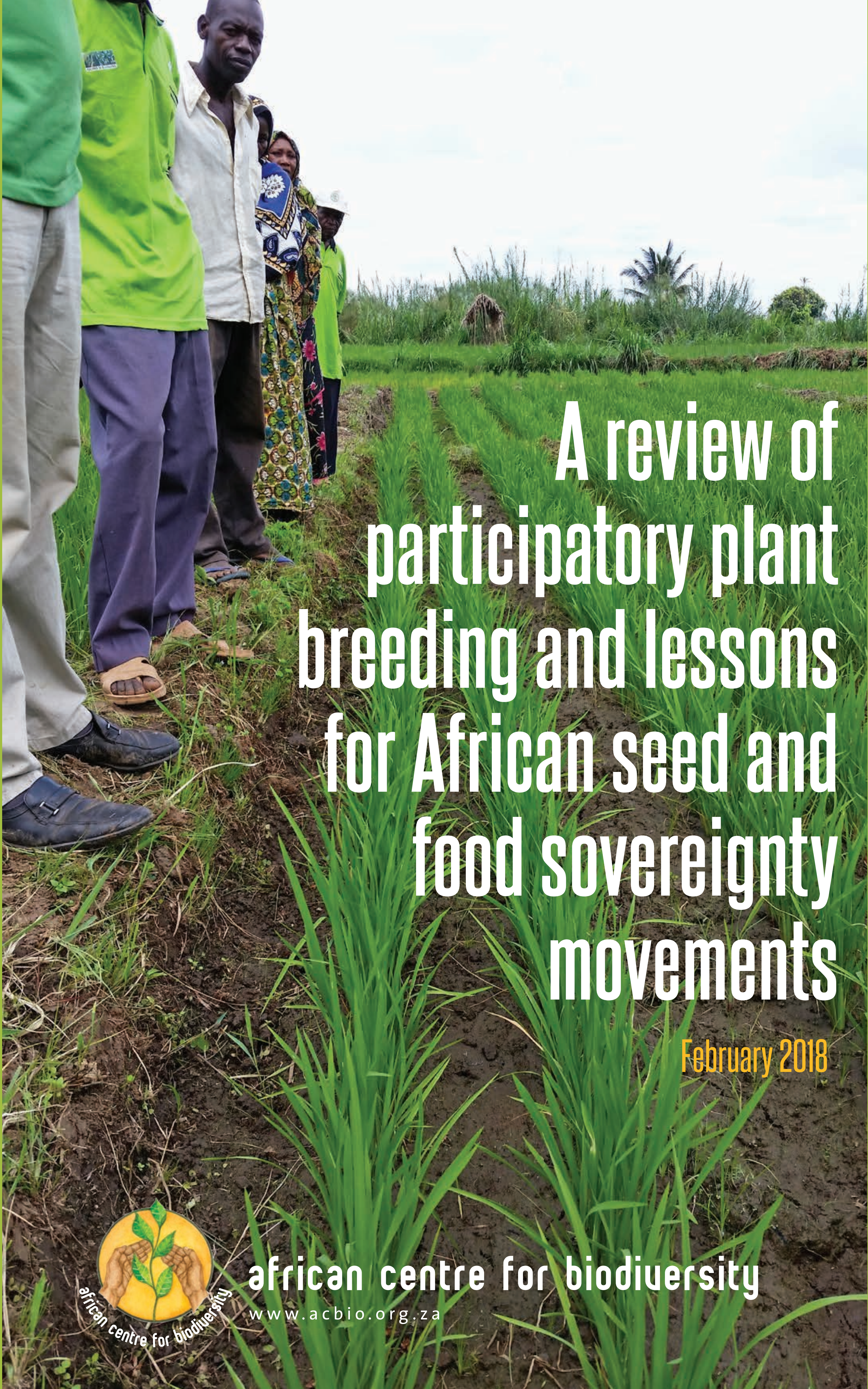

A review of participatory plant breeding and lessons for African seed and food sovereignty movements

February 2018

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Contents

On 7 April 2015 the African Centre for Biosafety officially changed its name to the African Centre for Biodiversity (ACB). This name change was agreed by consultation within the ACB to reflect the expanded scope of our work over the past few years. All ACB publications prior to this date will remain under our old name of African Centre for Biosafety and should continue to be referenced as such.

We remain committed to dismantling inequalities in the food and agriculture systems in Africa and our belief in people's right to healthy and culturally appropriate food, produced through ecologically sound and sustainable methods, and their right to define their own food and agricultural systems.

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Front cover picture: Rice demonstration plots, Mvomero, Tanzania

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Introduction

Despite their centrality for farmers in Africa and elsewhere in the world, farmer seed systems are marginalised when it comes to support or research. We define farmer seed systems as the wide range of diverse activities to maintain, enhance, use and share genetic materials outside the formal breeding and commercial production system. There may be some points of intersection with the formal sector but many of these activities operate outside any formal support. In recent times there has been growing recognition of the important role played by smallholder farmers[1] in maintaining and conserving agricultural biodiversity, and growing interest globally and in Africa in farmers' seed practices and means to support and strengthen these practices (for example, Ahmed, 2015; Smith et al., 2015; McGuire and Sperling, 2016).

Farmer seed systems can be approached from many angles, including: as a source of diverse germplasm; reintroduction of displaced indigenous and other local crops and varieties; biodiversity conservation and maintenance; breeding, including variety selection and enhancement; seed production; storage and management; distribution; farmer organisation; research, extension and knowledge sharing; public sector support; and others.

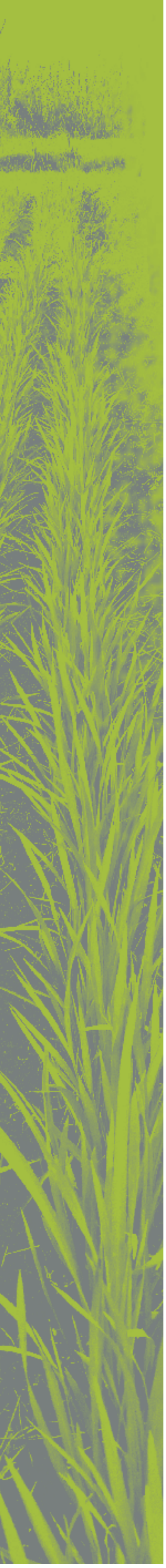
Farmers and organisations are working on a range of aspects of farmer seed systems, globally and in Africa. African Centre for Biodiversity (ACB)'s objective is to generate and share useful information to support and expand this work collaboratively with smallholder farmers, civil society organisations (CSOs), public sector organisations and donors. ACB considers smallholder farmers to play a critical role in the maintenance and stewardship of biodiversity, including agricultural biodiversity. This role falls specifically to smallholders because survival strategies incorporate polycultures, including trees. This is in contrast to large-scale commercial agriculture and Green Revolution approaches to agriculture in general, where mono-cropping is the order of the day and there are low levels of biodiversity is in segregated zones of production.

This scoping paper looks specifically at breeding (also known as crop improvement), which includes: priority setting; generating genetic variability, including crossing; selection; comparative testing; and sharing the resulting materials and knowledge. It touches on aspects of biodiversity maintenance and conservation, and seed multiplication and distribution as closely related areas. The objective is to understand these processes better and to identify strengths and weaknesses in existing approaches, with the goal of strengthening farmers' active and recognised roles in seed reproduction, maintenance, enhancement and use.

In this report we have adopted a definition of participatory plant breeding (PPB) that bounds the term, so that we focus our investigation. The way we have bounded it explicitly excludes farmer variety selection and enhancement activities, where there is no partnership whatsoever with formal breeders. This is not to say these farmer activities are not important. On the contrary, they are highly important. But PPB is a very specific set of institutional/organisational arrangements that has developed in practice over the past 25–30 years. It has emerged as a specific process, with farmers and formal breeders working together.

Participation refers to the role of farmers in breeding/enhancement. It can suggest that farmers are participating in something coming from elsewhere, and, indeed, most participatory approaches are just this. They tend to be mostly initiated by formal breeders in processes that link farmers and breeders, so that they share their knowledge and practice of improving plant materials. These are more or less equal relationships, depending on the specific context. While farmer participation may be used instrumentally to achieve breeder objectives, there also appear to be PPB projects where

1. Following Cousins (2014) we make a distinction between smallholder (land size) and small scale (enterprise size).



farmers have significant control over the process and the enhanced materials produced. Political questions about the roles and potentials of participation are considered in the paper.

The objectives of the scoping study are to:

- get a deeper understanding about plant breeding/crop improvement/variety enhancement and its role in seed systems;
- increase our understanding of the history and practices of PPB and its relation to other aspects of seed systems;
- identify sites of practice (globally and especially in Africa), and do some initial investigation to draw lessons and identify possible sites for field visits;
- draw lessons to date from global experiences on PPB for consideration in Southern and East Africa; and
- identify organisations and individuals working on PPB and related aspects of seed systems in Southern and East Africa.

Method

The research is primarily a desktop study based on a literature search and review. There is plentiful information, especially on earlier projects. We aimed for broad selections and sought a diversity of geographical experiences, especially in Africa and the Middle East, Asia and Latin America. The literature review was supplemented with communications with people working on PPB globally, and with a short survey we sent to a number of organisations doing current work, especially in Africa, to gather key information and lessons. A list of survey respondents is provided in the references.

A note on terminology

It is not necessary to split hairs about terminology, although we must be aware of the significance of different terminologies. In general use, 'improved' seed is understood to refer to certified seed from the formal sector. Farmer in situ improvements on seed under their control may be referred to as 'enhancements' to make a clear distinction.[2]

'Plant breeding', 'crop improvement' and 'variety enhancement' are used interchangeably in the paper. As the paper will show, the boundary between formal sector improvements and farmer in situ enhancements is very blurred in PPB projects, and in fact is mostly indistinguishable.

'Breeders', 'researchers' and 'scientists' are used interchangeably in this paper to refer to plant breeders working in the formal sector. In the context of this paper, research refers primarily to plant breeding research. There may be elements of process facilitation that involve research that is not directly related to plant breeding, as well as documentation of processes. These will be apparent in the paper. Reference is also made to farmer-breeders distinct from formal sector breeders.

We refer to 'varieties' in a looser sense than the term may be used by formal breeders, and include farmer seed varieties in which not all characteristics are fixed. Sometimes the term 'lines' is used to refer to genetic materials that are still segregating, as opposed to varieties in which traits are fixed. However this use is not followed absolutely strictly and sometimes segregating materials and germplasm are also referred to as varieties. 'Varieties' and 'cultivars' are used interchangeably to refer to 'finished' materials with fixed traits that are reproduced in the next generation. 'Germplasm' and 'genetic materials' are used mostly interchangeably to refer to living genetic materials, including seed, maintained for the purpose of breeding and further research.[3]

In quotes from others there may be reference to 'informal seed systems', which we have left in but do not use ourselves, preferring the term 'farmer seed systems' to give agency to farmers and not to side-line them. 'Informal' systems may be referred to from time to time as a contrast to formal means of distribution, for example.

