Plenary session interactions between increasing staple crop productivity, resilience to climate change, improving nutrition and sustaining agro-biodiversity

Overview of the session

This session focusses on crop breeding and the synergies and trade-offs that arise in the choice of crops and traits that the breeding program and extension efforts focus upon. One of the main critiques of the Green Revolution has been its impact on agricultural biodiversity, in terms of promoting concentration into a few crops, while also reducing genetic diversity of the crop varieties in farmer's fields. More recently, the potential nutritional impacts of the heavy focus on calorie availability rather than overall nutritional needs has been raised. Finally, the need to adapt to climate change is raising the question of what crops and traits are actually most important for breeding programs – and particularly public sector breeding programs – to address. The session explores the potential interactions among yields of major staple grains (rice, wheat, maize) and agrobiodiversity conservation, nutritional outcomes and resilience to climate change. Implications for crop breeding strategies and for the design of agricultural research systems will be discussed.

Two background papers were commissioned to guide the discussions in this session, and their findings are summarized below.

1. Trade-offs and synergies among climate resilience, human nutrition, and agricultural productivity of cereals – what are the implications for the agricultural research agenda? Ruth DeFries

Trends in production of cereals since the Green Revolution led to dramatic increases in availability of high-yielding rice, maize and wheat cultivars. Simultaneously, diversity of cereal production systems declined across cereal species and within species. Agrobiodiversity underlies the ability to alter current production systems towards a mix of crops and bred-cultivars that are climate-resilient, pest-resistant, and nutritious. Stagnating edible yields in some parts of the world indicate that new approaches and technologies are needed for sustained increases in production.

The Green Revolution was successful in expanding the supply of calories (and related plant protein), but less successful in expanding the per capita supply of other nutrients. The continued global scale of micronutrient deficiencies, often known as "hidden hunger", has raised attention to this gap.

The paper explores the implications of a shift from a limited number of Green Revolution cereals to additional crops that can supply a wider range of nutrients (see table below). Because cereals continue to supply the largest proportion of diets in the Global South, improved micronutrient content of cereals could help alleviate the burden of hidden hunger, although many analysts call for equal attention to the promotion of non-cereal nutrient-rich foods.

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Table 1. *Relative benefits of cereals in multiple dimensions of production, nutrient content, and climate resilience. Darker shades are more beneficial.*

	GREEN REVOLUTION CEREALS			COARSE CEREALS	
	RICE (milled)	WHEAT (whole)	MAIZE	SORG-HUM	MILLETS
PHOTOSYNTHETIC PATHWAY	C3	C3	C4	C4	C4
PRODUCTION:					
Yield	high	high	high	low	low
Increase biomass from CO_2 increase	high	high	low	low	low
NUTRIENT CONTENT:					
Energy	mid	mid	mid	mid	mid
Protein	mid	mid	mid	mid	mid
Iron	low	mid	mid	mid	high
Zinc	low	high	high	mid	high
Phytate[1]	low	high	high	mid	mid
Sensitivity of nutrient loss from CO_2 increase[1]	high	high	low	low	low
CLIMATE RESILIENCE:					
Water use efficiency	low	low	high	high	high
Yield stability	?	?	?	?	?

[1] low is beneficial and high is harmful

Predictions of climate change generally indicate increasing temperature and more variability in precipitation, but all such modelling includes wide ranges of statistical uncertainty. Yields of C3 cereals (e.g. wheat, rice) can benefit more from a carbon dioxide fertilization effect than C4 cereals (e.g. sorghum, millet), but C4 cereals can be more water efficient. Minor cereals are generally more resilient to climate variability than major cereals.

The paper summarizes a variety of systems approaches to decision-making, providing a case study of historical trends in production and consumption of cereals in India and consequences of several scenarios for cereal production across multiple dimensions. The author identifies key institutional issues that would need to be addressed for CGIAR to more fully embrace a systems orientation, including: the need for experts on nutrition and climate to interact with traditional researchers; interaction across programs to minimize stovepipes focused on individual cereals; measurable and practical metrics to quantify multiple dimensions of interest related to the SDGs; realistic monitoring of uptake of new cultivars and their outcomes in field settings; institutional arrangements that provide flexibility to adapt to required changes based on information from monitoring and re-evaluation; and, investment in coarse cereals to maximize advantages for nutrition and climate resilience.

2. Pathways of staple crop productivity through agrobiodiversity to diet diversity: evidence on links and trade-offs. Melinda Smale et al.

