing world live in poverty
- More than a quarter of the world's children are malnourished
- Agricultural research-for-development (R4D) and delivery systems are critical

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## Finite Land and Water Resources



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## Drought – Poverty – Land Degradation Nexus



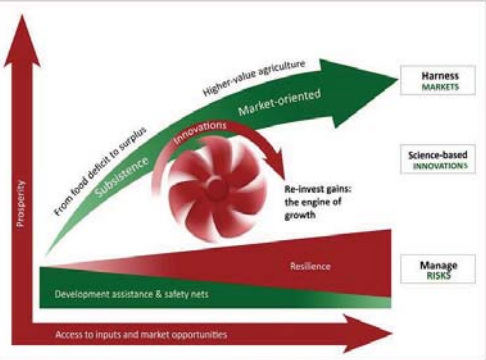
Water is the key issue

An Entry Point  
Community Watershed Management

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## Strategic Development Framework: Inclusive Market-Oriented Development (IMOD)



From food deficit to surplus

Higher-value agriculture

Innovations

Re-invest gains: the engine of growth

Development assistance & safety nets

Resilience

Access to inputs and market opportunities

Harmonize Markets

Science-based INNOVATIONS

Manage RISKS

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## A Paradigm Shift

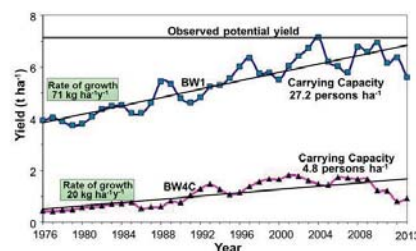
- New deal for dryland/rainfed farmers
- Knowledge-intensive smart agriculture
- Agriculture as the engine of rural growth thru sustainable intensification
- Address social, economic, environmental and technological constraints
- Well informed policies and scaling-up of R4D products



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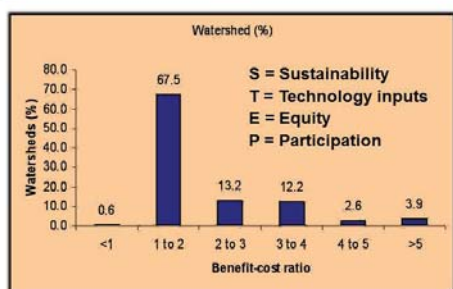
## Rainfed Agriculture: Large Untapped Potential

- 80% of global agriculture is rainfed (1.2 B ha)
- Current farmers' yields are lower by 2 to 5 times achievable yields
- Vast potential of rainfed agriculture needs to be harnessed



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## STEPS to Achieve Impact



- 99% of watersheds economically remunerative with B:C ratio of 2:1
- Two-thirds of watersheds' performance can be improved as 68% of watersheds were performing below average

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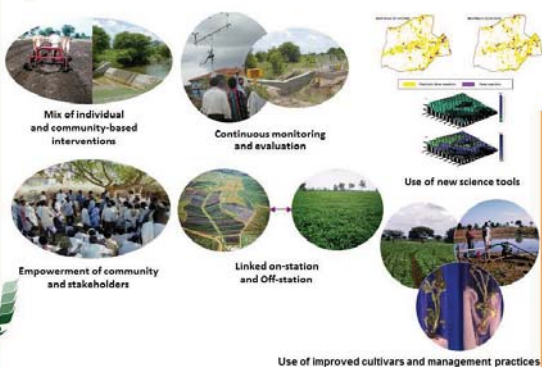
## Farmer-centric Watershed as an Entry Point for Improving Sustainable Livelihoods

- IGNRM, holistic livelihood approach
- Science-based consortium approach
- Profitability and sustainability
- Empowerment and knowledge sharing
- Social inclusion (equity, gender and youth)



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## Integrated Adarsha Watershed Management Model in India



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## Field-based Soil and Water Conservation Measures

- Contour cultivation
- Broadbed and furrow
- Flat on grade
- Conservation furrow
- Border strips
- Field bunds
- Vegetative bunds (*Gliricidia* and *Vetiver* plants)



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### Community-based Rainwater Harvesting/ Groundwater Recharging Structures