'Indigenous' refers to plants that originally come from an area or have been used locally for a long period of time. 'Farmer varieties' refers to seed and germplasm that has been adapted and reproduced by farmers for any length of time. This may include

2. Interview, Melaku Worede, Ethiorganic Seed Action, Addis Ababa, Ethiopia, 25 May 2015
3. https://en.wikipedia.org/wiki/Germplasm

open-pollinated varieties (OPVs) that at some stage went through formal sector improvements, especially through the public sector agricultural research institutes (ARIs), but that, over time, have been adapted by farmers to their local contexts.

'Genotype' refers to the genetic constitution or make-up of a particular organism. 'Phenotype' refers to observable characteristics of a plant. 'Ideotype' refers to the idea that farmers/breeders may have about the characteristics of a variety. 'Genotype x environment' (GxE) refers to the interactions between a genotype and different environments.

Structure of the paper

The paper is structured into four main sections, with a brief set of reflections in conclusion.

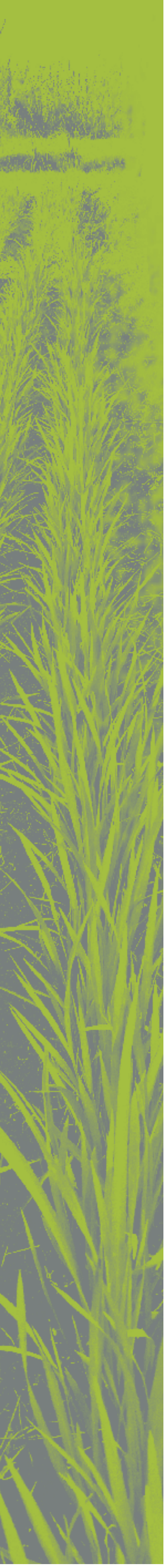
The first section is a background to plant breeding, which considers farmer historical roles; the rise of breeding as a specialised activity; an historical overview of plant breeding in Africa; trade-offs and limitations of formal breeding; and contemporary challenges to farmers' historical roles in biodiversity conservation and adaptation.

The second section provides a background and overview of PPB. It includes an introduction to PPB and comparison with conventional breeding; reflections on participation, including a critique and consideration of types of participation; and a brief historical background to PPB and current projects.

The third section discusses the structure of a plant breeding programme. It provides an overview of a generic plant breeding process; the links between biodiversity conservation and maintenance and crop improvement; and the stages in a plant breeding programme, including setting priorities and objectives and generating genetic variability and sources of germplasm. It also provides an overview of intellectual property (IP) rights and access in sourcing germplasm; selection, including participatory variety selection (PVS); testing of experimental cultivars and the relationship to formal registration processes; and some comments on multiplication and dissemination of varieties after breeding.

The fourth section provides an assessment and lessons of PPB from reviewed case studies. This section works through the structure of a breeding programme to see what happened and the lessons from practice, and reflects on key successes and challenges from the literature.

The paper concludes with short reflections on key issues for further consideration.



Background to plant breeding

Farmer historical roles

Plant selection is at the base of agriculture itself, when humans began identifying and domesticating selected plants for food. With conscious human selection over time, plants adapted genetically to cultivation and away from survival in the 'wild' (Almekinders and Louwaars, 1999). Domestication involved selecting crop plants for traits of uniformity, predictability and higher productivity. Contributing traits include: height, growth habit, ripening, seed dormancy, seed shattering, fruit/seed size, ease of dispersal, threshing, reproduction, germination, hair/spines and toxins (Brown, 2010).

Intrinsic farmer activities in relation to conservation include keeping seeds, preparing the soil, fertilising, planting, watering, weeding and harvesting. Farmers bring deep knowledge, such as how to identify varieties, ideal planting locations, care requirements, and harvest and post-harvest practices. These are linked to use of and adding value to resources (Meldrum, 2013:98). Across cultures, women play a central role in maintenance, conservation and enhancement of crops and varieties. Agricultural systems globally have a gendered division of labour. Women and men have different tasks in and around the homestead and farm, and distinct roles and responsibilities with respect to resource management. Women and men develop separate, shared and complementary sets of knowledge about the natural world (Elias, 2013). Women play a critical role in identifying and bringing wild plants into food systems, and women hold extensive and detailed knowledge about food, fodder and medicine. Worldwide, women smallholder farmers are active in breeding, selection, management, processing, storage and conservation of plant resources. Globally, women are the primary actors involved in smallholder seed selection and storage and in farmer-to-farmer seed distribution networks (Elias, 2013).

Rise of breeding as a specialised activity

Crop husbandry and stewardship by cultivators themselves has, thus, been the bedrock of agriculture for thousands of years. It is only relatively recently, at the dawn of the scientific revolution in the 1700s, that scientists began entering into this space, with contributions to a better understanding of plant anatomy and reproduction. Experiments at hybridisation started in the early eighteenth century. In the early 1900s, the United States Department of Agriculture (USDA) was collecting and disseminating germplasm to growers (Catotti, 2010). Plant breeding as a scientific discipline can be traced to Gregor Mendel's experiments in the early 1900s, on the inheritance of genetic traits (Shelton and Tracy, 2016). This led to the rise of plant breeding as a specialised activity, which, combined with commercialisation in agriculture, led to the separation of breeding from farming practices.

From the 1920s, the Rockefeller Foundation in the US began supporting hybridising efforts in maize to produce an improved crop for industrial agriculture. This led to yield expansion in the US, and the activities were taken to other countries: Mexico, Brazil and Argentina in the 1940s and Kenya in the 1950s. Parallel efforts were made in the 1960s to introduce similar programmes, mainly in wheat and rice, in India, Pakistan, the Philippines and Indonesia.

Scientific breeding for yield was the cornerstone of what has come to be termed the Green Revolution. These activities led to the establishment of what later came to be known as the International Maize and Wheat Improvement Centre (CIMMYT), based in Mexico, and the International Rice Research Institute (IRRI), based in the Philippines (Kaur, 2010). Undoubtedly, these efforts did lead to sharply increasing yields, but there were significant negative social and ecological impacts (Carson, 1962; George, 1976). The trade-offs were considered to be worth it by the ruling powers, and in 1971 the Rockefeller and

BOX 1: Plant breeding in Africa

Agriculture was and remains one of the core economic activities across Africa. In the immediate post-independence era of the 1960s, the public sector was tasked with agricultural research and development (R&D). Formal variety development in sub-Saharan Africa (SSA) began in the 1970s with testing through international varietal trials and a search for broadly adapted varieties. This was successful for wheat in Asia but was found to be "highly inefficient for maize under African conditions" (Lynam, 2011:37), given the wide range of agro-ecologies under limited input use and rain-fed production. These pose an inherent difficulty in developing commercial seed systems, even for dominant staples in Africa. There was a small amount of private sector investment in R&D and plant breeding in narrow channels of profitability.

Hybrid development is mainly limited to maize, mostly for use in East and Southern Africa, in particular South Africa, Kenya and Zimbabwe. The private sector has also invested selectively in 'closed' value chains such as cotton, coffee and tobacco, where companies organise the whole chain, including inputs, production methods and outputs. Otherwise, formal plant breeding research was, and essentially remains, a public sector activity in Africa (Lynam, 2011).

Following global economic crisis and the related debt crisis in Africa in the 1980s, structural adjustment programmes and the rise of neoliberal approaches led to stagnation and decline in agricultural R&D spending in the 1980s and 1990s. There was a shift to regional approaches, especially through the CGIAR regional centres and the creation of sub-regional agricultural research organisations, for example, Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the West and Central African Council for Agricultural Research and Development (WECARD).[4]

Political unrest in numerous countries accompanied structural adjustment and market liberalisation. Donor priorities shifted to governance and economic enterprises, and agricultural research was not considered a 'quick win' for results. National agricultural research systems (NARS) continued to rely on donor funding, with the World Bank and European governments amongst the main donors in national systems. In Malawi, donor funding to agricultural research almost stopped, with a shift to productivity increases through the farm input subsidy programme. This has produced a stratification of research capacity across countries, with stronger systems in South Africa, Kenya and Ghana, where there is more commercial agriculture, and an expectation that the private sector would fill the space vacated by the public sector, even in countries with limited commercial agriculture (Lynam, 2011:38).

Investment in agricultural R&D started to pick up again from around 2000, but under private sector authority (Beintema and Stads, 2011). This expansion was in response to the commodities boom and the search for profitable avenues for the use of excess capital being generated in the capitalist core at that time. Although this growth in investment in agricultural R&D in Africa has continued to 2011 (at least), it was mainly driven by a few countries – Nigeria, Ethiopia and Kenya in particular, with many other smaller countries falling behind (Beintema and Stads, 2014). Part of liberalisation and privatisation was decentralisation of agricultural research to semi-autonomous institutes, which faced issues around economies of scale for plant breeding and coordination of varietal testing (Lynam, 2011:39). It is also apparent that while public sector breeders could produce potentially useful varieties for a range of agro-ecological contexts, they did not always have the capacity to multiply and get these out to farmers. To this day, potentially useful varieties sit on the shelf without being used.

4. Conference de responsables de recherché agronomique africains (CORAF)

In 2006, the Bill and Melinda Gates Foundation created the Global Development Programme. Its principle focus was on agriculture, with a significant component supporting agricultural research. Together with the Rockefeller Foundation, the Global Development Programme established the Alliance for a Green Revolution in Africa (AGRA). AGRA's Programme for Africa's Seed Systems is dedicated to crop breeding and seed system development, including individual breeding programmes and start-up activities for seed companies (Lynam, 2011:39; ACB 2012). Currently, there is a mosaic of donor support for agricultural research in SSA. The World Bank has shifted from funding research projects to providing indirect agricultural loans, and promotes public-private partnerships. There is a disparity across national systems and a focus on regional approaches and strategic areas, where some capacity already exists to build on. Plant breeding may be a part of this (Lynam, 2011:39).

In 2007, ASARECA shifted to competitive grants. This is not conducive to the needs of ongoing breeding programmes. Plant breeding has its own organisational architecture, which relies heavily on predictable, recurring financial support, continuity and long investment horizons (Lynam, 2011:43). The shift to competitive grants broke the connection between the CGIAR centres and national ARI breeding programmes (Lynam, 2011:40). Regional breeding networks deteriorated significantly in the 2000s, with some regional breeding programmes closing, due to lack of funding (Lynam, 2011:43). Plant breeding capacity is a bellwether for the expansion and contraction of agricultural research. It is a long-term investment requiring commitment. However, it does not have a lot of policy visibility or short-term impact compared to interventions like input subsidies, and is often considered of lesser importance in funding decisions (Lynam, 2011:45-46).