This paper explores the synergies and trade-offs among staple crop productivity (measured as yields), various measures of agrobiodiversity, and diet diversity. Recognizing the complexity of relationships, the paper sketches pathways from breeding for increased grain yields through agrobiodiversity to diet diversity on small-scale, household farms that operate without fully developed markets. The paper is organized around a series of hypotheses as summarized in table 2 below. Staple crops are limited as rice, wheat and maize.

Table 2. *Summary of evidence by hypothesis and sub-hypothesis*

Hypothesis	**Analysis**
Hypothesis 1: Increasing staple crop productivity reduces agrobiodiversity	Agrobiodiversity is a permeable rather than a bounded subset of biodiversity. The fact that agrobiodiversity cannot exist without humans differentiates it from other biodiversity components (e.g. forests). Because land is limited, there is a trade-off between promoting biodiversity conservation and promoting agricultural commodities. Depending on where we are currently situated and chose to operate, however, making win-win choices could be possible. There is no clear evidence that agricultural research to improve the productivity of staple food crops, as it is conducted today, reduces agrobiodiversity; on the other hand, there is no evidence that it promotes it.
1a. Is staple crop productivity increase a major contributor to expansion of agricultural lands?	Most output growth of staples over 1961-2014 came from yield growth rather than area expansion. Land use change (e.g., loss of forests) is driven less by production technology and more by market led forces for commodity crops with high income elasticity of demand. Recent modeling with counterfactuals concludes the Green Revolution spared land.
1b. Do we see a relationship between breeding for productivity increase and diversity of crops grown?	Few clear links found in empirical literature, because establishing the counterfactual is beyond the data; but cites Pingali who distinguishes between high potential and marginal production areas with staple crop productivity increases in the former more likely to lead to specialization/monoculture and not as much in marginal areas. Some cereals such as sorghum and millets are found to do better in marginal areas. While there is some micro-economic evidence that suggests diversification is associated with some positive outcomes, it is not clear whether they would hold at larger scales or what they mean for policy.
1.c. Does modern plant breeding for productivity gain in major staples lead to loss of infra-specific diversity on farms?	Modern varieties of major cereal crops have largely replaced more diverse systems. With landraces, diversity is distributed across a plant population; with MVs, it is distributed over space and time

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	across a crop-producing area, allocated among more than within varieties.
1.c.1 Breeding and diffusion of MVs has resulted in genetic narrowing	We can't test how much diversity was in the fields before modern breeding. Studies indicate that the MVs have high degree of diversity - shows a significant positive trend in the number of distinct landrace ancestors in the pedigrees of MVs and rising genetic diversity at molecular level (e.g., synthetic hexaploids). An important point is that the international research system is continually bringing in germplasm with different genetic backgrounds. Independent of CGIAR, Van de Wouw et al. (2010) did a meta-analysis of 44 published studies. They found a drop in the 1960s compared to 1950s and a recovery since then—no clear trend. Jarvis et al. found that genetic diversity units (farmers' varieties) of major staples had higher richness and evenness than non-staples in numerous cross-country sites. Much variety richness was held at low frequencies in communities – implying their maintenance as insurance.
Hypothesis 2: Increasing staple food productivity reduces dietary diversity	While there is ample evidence that in the aggregate, raising agricultural productivity is associated with better nutrition, there is less evidence about how this occurs and even less to confirm that agricultural programs designed to enhance nutrition have been effective.
2.a. Does modern plant breeding for productivity increases in staple crops affect dietary diversity?	Evidence is inconclusive due to methodological issues. Difficult to make a connection because there are multiple and complex impact pathways. Essentially we could expect productivity increases to affect diets through either an income effect (e.g. increased income allows for purchase of more diverse diet) or own-consumption effect (where it could go either direction). No clear consensus emerges from the literature on this. Alwang et al. question whether most staple crop productivity increases are large enough to lead to income increases – and thus not likely to be a major effect on dietary diversity from income effects. Studies have found diversity of agricultural goods is a good predictor of diversity of food supply at national and HH levels.
2.a.1 Do higher levels of on farm diversity lead to higher levels of dietary diversity?	Generally positive but small in magnitude. But not robust results – increasing diversity on farm is probably not best way to increase dietary diversity – more important is market access. There is some indication that higher on farm diversity has a positive impact on women's dietary diversity.
2.a.2. Do higher diversity of wild plants lead to higher dietary diversity?	Generally yes, although the empirical evidence is sparse in terms of meeting nutritional adequacy.

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