- Check dams
- Percolation tanks
- Gabion structures
- Grassed waterways
- Diversion drains







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### Small Water Harvesting Structures

- Better equity
- Easy to construct and maintain by local community

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Water harvesting structure in northeast Thailand

Low-cost mini percolation tank at Kothapally, India

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### Water Alone Can't Do It

- ▶ Soil health
- ▶ Climate-smart crops and cultivars
- ▶ Pests and disease management
- ▶ Markets, institutions and policy support
- ▶ Need for integrated approach





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### Improved Soil Health

- Soil conservation
- Diversified systems with legumes
- Increased level of organic matter
- Balanced nutrition – Emerging wide spread micronutrient deficiencies

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### Crop Productivity Enhancement Initiatives






Evolution of Sweet potato varieties by 14 farmers

Integrated Pest Management (IPM)

50% cost on chemical spraying was saved when tobacco waste sprayed against rice insects

35 farmers grow Tujube and 10 farmers cultivated papaya on irrigated lands


Community nursery of Gliricidia

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### Superior chickpea variety developed through molecular breeding

JG 11\* shown 24% higher yield than JG11 under drought condition



JG11\*  
24% higher yield under drought

JG11

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## Climate Smart Super-early Chickpeas



Super early  
ICC 96029  
75-80 days

Extra-early  
ICCV 2  
85-90 days

Early maturing  
KAK 2  
90-95 days

ICRISAT is ahead of the game with its modern breeding program.



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## Superior groundnut variety developed through molecular breeding

Rust resistant TAG 24<sup>+</sup>, ICGV 91114<sup>+</sup>, and JL 24<sup>+</sup> showed 56-96% higher pod yield



TAG 24  
Susceptible parent

TAG 24<sup>+</sup>  
Resistant with improved yield

GPBD 4  
Resistant parent



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## Hybrid Pigeonpea: Innovative intervention to break yield barrier



- CMS based hybrid technology, first in any grain legume
- Hybrids are resilient for harsh environments of semi-arid tropics
- Yield advantage of 40 to 50 % under rainfed ecosystems



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## Climate Smart Super-early Pigeonpea

- Flowers in 32 days
- Matures in about 65-70 days



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## Pigeonpea in Maize systems in ESA

- Improved pigeonpea varieties enabled smallholder farmers to sell quality grain at higher prices
- Medium-duration varieties (ICEAPs 00554 and 00557) provide two crops a year
- Pigeonpea as green peas now sells at prices almost twice those of the dry grain
- Yields of green pod average 5 t ha<sup>-1</sup>



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## Climate-smart sorghum

- Grown in > 40 m ha in 104 countries
- Short duration multi-purpose smart food-feed-fodder-fuel-crop
- 23% less water requirement than corn to produce 1 Kg of biomass
- High nutrient use efficiency and tolerance to drought, salinity and low fertility
- Gluten-free grain needed for celiac patients
- Low glycemic index suitable for diabetic patients



Early maturing, high yielding, dual-purpose sorghum hybrids (grain yield 6 tons/ha) in rice-fallow of India




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### Pearl millet, a climate change-ready crop

- Can grow on high soil (up to 64°C) and air temperatures (up to 50°C)
- Developed two mapping populations segregating for heat tolerance
- These heat tolerant genes will have implications in breeding for climate resilient pearl millet





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### Fertilizer Microdosing

- Small, affordable quantities (20–60 kg of fertilizer/ha) at planting time to enhance fertilizer efficiency
- In sub-Saharan Africa, even this micro amount often doubles crop yields.
- 25,000 smallholder farmers in Mali, Burkina Faso and Niger have learned the technique and experienced increases in sorghum and millet yields of 44 to 120%, along with an increase in their family incomes of 50 to 130%

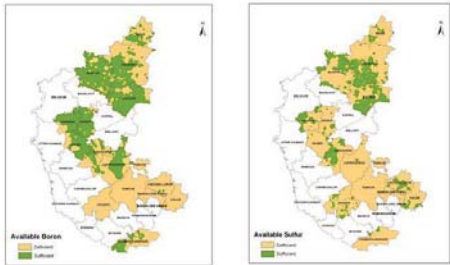



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### Bhoochetana (Soil Rejuvenation): Soil mapping as entry point

Widespread deficiencies of micronutrients (> 60-100%) are recorded in farmers fields




SAT Soils are not only thirsty but also hungry.