The plant breeding challenge for sub-Saharan Africa is to optimise existing genetic diversity to match agro-ecological, cropping system and consumption system heterogeneity that characterise food and agriculture on the continent (Lynam, 2011:43).

Ford Foundations, working with the World Bank and the United Nations (UN) Food and Agriculture Organisation (FAO), established the Consultative Group on International Agricultural Research (CGIAR) to expand the Green Revolution into more countries and more crops. Today, the CGIAR coordinates agricultural research in developing countries worldwide (Kaur, 2010:15). Its research agenda has evolved and now includes such issues as sustainable agriculture and adaptation to climate change. However, recent times have witnessed a decline in public sector spending on agricultural research, and a shift in research from public to private.

Formal breeding has historically focused attention on increasing yields (productivity). Many other major breeding objectives are indirectly related to this, for example, pest or disease resistance, and adaptation to abiotic stresses (drought, low soil fertility), as they aim to increase or stabilise yields in specific socio-ecological conditions (Weltzien and Christinck, 2009:76). Undoubtedly, yield and productivity are central concerns for farmers. Formal breeding responded to longstanding concerns for crop producers, including predictability, higher productivity, and for some farmers and some traits, uniformity. However there are also trade-offs in adopting formal breeding.

Trade-offs and limitations of formal breeding

Formal breeding tends to focus on relatively few crops and to direct activities towards favoured, high-potential areas, with little, if any, work on diverse demand in more marginal areas (Danial et al., 2007). Although farmer breeding practices have resulted in thousands of different and genetically unique varieties cultivated in farming systems, today only 150 plant species are widely cultivated, and just 12 provide three-quarters of the world's plant-based food. These 'mega-crops' include rice, wheat and maize along with sorghum, millet, potatoes and sweet potatoes. The result is genetic erosion and increasing dependence on a relatively few plant varieties, with species loss and reduction of diversity, as well as a gradual breakdown of processes that maintain the evolution of diversity (Fowler and Mooney, 1990; Vernooy, 2003:2–3).

The formal breeding system is not very responsive to issues beyond yield, with unintended consequences that ripple out into seed systems. Other traits and qualities, including appearance, conservation, processability and culinary value are marginalised or even traded off for yield. These are influenced by local factors, making farmer preferences difficult to assess and integrate into large-scale formal breeding programmes aiming for uniform outputs (Trouche et al., 2012:70). There is mounting evidence that the global availability of staple food alone is not sufficient for reducing hunger and malnutrition (Weltzien and Christinck, 2009:76). Participatory appraisals with farmers and users indicate a preference for a combination of multiple traits, with some willingness to trade off some yield advantages to retain these combinations – this is shown in the case studies later.

Materials developed in CGIAR institutes are often developed for wide use but are poorly adapted to diverse local conditions (Rios Labrada, 2005), and will need local adaptation and testing to be integrated into local farming systems. Often this will require crossing with local materials. Most conventional breeding activities use gene bank materials, rather than materials currently maintained in farmers' production systems, despite the continuing availability of considerable and unique local crop diversity (Gyawali et al., 2010).

Varieties that may perform well at research stations ('on-station'), under ideal conditions, with fertiliser, irrigation and so on are not necessarily good in relation to specific and unique socio-ecological contexts, especially marginal areas (Vernooy, 2003). Conditions 'on-farm' may differ considerably from those on-stations, with GxE interactions resulting in cultivars selected on-station being poorly adapted to conditions on-farm (Manu Aduening et al., 2006). Selection in an environment different from the target environment results in a decrease in selection efficiency (Wakjira et al., 2008:188).

Today there is widespread recognition that the conventional package of new varieties and external inputs, while successful in the more favourable production areas, has often failed to benefit small-scale farmers in marginal areas ... traditional farming and low-input systems are a very heterogeneous population of target environments and not easily served by centralised, conventional plant breeding" (Ceccarelli et al., 2009:vii–viii).

While technicians consider homogeneous lines a sign of genetic uniformity, this may not be what performs best in a highly heterogeneous, risky environment. Having more genetic variability in the field can be a way of avoiding the very real risk of total crop failure, and may be gained by mixing cultivars in the field (McElhinny et al., 2007).

Challenges to farmer historical role in biodiversity conservation and adaptation

Formal breeding is built on the separation of farmers from the breeding process. This has posed a major threat to agricultural biodiversity, as indicated in the limits to formal plant breeding methods and approaches. These limitations on formal breeding are also located in a broader context of pressure on farmer seed practices. In the process of pushing a commercialisation and modernisation project onto African agriculture in the form of the Green Revolution, for example, formal plant breeding has fallen under the sway of private interests. These interests are pushing for IP protection and standardised

quality controls shaped by their needs. This involves promoting certified seed as the only legitimate seed for farmers to use, and the simultaneous denigration of farmer seed as diseased, low quality and illegal.

There is limited recognition amongst government authorities that most seed is produced and reproduced in farmer systems (Hardon et al., 2005). This has produced a marginalisation of indigenous and farmer varieties and knowledge, despite the existing agricultural biodiversity maintained by smallholder farmers. Farmer knowledge and skills in selecting and breeding quality seed are being lost through breakdown of intergenerational knowledge sharing. Smallholder farmers are the natural custodians of biodiversity, in contrast with large-scale commercial farmers, who are locked into mono-cropping, which is not conducive to the maintenance and enhancement of agricultural biodiversity. Mono-cropping, whether on a large or small scale, leads to segregated zones of production with very low biodiversity. Men also tend to dominate these spaces, since mono-cropping is, more often than not, for cash crop production.

In places with large-scale commercial farming, farmers have completely lost their historical role in maintaining and expanding agricultural biodiversity. "The combination of industrialisation of agriculture and formal training for plant breeders created a gap between breeders and farmers, a gap that was exported to developing countries in the post-war era" (Ceccarelli et al., 2009:vii). Formal plant breeding deskills farmers by removing plant breeding from their range of activities and placing these skills with a separate, laboratory-based layer of specialised technical experts. This has created centralisation of decision-making and concentration of resources. Biotechnologies prompt even greater centralisation and concentration; for example, molecular breeding using markers; advanced molecular characterisation of germplasm; integrated information systems linking genetic, genotype and phenotype information; and the exclusive use of this information for private profit and integrated transgenic platforms linking biotechnology, seed and agrochemicals.

Experience in Asia indicates that the known benefits of agricultural biodiversity are constrained, due to the limited number of plant breeders who can respond to the needs of poor farmers. Reasons for this include: a small proportion of accessions are used by plant breeders; public sector investment in plant breeding is declining; there is an over-emphasis on biotechnological tools for plant breeding; young scientists are showing declining interest in conventional plant

breeding; and there is a lack of innovative and simple plant breeding methods for use by local institutions (Sthapit and Ramanatha Rao, 2007).

Farmers in sub-Saharan Africa also face other pressures. Poor soil fertility, low rainfall and frequent drought limit agricultural production across the region. Farmers who survive develop complex, adapted farming systems and strategies to respond to these realities (Weltzien and Christinck, 2009:76). However, these diverse farming systems themselves are presently undergoing rapid change, including declining size of landholdings, reduction in fallowing periods, and low productivity. Traditional crops and varieties ideally adapted to certain farming practices and site-specific conditions tend to disappear because of technological or climate change, economic pressure, changed food habits, and loss of traditional knowledge (Weltzien and Christinck, 2017:260). Climate change is manifested in rising temperatures, altered rainfall patterns, drought, and increasing incidence of pests and diseases. This has uneven impacts on farmer varieties/materials. Some varieties in some places perform better than certified seed but others perform less well.

Urbanisation and changing lifestyles and diets may require new varieties. Bulk commodity markets such as maize and soya may displace local crops and facilitate monocultures. The need for uniformity on the market means diverse forms of the same product will not be valued as highly as uniform products that can be used at large scales for processing and industrial value addition (Sthapit and Ramanatha Rao, 2007).

Participatory plant breeding background/overview

Introduction

In the context of the limits to formal breeding and the threats to farmers' seed systems and their role in agricultural biodiversity conservation and use, PPB emerged as a way to overcome some of these limitations and to bring farmers back into the breeding process as active participants. There is a comprehensive literature by practitioners providing detailed overviews of participatory plant breeding (for example, Witcombe et al., 1996; Sperling and Ashby, 1999; Sperling et al., 2001; Bellon and Morris, 2002.; Vernooy, 2003; Thijssen et al., 2008; Ceccarelli et al., 2009; Badstue et al., 2012; Kraaijvanger et al., 2016; Weltzien and Christinck, 2017).

Simply put, PPB is a form of participatory crop improvement[5] "based on the principle that farmers participate as equal partners alongside agricultural scientists, fairly sharing their knowledge, expertise and seeds. The results of such collaboration include not only more effective crop management practices, but also strengthening of farmers' capacity to experiment, learn and adapt" (Steinke et al., 2016:63). The essential core of PPB that we are adopting in this paper is collaboration between farmers and formal breeders through various stages of the breeding process. Breeding plots are located in farmers' fields, sometimes with parallel plots on agricultural research stations, with farmers actively involved in selection and testing for agronomic and quality traits tailored to their specific requirements (Shelton and Tracy, 2016:2).

The definition of PPB we are using excludes selection and enhancement activities by farmers without a partnership with formal sector breeders. These practices are very central to sustainability of farmer activities but are excluded from this particular study because: i) we are looking at ways in which farmers and breeders collaborate on practical projects; ii) there is very limited documentation of such practices, despite their widespread reality; iii) including any and all farmer practices on selection and enhancement essentially means reviewing smallholder farmer practices everywhere across the world which obviously is too large a project. PPB has developed over the past three decades or so as a particular form of collaboration and should be reviewed in light of the intentions of its practitioners over this time.

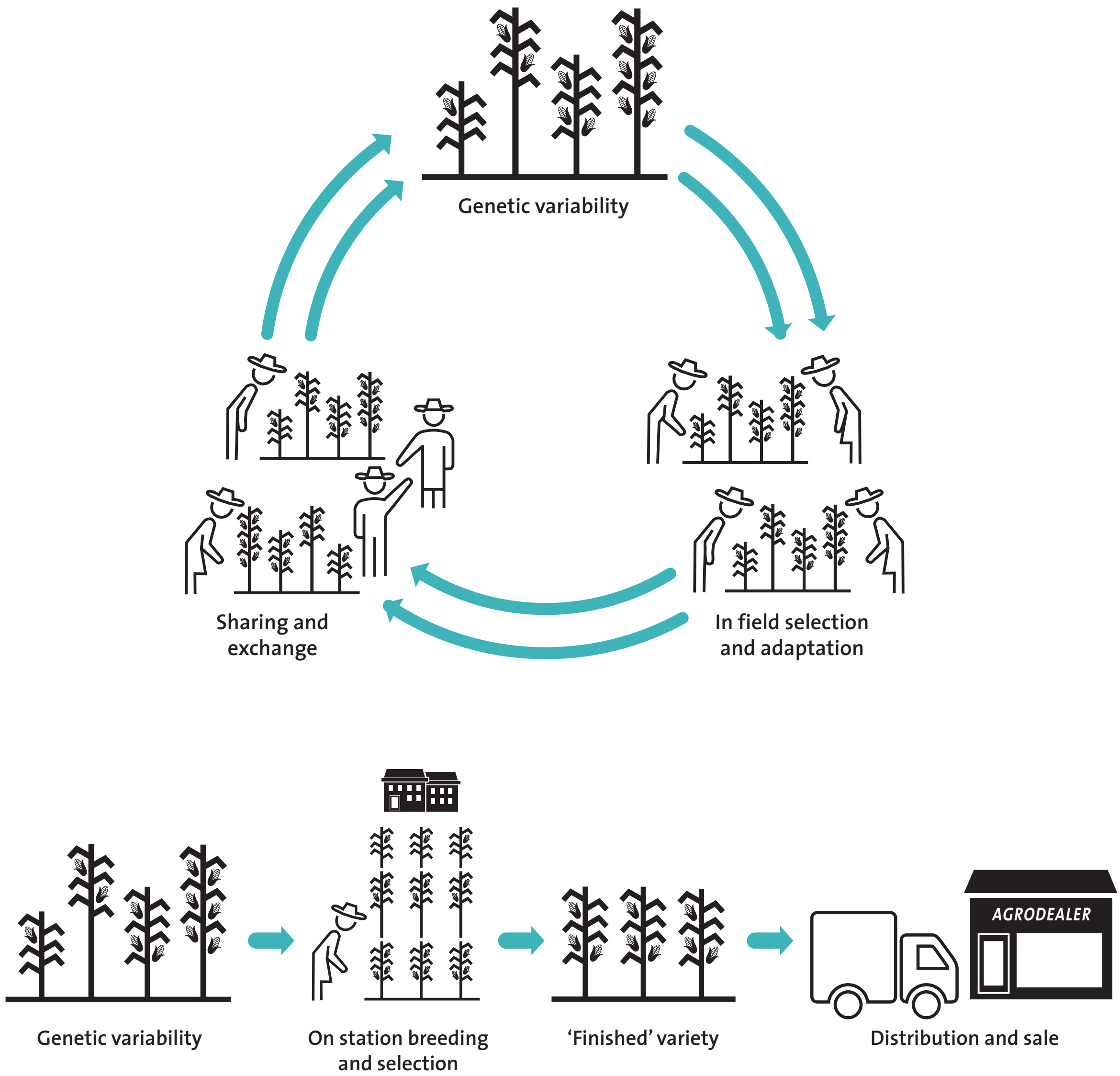
PPB is the active participation of farmers in some or all of the set of sequenced breeding programme activities discussed in more detail later in the report: priority setting, genetic materials acquisition and selection, crossing (not always), selection at early stages (many segregating lines) and late stages (a small number of nearly finished lines), in situ experimentation/testing, and production and sharing of genetic materials and knowledge. The general intention amongst practitioners is not for PPB to be a substitute for station-based research or scientist-managed on-farm trials; rather it is considered a complementary breeding process (Hardon et al., 2005; Aguilar-Espinoza, 2007; Ceccarelli et al., 2009). For many formal sector breeders, the objective of participatory plant breeding is to facilitate quicker and more extensive uptake of new cropping technologies (Morris and Bellon, 2004). "Although farmer participation is often advocated for reasons of equity, there are sound scientific and practical reasons for farmer involvement, too, as it can increase the efficiency and the effectiveness of the breeding programme" (Wakjira et al., 2008:188).

Three main objectives are common to most PPB programmes:

i) Improvements to genetic materials to suit farmer and user needs (product);
ii) Farmer access to a greater diversity of genetic materials, adapted to the local context (product);
iii) Farmer empowerment – technical and

5. Steinke et al. (2016) define participatory crop improvement as a broader term incorporating PPB, PVS and crowdsourcing of field trials as a more recent technique. Also see de Boef and Ogliari (2008).

Figure 1: Cyclical vs linear processes



organisational skills for maintaining and developing materials under their control, on-farm management, and local creativity/ innovation (process).

Table 1 shows the differences between conventional and participatory breeding. It indicates there is more to participatory breeding than simply being a more effective or efficient way to do plant breeding. Perhaps it upsets the notion that PPB is simply complementary to conventional breeding programmes, because it proposes a different structuring of priorities, objectives and processes. Systematic crop improvement will be more embedded in farmers' daily lives and will be shaped by the context. It will be more cyclical, with materials constantly feeding into new rounds of production, selection, adaptation and use. This is in contrast with conventional breeding, which generally seeks a finished, distinct product for commercialisation in a discontinuous or detached process (Figure 1). In conventional breeding, farmers may be involved in PVS but on its own this cannot qualify as PPB, since there are many other dimensions in which the process may remain centralised and controlled from outside. This is not to say conventional breeding fails to take farmer concerns into account. After all, farmers are the market for seed companies. But these priorities are defined from outside, and rarely with any direct discussion with farmers.

There are variations of PPB, including grassroots breeding (Sthapit and Ramanatha Rao, 2007), briefly touched on later in the discussion about conservation and maintenance of agricultural biodiversity.

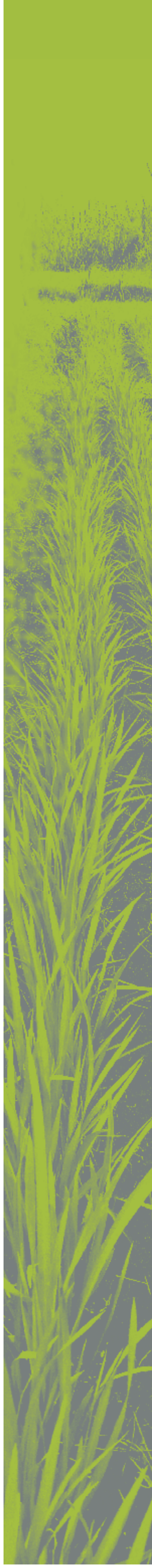


Table 1: Conventional vs participatory plant breeding

	Conventional	Participatory
Crop improvement	Linear with a distinct finished product as the output, disposal of unwanted germplasm	Cyclical with materials continuously feeding into living adaptive processes in the field, germplasm enters into the production system throughout the process
Priority setting	Private sector, breeders, industrial users	Farmers and breeders, at times other users
Sources of germplasm	Farmers via national gene banks, CGIAR institutions, private collections	Farmers directly, national gene banks, CGIAR institutions
Institutional locus	Private companies, ARIs/universities	Farmer organisations, ARIs/ universities, NGOs
Operational structure	Centralised	Decentralised
Selection and testing	Breeders, at times including farmers in PVS towards the end of the process	Farmers and breeders
Location of field trials	On-station	In farmer fields and on-station
Product	Officially released varieties	Improved materials for own use, sometimes officially released varieties
Characteristics	Few traits, yield maximisation, genetically homogenous, broad adaptability	Bundle of traits, diverse characteristics, genetically heterogeneous, local adaptation
Extension	Private, public	Public, farmer-to-farmer

Evolutionary plant breeding (CENESTA, 2013; Rahmanian et al., 2014) is another recent variation, which builds on farmer practices of mass selection and related methods, such as grid selection and field gene banks (Almekinders and Louwaars, 1999:37). It is a less controlled process. Populations with large genetic variability are deployed in the hands of farmers and the plants gradually evolve and adapt to climate and management changes, producing a 'living gene bank' in farmers' fields, which is a constant source of genetic variability. Farmers then select desired materials from this pool to multiply as single lines.

The process is a combination of farmer and natural selection. Mixtures are used that may include landraces, new lines and commercial varieties. Populations are made by varieties of the same or different crops. The process tends to give more stable yields over time than uniform crops, and they are generally more resilient to drought, pests and diseases. Evolutionary plant breeding is considered to be a dynamic and inexpensive strategy to quickly enhance adaptation of crops to climate changes (CENESTA, 2013).

Participation

Critique of participation

The concept of participation has its fair share of critics. Rahnema (1993) links participation as a concept to the US-led development model in the period after the Second World War. The objective of participation is "to involve patients in their own care" once they have been defined as patients through development discourses on poverty. In this view, participation prepares the frontiers for absorption into commodity relations in a number of ways. It can dampen and divert resistance to development. "Peacefully negotiated forms of participation can take the heat out of many situations where development policies create tension and resistance on the part of their victims" (Rahnema, 1992:118).

Participation enables the presence of an external authority. Needs are created (see Illich, 1993) and then participation is introduced to ensure support for the same needs and services (for example, specialised breeding). Participation, networking and co-operation can be used technocratically to increase knowledge of the 'field reality' for purposes not defined by farmers living those realities. They can lead to "more refined and deceitful means of action and persuasion" (Rahnema, 1992:124). Non-professional, grassroots-oriented intermediaries replace the alien authority of the outsider with a 'co-actor' (Rahnema, 1992:123). Participation can go hand in hand with the privatisation of services, for example, agricultural extension and R&D. Participation may also be used to reduce the costs of development by transferring costs to farmers and the poor. Restricted forms of participation may facilitate greater productivity at low cost, the benefits of which may be extracted from the participants if the process is controlled externally (Rahnema, 1992:117).

Rahnema refers to the more critical strand of participation thought, including dialogical interaction, conscientisation and participatory action research as 'popular participation'. She says this strand proposes to reorient development to start from existing local knowledge, empowering the voiceless and powerless, and offering new alternatives to failed development approaches. Rahnema critiques this approach, too, saying that, although it has had a few positive impacts, overall it has not produced an alternative to the development paradigm. "Any attempt to realise a mix of the two knowledges, represented by local and outside persons interacting with each other, is … a conceptually reductionist and patchwork type of exercise" (Rahnema, 1992:122). She questions empowerment as a concept: if some people consider it necessary for other people to be empowered, they assume that those people do not have the appropriate power, and that they themselves have a formula of power to which these others must be initiated (Rahnema, 1992:123).

Rahnema puts her own faith in "informal networks of resistance which ordinary people put up" (1992:123), arguing that many activists for the participatory approach have

ended up contributing to the devaluing of these traditional and vernacular forms of power, by imposing ideological frameworks and definitions of the aims of struggle (Rahnema, 1992:124). This argument suggests these informal networks are forever local and do not interact with the 'outside' world. Rahnema essentially argues against any development intervention at all.