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### Bhoochetana: Mission to Help Farmers in Karnataka, India

To touch the lives of 3.6 million farm families in 3.7 million ha of the state by increasing productivity of crops by 20% in 2009-2013



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### Soil Health Knowledge Dissemination






Soil health atlas

Soil health card

Community bill board



Web GIS-based soil information

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### Innovative Extension Systems Empowered Farmers as Extension Agents

- Farm Facilitators (FF) and Lead Farmers (LF)
- Every 500 ha one FF and 2-3 LFs
- Training and empowering FFs and LFs
- Strengthened this novel extension approach

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## Improved Delivery Systems

Decentralized input delivery at village level



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## New Innovative Extension Systems

Trained farm facilitators for every 500 ha



Farmer to farmer videos



Pico projector



Tablet-based extension system

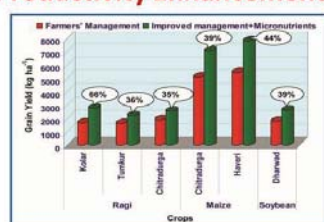


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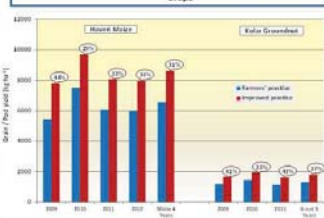
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## Productivity Enhancement in Karnataka



Mean yields of ragi, maize and soybean from farmers' fields in different districts of Karnataka during Kharif season 2009

Increased Crop Yields by 20-66 % for Smallholder Farmers

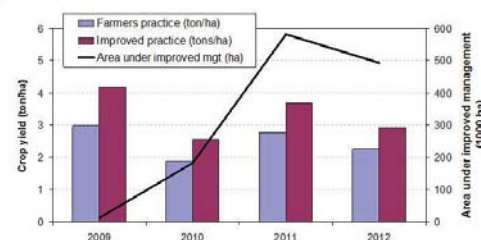


Increased yields of maize in Havari and groundnut in Kolar districts with improved management during 2009-2012

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## Improved Agricultural Practices Increased Crop Yields and Incomes in Karnataka, India



Year	2009	2010	2011	2012	Total
Net income (Rs in Crores)	11.49	204.81	599.45	451.80	1267.60
Net income (Million US\$)	2.52	45.72	112.48	82.44	243.16

Example: Bhoochetana

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## Achievements and Impacts

- Increased crop yield by **20-66%**
- Rise in agriculture growth annually above **5%** since 2009
- Benefit cost ratio for the farmers **3-14:1** resulting in average gain of US\$500 per ha per season
- Net benefits accrued in 4 years **US\$ 240 Million**



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## Drivers of Success for Sustainable Intensification

- Enabling policies and institutions
- Demand driven
- Inclusiveness and participation of stakeholders
- Tangible economic benefits
- Knowledge-based entry point
- Good local leadership
- Transparency and social vigilance
- Empowerment and capacity development
- Markets and rural infrastructure

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### Scaling-up and Scaling-out are a Must to Feed the World

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### Five Steps to Solve the World's Food Dilemma\*

1. Freeze carbon foot print of agriculture at the current level or reduce
2. Grow more on existing farms
3. Use resources more efficiently
4. Change diets
5. Reduce post-harvest losses and food wastage

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\*Thanks to Jonathan Foley and National Geographic

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### Five Steps to Solve the World's Food Dilemma

1. Freeze carbon foot print of agriculture at the current level or reduce
  - Agriculture contributes 1/3 of GHG emissions
  - Stop deforestation
  - Increase C sequestration
  - Reduce CO<sub>2</sub>, CH<sub>4</sub>, NO<sub>x</sub> emissions from agriculture

E.g.: Biological Nitrification Inhibition (BNi)

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### Five Steps to Solve the World's Food Dilemma