What are we to make of this challenge? It has a lot of force and resonance with the reality of development as we see it in Africa. Rahnema negatively assesses participation as a method for realising radical political change, since it is tied into a particular development system and relations of power. In a related conversation, Eric Holt-Gimenez and Annie Shattuck from Food First divide contemporary food system politics into a corporate regime that includes strong neoliberal and weak reformist elements, and food movements that include progressive and radical strands. Within the food movements, progressives are doers and seek practical solutions, based on agroecology and food justice. Radicals emphasise structure and political control over food systems and direct their energy at changing regime structures and creating politically enabling conditions for more equitable and sustainable food systems. Progressive projects can be very energetic, creative and diverse, but can also be locally focused and issue- rather than system-driven. Strategically, Holt-Gimenez and Shattuck propose that, if the progressive strand is drawn to the reformist strand in the corporate regime, it can break the back of food movements. Rather than pushing for forms of collaboration with the (reformist) corporate food regime, food movements should aim to build co-operation between the progressive and radical strands within the movements (Holt-Gimenez and Shattuck, 2011).

We should not think that, merely because breeders work in formal institutions and are technical experts, they are automatically part of the corporate food regime. If we acknowledge that breeders can be part of the food movement (for example, breeders and small seed enterprises that participate in the Open Source Seed Initiative), the discussion with breeders is, then, within the food movement and relates to how practical, technical work and radical work aimed at systematic changes relate to one another. As Holt-Gimenez and Shattuck suggest, the strategic decision for food movements is then to assess whether such forms of collaboration could result in splitting the food movement by drawing farmers into formal sector seed projects that may entrench formal sector power and authority over farmers and blunt the edge of resistance, or whether it can be considered an instance of shifting public support towards diversified agro-ecological production systems. Such a shift is one of seven transition pathways from corporate-industrial agriculture to agro-ecology identified by IPES Food (2016). This scoping report is intended to assist the food movement in reflecting on this question.

Types of participation

The progressive or radical effect of participatory activities will depend, at least in part, on the types of participation and forms of co-operation. Jones et al. (2014) propose a distinction between outcomes and types of participation. They identify manipulative, instrumental and empowering outcomes (Jones et al., 2014:98).

In manipulative processes, participants may not feel they are being forced into doing something, while being led to take actions inspired or directed by centres outside their control. "More often than not, people are asked or dragged into partaking in operations of no interest to them, in the very name of participation" (Rahnema, 1992:116). In a project in Mexico and Cuba, there were questions about whether farmers should be paid to grow experimental plots. Those in favour of this approach eventually withdrew from the programme (Rios Labrada, 2005). This is a sign that farmers were being drawn into something they did not have intrinsic interest in doing, and it certainly was not something they had prioritised for its own value to them. For the purposes of this paper, we will rule out manipulation as part of the definition of participation. We are interested in investigating participatory approaches, where farmers are actively involved in making and implementing decisions on issues they have prioritised, and in which resources are made available to assist them to do this.

Instrumental outcomes indicate the product outcomes of a participatory process, the objectives of the programme in tangible terms, such as an enhanced/improved variety. We should distinguish between instrumental outcomes and instrumental processes. Instrumental or product outcomes will be an element of any PPB programme. These outcomes are the tangible benefits to farmers of doing crop improvement. Instrumental and empowering outcomes are not mutually exclusive and, in fact, should go together: for example, producing enhanced varieties can and should occur hand in hand with strengthening farmer agency. On the other hand, farmers may be

Table 2: Political orientations and modes of participation

Political category	Mode of participation	Description
Neoliberal corporate food regime	Contractual	Scientists contract with farmers to provide land or services.
Reformist corporate food regime	Consultative	Interactions take place, but these are dominated by technocratic authority, with solutions developed separately from 'participants'.
Progressive food movement	Collaborative/collegial Farmer-led	There is continuous interaction between researchers and farmers, with farmer input and action at various stages.
Radical food movement	Farmer-led	Projects have limited external resources and depend on autonomous grassroots agency; researchers can assist with knowledge, information and networks.

used instrumentally in processes of trait and varietal identification, varietal testing, and work with technicians, if they have no involvement in other aspects of the programme.

Empowerment is defined as changes in innovation processes that shift the balance of power between farmers and researchers in favour of the former. This is a process outcome. There are debates about the meaning of empowerment, at what level it takes place, and where it materialises on a continuum from individual to collective empowerment. For example, an over-emphasis on individual achievement in mainstream development focuses on individual agency, which may not be sufficient to dislodge structural power differentials (Jones et al., 2014:93).

Biggs (1989) identifies four modes of participation: Contractual, consultative, collaborative and collegial. To this we will add 'farmer-led' as a distinct category. Jones et al. (2014) suggest that modes of participation should not be viewed as mutually exclusive and it may not be fruitful to assign normative status to the various modes, that is, that one is better than another. For example, "in many cases that involve high levels of scientific or technical expertise, communication and control of problem analysis and project goals do not immediately lend themselves to a shift from outside experts to participant communities, so that consultative participation may be the most appropriate process to achieve desired outcomes" (Jones et al., 2014:94). These processes are also dynamic and ongoing, so engagements and interactions can deepen over time.

However, a rough mapping between Holt-Gimenez and Shattuck's political orientations and Biggs' modes of participation (Table 2) can enable us to consider the systemic effects of particular modes and choices. For example, if a contractual or consultative mode of participation is repeated over a number of years without moving into a different mode, this can signify a particular political orientation. We would certainly argue that there is a need to move along the continuum of modes of participation over time towards greater active and direct involvement of farmers and other users, with the ultimate goal of self-organised farmer associations driving processes of plant breeding/crop improvement. There may be various steps and starting points to get there, but this is the longer-term objective. If this is not the long-term objective of organisations, then this provides an indicator of political orientation. As such, we do implicitly attach differential values to the different modes of participation.

In the contractual mode, scientists contract with farmers to provide land or services. This is very similar to contract farming and can align as a methodology with a neoliberal corporate outlook, where farmer involvement is reduced to a financial relationship. This is not to say that every breeder who ever contracts a farmer to plant and manage trials, for example, is adopting a neoliberal outlook. But the mode of participation is amenable to neoliberal co-optation, which means co-optation by forces of exploitation and appropriation. Simply using farmers' fields for trials against payment of rent (as happens in many conventional breeding programmes) is not PPB, since farmers do not participate in selection of breeding material (Ceccarelli, 2009:68–71).

In the consultative mode, researchers in the formal system seek information from farmers and others and then develop solutions separately. Farmers and others have little or no direct influence on the project and no decision-making power to direct the project in one way or another (Vernooy 2003:17). As Jones et al. (2014) indicate, this may be an entry point into farmer participation, but over time this would need to deepen into more active forms of participation, otherwise it can become a means to legitimise plans developed separately from farmers.

In the collaborative mode, there is some degree of task sharing between farmers and researchers, with continuous interaction between them. The emphasis is on farmer participation as a 'monitoring' function to assist with planning research. Research-minded farmers/custodian farmers are sought and relationships built with them. Methodologies are usually context specific and strict stages of research are not followed. Results are used to assist to direct activities in the formal system (Biggs, 1989:7–8). The extent of involvement of researchers will depend in part on the objectives of the specific research. Participation of researchers may increase, for example if farmers are working with more than one variety at a time, because this needs experimental design, in which farmers could make planting errors, if unassisted. Researcher contributions will also depend on the amount and type of data to be collected (Witcombe et al., 1996:3).

Sperling makes a distinction between 'formal-led' and 'farmer-led' PPB. In 'formal-led PPB', farmers join in breeding experiments initiated by formal breeding programmes. Researchers invite farmers to participate. Researchers may have an obligation or priority objective to feed information back to the formal research sector, with scientific standards of replicability and validity of results to be met. Such processes have strong linkages to formal variety release and seed production systems (Sperling et al., 2001:440). Contractual and consultative modes of participation will be formal-led, as will most collaborative projects, given the difficulties of farmers initiating co-operation with the formal sector, and given the specialised technical knowledge breeders bring (Witcombe et al. 1996:5).

The collegial mode of participation is on one end of Biggs' continuum. This suggests the continuum is designed from the perspective of the breeder. Collegiality refers to the (theoretical) relationship of open sharing and exchange of information and knowledge between academics at a university. It is about how researchers engage with farmers, actively encouraging the informal R&D system in rural areas. The aim is to increase the ability of informal systems to do research and to request information and services from the formal system. Research-minded farmers have the major say in running the sites. Formal researchers provide technical and organisational backstopping (Biggs, 1989:8). Without initiatives coming directly from farmers themselves, this is as far as researchers will be able to go with participation. It is a way of introducing knowledge and topics to farmers for further work. It is most likely to be successful if researchers have a history of interaction with the farmers. In this sense, consultative and collaborative modes of participation can be entry points into potentially longer-term relationships through which collegial relationships can develop. If an objective of a programme is farmer empowerment, collaborative or collegial processes will be required (Hellin et al., 2008).

Following Sperling et al. (2001), we have added a farmer-led mode of participation as an approach arising from organised farmers themselves. In 'farmer-led PPB' researchers are guided by farmers from the outset, and seek to support farmers' own systems of breeding, varietal selection and seed maintenance. Within the framework of our bounding definition of PPB (involving researchers and farmers in collaboration) researchers/extension services facilitate

a process in which farmers establish the breeding/crop improvement objectives. Farmers bear the main responsibility and often costs of conducting the experiments, selecting materials for seed multiplication and dissemination of materials. The objective is to provide varieties or populations suited to the local context, and broader applicability beyond the site is not the primary aim. There is no obligation to feed information back for extrapolation, or to generate products, such as varieties for formal release and seed systems (Sperling et al., 2001:440–441). Ceccarelli (2009a:200) refers to decentralised breeding and says "transferring a breeding programme to outside a research station almost always implies losing some degree of control of a number of steps and operations".

Farmer-led PPB is demand driven, so farmers will approach researchers. There are obstacles to this, such as farmer access to the right people to speak to. Extension services and non-government organisations (NGOs) usually operate as the link between farmers and researchers. However, in most of Africa, for example, there is limited availability of extension services and appropriate methodologies. These often use top down, 'transfer of technology' approaches, introducing technologies developed elsewhere. Note that even in farmer-led PPB, formal sector researchers are involved. As indicated above, this is a defining characteristic of PPB, which distinguishes it from farmers' activities in selecting and enhancing seed on their own, without any external support.

Farmer's roles in PPB in practice cover a wide range of activities (Sperling et al., 2001). These include technical leadership, including substantial technical contributions to the practical breeding process, such as matching specific varieties to specific environmental niches and uses, or varietal performance over time and in different locations. Community specialists may lead and manage the breeding work itself, especially minor crops, in remote areas, or where there is a limited presence of formal R&D. Farmers also play an essential role in social organisational leadership, with farmer associations, co-operatives and other networks forming the organisational base for PPB activities and sharing. Farmer organisations assist with representative sites for on farm testing, seed multiplication and distribution.

Assessing the impact of participation can be a challenge. Farmers may have multiple reasons to be involved with researchers and practitioners, which are not necessarily directly aimed at improving knowledge and skills. For example, participation may be driven by incentives, such as free seed, fertiliser or access to credit. Other perceived

benefits could be contact with outsiders, for example, access to knowledge and social status. As such, external and cognitive inputs need to be reduced to a minimum, as they might lead to dependency. Process inputs may ideally be restricted to facilitation (Kraaijvanger et al., 2016:39).

There may be different degrees of participation in different phases of a PPB project, for example, start-up and priority setting may be initially driven by external researchers to identify interest amongst farmers and get them on board. Later stages, such as varietal testing, peer learning and diffusion of new varieties, may be much more farmer driven. Practical knowledge shared by technicians with farmers can form the basis for later farmer peer-to-peer learning and sharing (Jones et al., 2014:98). Therefore, we can understand participation as a process, which may start off in a relatively contained way and then expand and be deepened over time.

Historical background to PPB and current projects

PPB grew from critiques that began in the 1950s of the ineffectiveness of development projects to bring useful new technologies to new areas. These critiques emerged in a context where technical expertise was separated from farmers, and farmers were converted into passive (or at least choice-restricted) recipients of interventions and technologies, which were not always appropriate to their needs and conditions.

A counter-trend emerged in the 1970s, to bring farmers back into agricultural development activities and experimentation, for example, farming systems research and farmer-to-farmer models. The theory is that farmers are more likely to adopt technologies when they are actively involved in developing them (Shelton and Tracy, 2016:2). PPB in practice was part of this counter-movement. It originated "as part of a movement promoting the concept of participatory research, in response to criticisms of the failure of post-green-revolution, experiment-station-based research to address the needs of poor farmers in developing countries" (Ceccarelli et al., 2009:viii).

Some public researchers at the CGIAR institutions began to experiment with more participatory approaches, for instance the International Potato Centre in Peru, the International Center for Tropical Agriculture (CIAT) and IRRI in the 1970s (Shelton and Tracy, 2016:2). These efforts stood in contrast to the dominant model in the CGIAR, which was a top-down 'transfer of technology' model going via the national research system and extension workers to farmers, in a one-way process. This is also termed a 'central source' model (Biggs, 1990).

By the late 1990s, a range of participatory research projects by CGIAR institutes, national research centres and NGOs showed success, including PVS in plant breeding. This is farmer selection of advanced breeding lines in their fields, and evidence was produced that showed this process was superior to on-station selection of varieties for formal certification. PVS and PPB terms were first used at a workshop in 1995, sponsored by Canada's International Development

Research Centre (IDRC) (Shelton and Tracy, 2016:3).

Based on the success of participatory projects, in 1996 CGIAR launched a system-wide initiative called the Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation (PRGA), co-sponsored by CIAT, which served as the convening centre, and by CIMMYT, the International Center for Agricultural Research in the Dry Areas (ICARDA), and IRRI. PRGA program activities were funded by the IDRC, Ford Foundation, and the governments of Canada, Italy, the Netherlands, New Zealand, Norway, and Switzerland (McGuire et al., 2003). In 2000, a recommendation was made to the CGIAR Technical Advisory Committee "that PPB become an integral part of each CGIAR centre's plant breeding program" (Vernooy, 2003:55).

IDRC's Biodiversity Program supported a number of PPB projects globally in the 1990s and the early 2000s (Vernooy, 2003). Other early donors included Ford Foundation, development co-operation agencies from Switzerland, Germany and Norway, the Netherlands, and various other governments. More recently, a number of other organisations are also providing funds for PPB work, ranging from the McKnight Foundation to AGRA and the United States Agency for International Development (USAID). Since 2000, a wide range of PPB projects have been recorded globally. According to Salvatore Ceccarelli, one of the pioneers of PPB who has worked extensively in West Asia and North Africa, in 2009 there were about 80 known PPB programmes worldwide (Ceccarelli et al., 2009:vii).

There are a significant number of published studies on PPB and PVS at national and regional levels. In the Americas we found studies from Honduras, Nicaragua, Mexico, Costa Rica, Cuba, Bolivia, Brazil, Ecuador, Peru, the Andean region and the US. In Europe there are studies from Italy, Portugal and Germany. In Asia there is documented research from India, Bangladesh, Bhutan, Lao PDR, China, Nepal, the Philippines, Indonesia, Vietnam, Cambodia and South East Asia as a region. In the Middle East and North Africa there are some regional studies as well as specific country studies in Iran, Syria and Morocco. In South and East Africa there is recorded work in Zimbabwe, South Africa, Zambia, Malawi, Ethiopia, Uganda, Kenya and Rwanda. In West Africa there are cases from Sierra Leone, Benin, Burkina Faso, Cameroon, Mali and Ghana. Crops include maize, wheat, sorghum, barley, rice, quinoa, teff, cassava, potatoes, beans, cowpea and tomatoes. Undoubtedly these case studies do not cover all the work that is being done on PPB and

related fields globally or in Africa. However, even a selection offers a basis to start looking at the processes of PPB and to draw out some of the lessons.

Some current multi-country and multi-regional programmes include:

- USC Canada (charity) Seeds of Survival programme[6] in 13 countries: Burkina Faso, Ethiopia and Mali in Africa; Bangladesh, Nepal and Timor Leste in Asia; Bolivia, Canada, Cuba, Guatemala, Honduras and Nicaragua in the Americas, with a mix of biodiversity conservation, PVS and PPB;
- Oxfam-Novib (charity) Sowing Diversity, Harvesting Security (SD=HS)[7] in Peru, Zimbabwe, Vietnam, Lao PDR and Myanmar, with a mix of biodiversity conservation and enhancement;
- Bioversity International (CGIAR institution) Seed for Needs initiative[8], which started in Ethiopia in 2009, and now has sites in 15

6. http://www.usc-canada.org/what-we-do/seeds-of-survival/
7. https://www.sdhsprogram.org/
8. https://www.bioversityinternational.org/seeds-for-needs/

countries: India, Cambodia, Laos and Papua New Guinea in Asia; Colombia, Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua in the Americas; and Ethiopia, Kenya, Tanzania, Rwanda and Uganda in Africa.

USC Canada Seeds of Survival

This programme seeks to build and support collaborative relationships between farmers, scientists, governments and local NGO workers, on the basis of farmers' time-tested local knowledge and practices. Local partner organisations implement the programme. The programme has its origins in work started in 1989 in Ethiopia by Maleku Worede – then director of the national gene bank – and Canadian researcher and activist Pat Mooney, on rescue, multiplication and return of seed to farmers. The project expanded to other countries from the 1990s, and incorporates conservation, exchange and use of seeds, knowledge and practice amongst farmers and with scientists. It supports agro-ecology and its application in various cultural and ecological contexts, including marginal areas, where there is limited access to external resources.

In Ethiopia, the focus is on farmer access to a diversity of locally adapted seed, working with Ethio-Organic Seed Action (EOSA). The programme promotes local seed exchange networks and includes work on community seed banks, PVS and farmer-scientist collaboration. One result is publicly funded community seed banks in Southern Region, with expansion of activities to other regions in Ethiopia under way. Farmers conserve crucial genetic resources adapted to their locality and develop back-up stores of local seed supplies.

In Burkina Faso, the programme focuses on strengthening local seed supply systems, rehabilitating degraded soils, supporting farmer-to-farmer knowledge exchange and promoting sustainable biodiversity-based agriculture. It includes community seed banks and a seed bank network, on-farm seed conservation, and women's groups. Diversification and adaptation of varieties to dynamic local conditions is identified as an area for more work.

In Mali, the programme aims to strengthen resilience of local farming systems and support community-based seed supply systems, including a seed bank network and one field gene bank. Activities include seed conservation, crop multiplication, PVS, multiplication of improved local varieties, soil and water conservation and agro-forestry. The focus is on production for markets. In the context of high political conflict and violence, farmer networks and seed banks have enabled farmers to continue planting. Village committees coordinate monitoring and evaluation of activities.

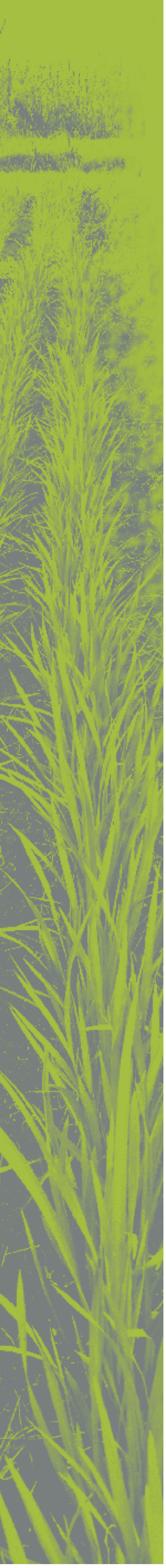
In Asia, work in the programme is being done with women's farmer groups, home and community gardens, and vegetable seed saving (Bangladesh); seed supply and diversity of plant genetic resources, including enhancement (Nepal); and sustainable agriculture and home gardens with biodiversity and seed as integrated components (Timor Leste). The programme works with the NGO, Local Initiatives for Biodiversity, Research, and Development (LI-BIRD), amongst others, in Nepal.

In Latin America, activities include: broad agricultural biodiversity (Bolivia); increasing the availability of indigenous crop varieties and saving and sharing seeds, seed diversity management at municipal level, participatory seed diffusion and plant breeding, on-farm conservation of farmer seed varieties and seed banking, securing seed supply through seed reproduction and diversity, and farmer-scientist collaboration (Cuba); working with Comités de Investigación Agricola Local (CIALs) farmer-researchers in farmer co-operatives on plant breeding/crop improvement and seed banks, and preserving biodiversity of maize and beans (Guatemala); on-farm conservation of farmer seed varieties, PPB, seed reproduction and sale, and seed banks (Honduras); and piloting CIALs working with farmer co-operatives, training in PPB and PVS, and seed banks (Nicaragua). USC Canada works with the Program for Local Agricultural Innovation (PIAL) of the National Institute for Agrarian Science (INCA) in Cuba; and the Foundation for Participatory Research with Honduran Farmers (FIPAH) in Honduras. No detailed reports of activities are readily available.

Oxfam-Novib Sowing Diversity, Harvesting Security (SD=HS)
The aim of the programme is to improve access to and use of crop diversity and to change current unequal and unsustainable food systems through farmer-based seed conservation and maintenance, and creation of new diversity. Activities include farmer field schools (FFS) with farmers, scientists and extension workers on breeding and selection, farmer seed enterprises for production and marketing, community seed banks as a basis of diversity for crop improvement, seed fairs to share materials and knowledge, and policy engagement.

In Zimbabwe, the programme works with Community Technology Development Trust (CTDT), with FFS in eight districts. They have produced a facilitator's field guide for PPB in maize, pearl millet, sorghum and groundnut. Seed and food fairs are linked to access to farmer materials by gene banks. A farmer seed enterprise has been started with the aim of testing laws with regard to sale of farmer seed in local markets. In Peru, the programme works with Asociacion ANDES on repatriation and multiplication of potato varieties with materials from gene banks and FFS. In Vietnam, Lao PDR and Myanmar, the programme works with Southeast Asia Regional Initiatives for Community Empowerment (SEARICE) and farmers, local NGO partners, ARIs, universities, and extension services. Seed clubs are based on past work in FFS and PPB. The focus in Asia is on access to diverse genetic resources, variety selection and enhancement for local adaptation.