2. Grow more on existing farms
  - Bridge large yield gaps
  - Increase yields on less productive lands
  - Use high-tech precision farming
  - Apply balanced fertilization
  - Adopt organic farming approaches

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### Five Steps to Solve the World's Food Dilemma

3. Use resources more efficiently
  - Enhance resource use efficiency through precision farming
  - Use drip irrigation = more crop per drop
  - Use improved cultivars
  - Improve IPM
  - Apply integrated productivity enhancement interventions

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### Five Steps to Solve the World's Food Dilemma

4. Change diets
  - Shift to less meat-intensive diets
  - Choose chicken or pork over beef
  - Go vegetarian
  - Less crops for biofuel enhances food availability

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## Five Steps to Solve the World's Food Dilemma

### 5. Reduce post-harvest losses and food wastage

- Serve small portions
- Eat leftovers
- Improve food storage and transportation



## Conclusion

How to feed  
the world in 2050?

- Feeding 9.2 billion population by 2050 sustainably is possible
- Sustainable intensification is one key approach of climate-smart smallhold agriculture
- Beyond sustainable intensification, let's all start adopting the 5 steps to solve the world's food dilemma today



# Thank you!



ICRISAT is a member of the CGIAR Consortium





**Chair Koyama:** Good morning. My name is Koyama. I am pleased to introduce our keynote speakers today. We have two prominent keynote speakers. I'd like to introduce one by one. The first keynote speaker is Dr. William Dar. Among us he is so famous, maybe there is no need to introduce him again, but this is my role. I'd like to introduce him very briefly.

As you see in this leaflet, he occupied many responsible posts in the National Agricultural Research System in the Philippines. After that, since the year 2000, he is the Director General of International Crops Research Institute for the Semi-Arid Tropics, in short ICRISAT. ICRISAT is also very famous among us, one of the leading CGIAR research centers.

But not only that, he played a very important role in coordinating CGIAR centers as well as in making consensus among the different opinions from research centers in the stage of reforming and other strategy settings. He is leading the whole CGIAR system.

As you see, he has a Ph.D. in Horticulture from the University of the Philippines Los Baños. But each time I listened to his speech, I wondered who is he? He must be a prominent economist or sometimes I felt he must be the expert of information and communication technology or crop breeder. So, he has a very wide range of knowledge in agricultural research and at the same time his research experience is very much integrated.

He received so many awards for his research achievement in his young age and for his leadership in agricultural research system in recent years. But he is concluding his work in ICRISAT. I heard that he would be leaving ICRISAT very soon. Today, we have very precious chance to know a part of his enormous experience in agricultural research. Today, we will feel that he must be a natural resource management expert.

The title of his speech today is "Sustainable Intensification through Improved Soil Health in Smallholder Agriculture." Dr. Dar, floor is yours.

**Dr. William Dar:** Thank you very much, Dr. Koyama, for the very kind introduction. At the outset, let me thank our good friend, Dr. Masa Iwanaga, for this kind invitation to attend this JIRCAS International Symposium 2014. As you are all aware, JIRCAS and ICRISAT have been working all this time in the dry land areas of Asia and Sub-Saharan Africa and for that we also have good links with various research institutions here in Japan. And Ministry of Agriculture and Food, including the relationship with the Ministry of External Affairs, I will be tackling this topic of sustainable intensification, particularly emphasis on soil health in smallholder agriculture.

As you are all aware, we are part of a bigger family, this is the Consultative Group of International Agricultural Research, CGIAR, 15 centers working together to help and work with partners help reduce poverty, hunger, malnutrition, and protect the agricultural ecosystems in most of the developing countries of the world. Now the big threat that's looming before planet earth which will have impact and which now starts to affect smallholder agriculture in developing countries is Looming Perfect Storm, we call it, and this would include challenges brought about by climate change, land degradation and desertification, loss of biodiversity, food price spikes which will lead to food crisis, energy crisis for that matter, and exploding population on this planet. So taken as one, this is what we call the Looming Perfect Storm.