Bioversity International Seed for Needs
The programme contributes to the CGIAR Climate Change, Agriculture and Food Security (CCAFS) programme, focusing on improved access to a diversity of adapted crops and varieties. The primary objective is the effective dissemination of diverse materials to farmers to select and adapt to their conditions, and to feed preferences back into priorities for formal breeding programmes. The programme makes use of a citizen's science approach, upon which thousands of farmers can become involved. This is a novel feature, not previously adopted by any PPB programme or project globally. Methods include farmer field schools for variety selection, seed banks and crowdsourcing trials, which involve widespread dissemination to many farmers in diverse contexts, to carry out small trials and feed results back quickly (see Steinke et al., 2016).



Structure of a plant breeding programme

This section covers the steps in a (formal) breeding programme, from priority setting to production of a cultivar. As indicated, PPB as a concept itself is a product of the historical separation of farmers from breeding and then efforts at selective reintegration into an externally developed and controlled structure. However, even for a less structured programme, it can help us to see what different stages there may be and what may require consideration when starting off on a systematic, deliberate crop improvement or breeding programme. This section briefly touches on biodiversity conservation and maintenance for a diverse genetic base, and issues related to multiplication and dissemination of cultivars. These activities are interconnected with plant breeding/crop improvement, but are also fields of study in and of themselves. For the purposes of this paper we mainly consider points of direct relation with the breeding/crop improvement process.

Links between biodiversity conservation/maintenance and crop improvement

Biodiversity conservation and maintenance, use and variety improvement/enhancement are intertwined. Plant breeding/crop improvement depends on a wide base of genetic variability to work with, and there may be a need to build up this base. PPB may play an important role, both in contributing to widening biodiversity in a locality, and as an activity that follows on from conservation and maintenance. This reinforces the reality of ongoing, cyclical, rather than linear, processes of conserving, maintaining and enhancing genetic materials.

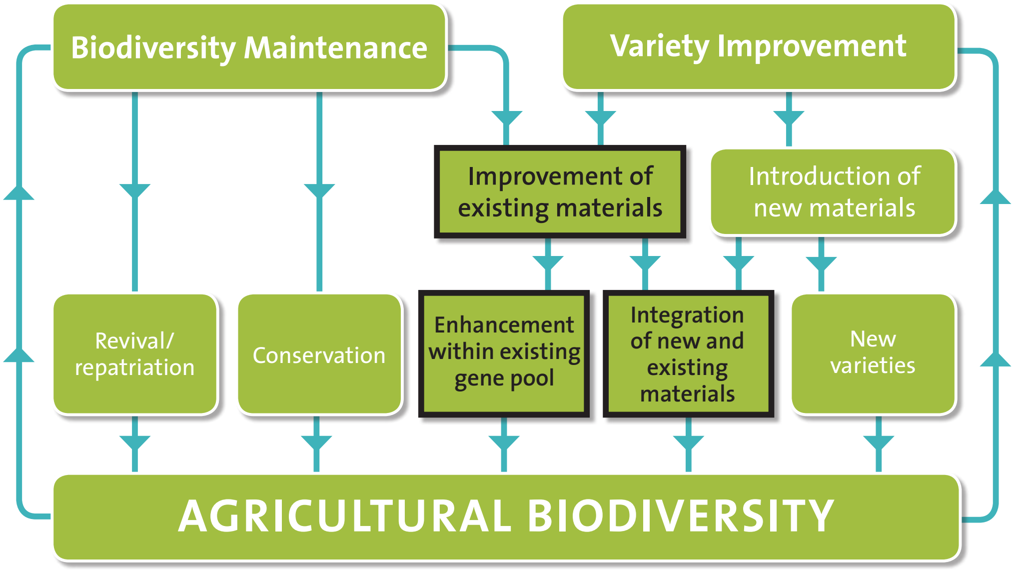
The objective of biodiversity conservation, maintenance and enhancement is a base of flourishing agricultural biodiversity. There are various sources of material that contribute to this diverse base (Figure 2). These include maintenance and enhancement within the existing gene pool, mixing of new and existing materials, and introduction of finished new varieties. The focus of this paper is on improvement/enhancement of existing materials, both from within the locally available gene pool, as well as mixing of materials from the existing gene pool with introduced materials. The static preservation of crop diversity in ex situ gene banks is not a sustainable conservation approach. Seed continually needs to be exposed to dynamic local conditions and preferences in order to adapt. Crops are continually subjected to natural and farmer selection (Meldrum, 2013:98). National gene banks will have some local varieties but accession may be long ago and local varieties will have adapted to dynamic local conditions in the meantime. If gene bank material is not reproduced in real conditions, it is in danger of becoming sterile and useless.

For the purposes of this paper, revival and repatriation are considered to be elements of maintenance and conservation of the existing gene pool. Revival refers to the rescue of seed that is still in local use but only in small pockets or by few people, and where use is declining. This is especially the case for local varieties that are remembered as good varieties for specific characteristics but have been displaced over time. Repatriation is the process of reintroduction of materials from gene banks that came from a locality but have fallen out of use there.

Conservation, maintenance and use are required to prevent existing agricultural varieties from degenerating through exhaustion and lack of evolution. This may occur where the genetic base for a particular crop gets too narrow. There is some urgency to the issue because traditional/indigenous varieties are being lost at a rapid pace, especially in the industrial era (Fowler and Mooney, 1990). "Continued cultivation of traditional crops, landraces, indigenous and heirloom varieties, which together represent the majority of the world's crop diversity, is essential to prevent their disappearance" (Meldrum, 2013:97–98).

An example of this is work on 'grassroots breeding' in Nepal. Here the focus is on rescue, identifying and spreading traditional and local varieties in danger of being lost, to increase diversity, especially for poorer farmers who may not know about these

Figure 2: Biodiversity maintenance and variety improvement



Source: Based on Almekinders and Louwaars, 1999

varieties. This may be cost effective and widen agricultural biodiversity, including amongst poorer households (Sthapit and Ramanatha Rao, 2007). Although the immediate focus is on spreading diversity without immediate action on improving/ enhancing the materials, the 'mere' use of rescued varieties and on-farm experimentation and adaptation shade into one another in practice. Rescued varieties are integrated into farming systems over time, as the new materials mix with existing varieties and farmers select seed from season to season (Sthapit and Ramanatha Rao, 2007). Institutionally, grassroots breeding is primarily driven by farmers, with no major role for extension, ARIs, etc. (Sthapit and Ramanatha Rao, 2007). This places it in the farmer-led mode of participation.

Grassroots breeding focuses on two basic breeding steps: participatory pre-breeding efforts (locating, assessing, multiplying and making germplasm available); and enhancing germplasm through simple selection, healthy seed production and deployment of seed through social networks. Without going into detail here, key methodologies are diversity fairs; community and household seed banks; in situ, living gene banks, with diverse materials that farmers can draw from as and when needed; and support for diversity in home gardens (Vernooy, 2003; Rios Labrada, 2005; Sthapit et al., 2012). Seed banks can be used to hold varieties for ongoing sharing and use. They overcome the 'tragedy of the commons', where everyone assumes someone else is retaining a variety but actually no one is (Sthapit and Ramanatha Rao, 2007).

At the other end of the biodiversity spectrum is the introduction of entirely new varieties. This can add to biodiversity, although there may be cases where some materials replace others over time, which can (but does not necessarily) lead to loss of biodiversity. There may be concern at times with the displacement of many local varieties with few 'improved' varieties coming from the formal plant breeding system. Introduction of new materials should, therefore, be undertaken with caution (Sthapit and Ramanatha Rao, 2007). Fieldwork conducted by ACB and our partners in Southern Africa indicates that smallholder farmers seek both to retain diverse existing varieties and also to have access to new varieties appropriate to their contexts. A balance is required to ensure existing varieties and materials don't entirely fall out of use, thereby reducing choice available to farmers in difficult and changing production conditions.

Another way in which new materials may be introduced is through integration of wild plants into cultivation systems. This is an ongoing activity, especially by women, with home/kitchen gardens as key sites for integration of wild/indigenous crops into agricultural systems for food and medicine. These can be considered to be indigenous experimental stations and gene banks. Home gardens contain many semi-domesticated species transplanted from the wild. Experimentation, especially with fruit trees and local foods, is inherently decentralised and embraces the evolutionary components of biodiversity. These activities highlight local level innovation/creativity, reproducing not only the genetic material but also the knowledge about its reproduction and use (Sthapit et al., 2012). Agricultural biodiversity should, therefore, not be separated from wider biodiversity and its maintenance and conservation.

Simultaneously with securing a diverse base of locally managed genetic material, farmers may want to improve or enhance the qualities of genetic material available to them. The focus of this paper sits between conservation and maintenance of the existing genetic base and introduction of entirely new materials, as highlighted in Figure 2. This includes enhancement of genetic materials already available to farmers, as well as enhancement through mixing of existing and introduced materials. Formal sector breeders may be able to assist in both of these.

Stages in a plant breeding programme

This section goes through the main stages in a plant breeding programme. This is based on the structure of a formal programme but identifies key considerations for plant breeding/crop improvement activities even in less formal contexts.

After this, if the objective is not sale of cultivars, enhanced materials are distributed to farmers to use. If the objective is sale on a commercial scale, varieties must go through a number of additional steps once the final cultivar is developed (detailed below). Intellectual property (IP) issues arise around ownership on the germplasm used as source material, as well as registration and ownership of varieties developed through the process. These are dealt with in the relevant sections below.

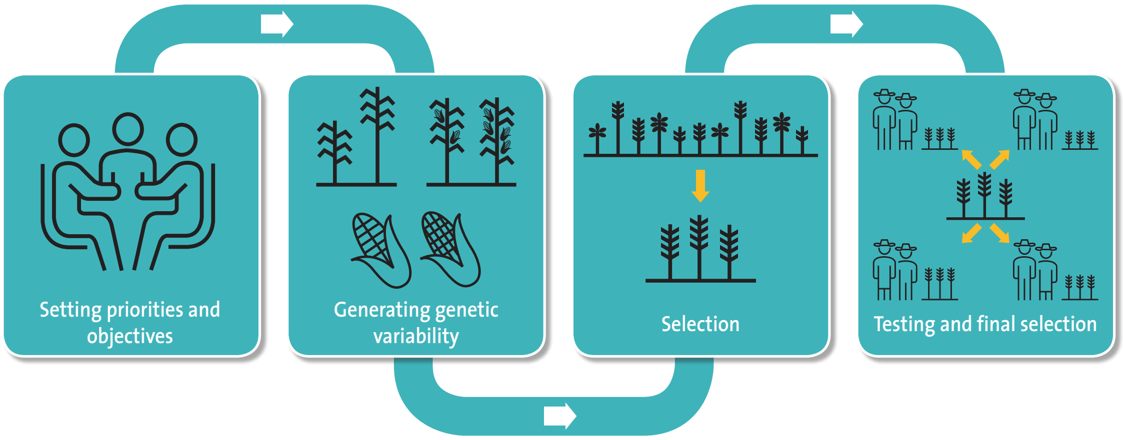
Setting priorities and objectives

The first step is to set the priorities and objectives of the programme. Priority setting needs to consider: goals (specific, not too complex); target groups and target environments (the production conditions under which new varieties should perform better than existing cultivars); the specific needs of the target group of farmers (and potentially other users); priority traits to be used for selection criteria; appropriate choice of germplasm base; variety type that is best suited for objectives; intra-varietal diversity requirements; and key roles and responsibilities of partners.