The big challenge for all of us, not only in the CGIAR family but governments like Japan and other development investors, is how to feed the world. Today, there are 7 billion people living on this planet. But by 2050, there will be 9.2 billion people and that will call upon an increase of about 70% to 80% food production to feed the increased population. How in the light of dwindling resources, which I will also mention later on, can we feed sustainably this growing population? So, it's not just a need to feed this population, but a moral imperative. Again, just to highlight that, it's because there are many people who are still in poverty, 1.4 billion people in the developing world that needs all this help to get out of poverty, so that they can have security in terms of the food that they need. To also further highlight that, more than a quarter of the world's children are malnourished. Just to highlight, India for one, 42% of its children are malnourished, and Sub-Saharan Africa has the level of 28% of their children malnourished. So as part of the CGIAR family, we in partnership with developed countries like Japan, we have to do agricultural research for development and delivery systems that are needed to really

help the poor and the smallholder farmers in the developing countries of the world. Just to highlight also that, ICRISAT is focused on Asia and Sub-Saharan Africa.

I was already alluding to this problem of dwindling land and water resources in this planet. It's finite and this is one of those issues that have to be critically managed, if we want to sustain higher levels of productivity and also with the aim to make smallholder agriculture a remunerative or with profitable venture and to tap it all sustaining the environment of this planet. So taken as one, increasing productivity, increasing profitability and sustainability, these are the big goals that we need to achieve together balancing out in spite of this finite land and water resources that we have.

To make it the toughest of them all is to highlight the nexus between drought, poverty, land degradation, and this is more so in the dry land tropics of Asia and Sub-Saharan Africa where these are working as one and giving the headache and all the challenge to smallholder farmers to really increase productivity in this area. To highlight that, yes, again drought is related to our soils and of course water. To make it a point this early, I would like to highlight, particularly for smallholder agriculture, the importance, as an entry point, community watershed management. Community watershed management is one of those areas with which ICRISAT has been pioneering all this time, where there is agricultural production in dry land tropics. We treat that, even a minimum of 500 hectares, as a community watershed where agricultural production is taking place. In this entry point, again you look at the issues of soil, water, land degradation and many, many other issues.

Now ICRISAT has been there for the last 43 years and every 5-10 years we reinvent ourselves. I have been there as the Servant-Leader of ICRISAT for the last 15 years; and 5 years ago, we institutionalized a strategic development framework that is guiding our work and our work with our partners and we call this Inclusive Market-Oriented Development. Why inclusive? Inclusive is referring to the smallholder producers, the farmers themselves to be part and be considered as real partner in the whole paradigm of agricultural development. They are not just beneficiaries, but they are part of the solutions. They are part of the process of generating the solutions for their problems as well. So every step of the way, smallholder farmers, that would include women and the youth, to be part of this paradigm and market as a driver for transformation of subsistence farming to a market economy. So subsistence, as you are all aware, 60% to 70% of smallholder farmers in the dry tropics of Asia are in subsistence. It's a long process, but it has to be started and we have to do it with partners, national programs, private sector, civil society organizations, with the support of development investors. How can we elevate subsistence farmers to the next stage, even to self-sufficiency? And from there, they are starting to build their capital when they have surpluses, because they are starting to bring their produce to the markets, and innovation will drive the game, will drive this process of them going to the next step of market economy. So harnessing markets, science-based innovations, and managing risks will be the key strategies under Inclusive Market-Oriented Development, looking for the solutions that will propel them to higher levels of productivity, profitability and sustainability.

It's a paradigm shift that's taking place. It's a new deal for the dry land and rainfed farmers of Asia and Sub-Saharan Africa and we have already good successes in pursuing this framework. It's a knowledge-intensive smart agriculture and where you bring those challenges that I have mentioned earlier on. And we still believe that agriculture as the engine of rural growth through sustainable intensification properly done and also addressing social, economic, environmental and technological constraints. And elevating the game in terms of policy support and seeing to it that the products and technologies that we do generate and develop are scaled-up, are commercialized in a big way.

Rainfed agriculture is a potential as one of those ecosystems to feed the world. I'd like to highlight here our experience in ICRISAT for the last 40 years, because we have long-term experiments to show that, yes, there is so much potential but this potential has yet to be harnessed. This yield gaps must be narrowed down to the point that you have this opportunity to really handle the food problems of the world. As we all are aware, 80% of global agriculture is rainfed, current farmers' yields are lower by two to five times and there is vast potential of rainfed agriculture to be harnessed. So, the big challenge then is how can you narrow that gap from the level, say, of 1.5 tons to, say, 3 tons to 4 tons, because the farmer can only produce 1.2 tons of food per hectare that can support the requirements of five to six people per year. While using improved practices, good agronomy, good improved cultivars and resource efficiency, it can produce as much as 5 tons of food per hectare



per year that can support the requirements of 27 people per year. So, I will always use this informed data that we have, that we can say that we, yes, have to unlock. We should have to unlock the potential of rainfed farming to feed the world as one of those many sources of food production.

In our experience, we need to do really again, as I mentioned, the community watershed management as an entry point in the dryland areas of Asia and Sub-Saharan Africa. You can see here that in this study that we have made on watersheds, this is particularly for India, that 99% of watersheds are economically remunerative with a B:C ratio of 2:1. So you can also see here that two-thirds of watersheds' performance can be improved, as 68% of watersheds were performing below average. So, the potential is there. There are many ways again some innovations that must be done to achieve the fullest impact of this watershed management.

We always believe that we have to have the farmer as the central of the activity that we do for the research for development activities for us to improve and for them to sustain their livelihoods, integrated genetic and natural resource management is key. Holistic livelihood program is also important. Science-based consortium is as vital as any intervention because you need to harness the power of many of research and development institutions for that matter, to us to sustain higher levels of profitability and sustainability. And in the process, empowerment of the smallholder producers is a must and having to sustain sharing of knowledge between and among them, and of course delivery system has to be improved; and looking at every opportunity to handle the issue of equity, gender and youth engagement.

This is a case in our Integrated Adarsha Watershed Management Model in India. This is now a learning center of India showcasing the watershed management that we continue to innovate. Science that's the opportunity it gives us that we continue to innovate. So, it's a range of all of these factors and we believe that mix of individuals and community-based interventions are key. We need to empower the community and stakeholders. We have to link on-station and our off-station work. We monitor and evaluate, and use the new science tools that are there and the interventions like soil, water conservation measures, agronomy and improved cultivars plus the policy support. This makes a holistic approach to really helping make this dry land watersheds maybe more productive.

These are many field-based soil and water conservation measures that we implement, were relevant. Again, it's a basket of options in many ways. These are contour cultivation, broad bed and furrow (BBF), flat on grade, conservation furrow, border strips, field bunds, vegetative bunds using *Gliricidia* and *Vetiver* plants. So again, this is a suite of options to the farmer but there are a mass or a number of these measures to be pursued.

Now rainfed farming for that matter, it is always an opportunity and a must for us to harvest whatever rain that come, because that's the nature of rainfed agriculture, water is key in agriculture. So every opportunity that we can implement, water conservation measures, water harvesting measures, check dams, percolation tanks, Gabion structures, grassed waterways, diversion drains. When the community is involved then it is much easier for them to sustain these innovations, these improvements that are taking place in their respective rural farming communities.

This is small water harvesting structures will really give equitable engagement because the community is engaged. The community manages the whole innovations, water harvesting structures and the introductions of these. Again, we have to look at what are the cost-effective water conservation measures, where it's easy to construct and maintained by the local community.

Now while emphasizing that water is important, water alone can't do it. Again, the main theme of this conference of JIRCAS, soil health, like anybody, any human being has to consider your health to be productive, to engage profitably in our business. So in the same manner when we produce food, it's simple, we need to sustain, maintain and conserve the soil health conditions. Other interventions would include climate-smart crops and cultivars, as this is one of the global contemporary challenges that is obtaining today, the pests and diseases that are there. When there is a change in climate, there is also the occurrence or there are emerging pests and diseases that we need to now study way ahead and think to it that the markets, institutions, and policy support are there and many other support system.

Now soil health – these are again the basics in improving soil health, soil conservation, diversified systems using legumes, increased level of organic matter and balanced nutrition. Emerging widespread micronutrient deficiencies has been found in most of the developing countries.

I'd like to use that as an entry in seeing to it that we are able to optimize crop productivity. We have done this in many community watersheds, Thailand, China, and India of course, and many other countries as well.

Now this is already to highlight that because of climate change and the climate variability that has been there, we have now developed superior chickpea variety through molecular breeding.

We have now climate smart super-early chickpeas.

We have now superior groundnut variety developed through molecular breeding. We use modern science. We are the only center that is leading genome sequencing. We have done pigeonpea, chickpea, pearl millet. We are now doing finger millet.

Hybrid pigeonpea – this is the first in the world. It can give as high as 40% to 50% more yield.

So climate smart super-early pigeonpea as well, 65 days you have pigeonpea. You can use this after rice or wheat.

Pigeonpea in maize systems – this is the system in Sub-Saharan Africa as part of sustainable intensification system. Already almost a million hectares of this technology is obtaining in Sub-Saharan Africa, exporting the produce to India, some for local consumption.

Climate-smart sorghum – this is already ready in most of the countries of where we work, particularly West and Central Africa.

Pearl millet, the climate change-ready crops, growing on high temperatures, even up to the level of 50oC

Now fertilizer microdosing, Andre Bationo may highlight this in his presentation. It was connected with ICRISAT, started microdosing early enough, 20 years ago, 25 years ago. It's now moving to a million hectares in Sub-Saharan Africa. Africa is one of those continents using less fertilizer, but even just doubling the 8 kilograms that they use for nitrogen, then this giving them good productivity already.

Now just to highlight what we have done in Karnataka, this is Bhoochetana, soil rejuvenation, soil mapping as an entry point, and there were widespread deficiencies of micronutrients. And again to highlight the point that semi-arid tropic soils are not only thirsty but also hungry.

Bhoochetana was a mission to help farmers in Karnataka, 3.6 million farm families in 3.7 million hectares, by increasing productivity of crops by 20% in 2009 to 2013. And we have achieved this and I'll show you the results.

Again soil health knowledge and dissemination, as per the soil health mapping that we have done; we have done that again in those millions of hectares. Soil health cards were given out to farmers.

The innovative extension systems have been done. Farm facilitators were hired and they continue to do the extension to their co-farmers. This is one success story that we can highlight in this new innovative extension system.

We have decentralized input delivery at the village level.

We have introduced ICT for development as well.



These are the results. Increased crop yields by 20% to 66 % for smallholder farmers, very, very possible. I mean we have achieved this.

Improved agricultural practices increased crop yields and incomes in Karnataka. You go to the last figure there. As a result of Bhoochetana, \$243 million has been the result of additional income to the State of Karnataka in four years.

The achievements, in short; increased crop yield by 20% to 66%, 5% growth in agriculture. The benefit cost ratio for the farmers, 3 to 14:1, resulting in average gain of US \$500 per hectare per season. Again, net benefits accrued in 4 years, \$240 million.

These are the drivers of success for sustainable intensification, again policies, demand driven, inclusiveness and many others, good leadership empowerment, markets and rural infrastructure.

The message is we need to scale-up and scale-out to feed the world. The technology should not stay in the files, should not stay in the laboratories, it should reach the farmers.

We have to feed the world and there are only, again to highlight what are five steps to solve the world's food dilemma. Freeze carbon footprint of agriculture at the current level or reduce. This is done. Number 2: grow more on existing farms. Use proper technology. Use resources more efficiently. Change diets. The Japanese diet is a balanced diet. We can feed the world if we follow this diet. We have to reduce meat. Number 5: reduce post-harvest losses and food wastage. I have a slide for this, but I will skip that and go to the last slide.

In conclusion, feeding 9.2 billion population by 2050 sustainably is possible, sustainable intensification is one key approach of climate-smart smallholder agriculture; and beyond sustainable intensification, let's all start adopting the five steps to solve the world's food dilemma today.

Thank you and good day.

**Chair Koyama:** Thank you very much, Dr. Dar, for your excellent speech. We learned the comprehensiveness of the ICRISAT activities in sustainable intensification. Surely it formed guidelines and frameworks of the further discussion today. Thank you very much.