What will be done?

In the context of limited time and resources, it is necessary to prioritise. The question is how to find out what the priorities are, which could be done in a top down/external or bottom up manner, or some combination of the two. Because PPB involves interactions with the formal system, it will generally be a combination of some sort. Whatever the extent of farmer involvement, the first step in a breeding programme is to define what the priorities are in particular contexts. Priorities can arise from many places, such as industrial processing needs, farmers' specific production and consumption needs, other end user needs, or from the researchers themselves, based on their work to date. Setting priorities may best be considered as an iterative and progressive process that occurs throughout the breeding programme, because options may emerge in the course of the research (Weltzien and Christinck, 2009:79).

Figure 3: Main stages in a plant breeding programme



(Adapted from Ceccarelli, 2009:64)

A standard breeding programme can take anywhere from 3 to 13 years, depending on the objectives. The norm is 8–10 years for a full cycle following all the procedures.

Farmers' active participation in setting priorities and objectives is one of the key features of PPB. There can be no PPB without direct and active farmer engagement in establishing priorities for breeding, including identification of priority traits. A key issue in identifying priorities and objectives is the locus of control of decision-making about the objectives of the plant breeding and the kinds of results and data required to support these (Sperling et al., 2001). A wide range of participatory methodologies have been developed over the years, both to inform farmers about the topic and elicit interest, as well as to identify priority crops and traits for breeding purposes (Action Aid, 1996; Chambers, 1997, on participatory action research methods; Sthapit et al., 2012; Trouche et al., 2012; Otieno, 2016, on participatory identification of priorities on seed).

Selection of methodologies will be shaped by the broad needs, for example, whether availability, access, diversity or quality are key issues facing farmers in a particular context (Sthapit and Ramanatha Rao, 2007). Issues to be discussed will include: varietal preferences, plant types or desired traits to be maintained or introduced; trade-offs farmers are willing to make between characteristics in designing the ideotype; which characteristics are most important to farmers and why; and the range of acceptability within a characteristic (for example, stem height, length of cycle) (Gabriel et al., 2004). There will usually be a large number and diversity of desired traits (Gibson et al., 2011).

A review of experience (detailed below) indicates that farmers generally prefer a bundle of traits, rather than an emphasis on a single trait. Increasing productivity and yield is usually a key goal of breeding programmes. However, there are other objectives, including improvements to organoleptic traits (having to do with the senses, for example, taste, colour, texture), storability, processing and other characteristics. Simple breeding strategies, such as improving yield by increasing the ratio of the edible part of the plant at the expense of other plant organs (foliage, roots) do not generally work under conditions where 'minor' characteristics may be related to environmental adaptation, or non-edible plant parts may have a high value in particular situations (for example, biomass for animal feed) (Weltzien and Christinck, 2009:76–77). Trade-offs will, thus, also be required in the technical sphere.

Goals are the guiding principles for priority setting. A situation analysis should precede the definition of goals. This analysis will include details of the production environment, including existing varieties and how farmers use them; anticipated changes and farmers' needs; preferences and relevant resources (for example, local knowledge, skills and germplasm); and major constraints to production increases and income generation.

Participatory methods can be used to carry out this situation analysis (Weltzien and Christinck, 2009:80–81).

Apart from instrumental outcomes/product goals, overall objectives may also include process goals, such as farmer empowerment through increasing technical skill, knowledge, and shifting power relations towards farmers in the breeding/crop improvement process. Another objective may be making breeding programmes more cost-efficient, particularly through decentralisation, targeting niches. Yet other goals may include conservation of local diversity, policy and regulatory changes, increasing research efficiency, or benefits to specific users (Weltzien and Christinck, 2009:79). It will be helpful to set measurable indicators for monitoring (see Sperling et al., 2001:445–446 for suggestions). In the context of resource and time limits, trade-offs in goals will be required.

Goals and objectives are not set in a vacuum. Practical and technical considerations must be taken into account. For example, the programme will need to decide whether to go for broad or narrow adaptation, that is, populations that perform well under a wide range of conditions, or different cultivars for different conditions. Setting breeding goals is a recurring activity and must include variety type, farmer preferences and end user needs (for example, millers and consumers) (Smolders 2006:24), as well as an assessment of the potential and limitations of available breeding materials (Gyawali et al., 2010:70).

This stage of defining objectives may also include defining and developing quality controls as required. If objectives include the official release of a variety, formal quality control procedures as spelled out in laws and regulations will need to be followed. But even where the objective is only to produce enhanced materials for local use, quality controls will be used throughout the process and these should be developed up front. Formal researchers/technicians can assist in identifying key control points. Training/skills development may be required throughout the process, including organisation, farmer-to-farmer methods, genetic resources management, and technical/breeding. These will need to be structured into planning at the beginning.

Who and where?
There is always the question of who initiates the process. Ideally, farmers would approach researchers with a request for assistance and support. This is a farmer-led, demand-driven approach. However, in reality, entry points to the formal system are few, research institutes and universities are physically distant from farmers, and many farmers are not organised and do not have sufficient information. Farmers may be unaware of possible forms of support from the public sector and other research institutions. The ruling ideology is that what smallholder farmers do with regard to seed is inferior and obsolete. Farmers themselves may not value this work, having absorbed these ideas. There may be need for externally initiated interaction to bring these dimensions of seed to the surface, to raise awareness that the seed and knowledge farmers have are valuable assets and should be protected and supported as the foundation of an indigenous economy.

Smallholder farmers are part of the broader society and play a central and critical stewardship role for biodiversity that all humanity is dependent on. This specifically applies to smallholder farmers, since large-scale commercial farming is based on a mono-cropping model of planting the same thing across large areas. The biodiversity in areas of production is, consequently, extremely low. As commercial production systems encroach on diverse agro-ecological systems, they reduce and push biodiversity to the margins. This is the same biodiversity that commercial breeders rely on to produce constant remixes. Corporate-sponsored digitisation and dematerialisation of genetic information seek to eliminate dependence on this genetic diversity tended outside corporate control. Farmers may not be aware of these dynamics.

In practice, it is very difficult for farmers to initiate work directly with breeders, without facilitation to link the two. Public sector extension services exist, but are denuded and reactive, rather than proactive. Structural adjustment programmes and neoliberal policies have removed resources from public sector extension. These services are increasingly replaced with closed private sector services for particular commodities or projects, tailored to the specific needs of

the project but closed to other participants. These are invariably commercial projects where seed development is driven by profitability interests. They also focus attention in higher potential production areas, leading to marginalisation of areas with lower commercial productive potential, which are nevertheless still areas in which significant production takes place outside formal commercial markets. The many smallholder farmers in these areas will not receive meaningful extension services and will find it more difficult to engage with the formal sector, even if they choose to.

The role of farmer associations and NGOs is important in organising farmers and in widening farmer networks, with links to formal breeders and other organisations. Good farmer associations and NGOs will have a history of working with farmers at field level. Ongoing engagements between these organisations and farmers may result in the identification of farmer interest in work on breeding/crop improvement. Otherwise, we can anticipate that PPB programmes will be initiated from outside, by breeders.

'Smallholder farmers' is not a uniform category anywhere in the world, and, within the category, there are class and gender dimensions, in particular. Ethnic, and, in some instances (like South Africa), racial divisions affect access to resources and opportunities. At 'community' level, people belong to different social groups, even when they are working under similar agro-ecological conditions. They may have different requirements for seeds and varieties, so there is a question about which farmers are brought into participatory programmes and how they are identified (Weltzien and Christinck, 2009:81–82). Evidence from case studies shown below indicates women tend not to be actively involved in PPB programmes, even though they are the main custodians of seed.

In a formal PPB programme, farmers do not define priorities in isolation, but together with breeders and extension and technical support services; other users, including individual consumers, vendors and other commercial buyers; and rural co-operatives (Sperling et al., 2001:439). Even PPB that does not seek the registration of a new variety on a formal list can involve multiple stakeholders, including consumers (of both seed and the agricultural products arising from the seed). This allows consumers to also have a say in shaping the variety to meet their requirements. Again, ideally this will involve collective consumer organisations.

Close interaction, exchange visits and joint planning workshops held at the sites of the different partners (for example, research station, village, trading place) are important for achieving mutual understanding of different partners' perspectives. These may alter in the research process. It is also important for partners to understand that breeding is just one process and is not the cure-all for all issues (Weltzien and Christinck, 2009:79–80). As indicated, breeding is situated as part of a wider process of biodiversity conservation and maintenance, seed production and dissemination, and is integrated into wider agro-food systems, from local to global. These, in turn, are located in wider financial, ecosystem and demographic dynamics.

According to Ceccarelli (2009a:218) institutionalising PPB (that is, mainstreaming and scaling up) should be one of the main objectives when setting up a participatory breeding programme. Institutionalisation is needed because PPB is a long-term process that ultimately needs to link to public sector programming to be sustainable (Hardon et al., 2005; Aguilar-Espinoza, 2007). This is because it is very unlikely that individual, small-scale PPB projects, even though very successful at local level, will ever determine impact at national level. This constitutes a limit to progressive food movement strategies limited to individual projects.

Restrictive IP laws constitute a significant obstacle to government participation and upscaling. Changes in the organisation and execution of national breeding and extension will be required (Hardon et al., 2005). PPB can be an inherently political process, starting with a technical intervention, which is, in itself, political, in terms of opening opportunities for farmer empowerment/ organisation and for making policy interventions (Hardon et al., 2005).

Skills and knowledge sharing is an important part of PPB. Farmers may require additional information, knowledge and skills, but they also bring these into a breeding programme. The process may be better understood as mutual learning and sharing, recognising farmers as active contributors to the processes. Sharing skills and knowledge is of value if done in partnership; especially technical and formal research methods. In some cases, permanent technical assistance to farmers may be needed, especially in the early stages of the breeding process but also in the later stages (Gabriel et al., 2004).

Generating genetic variability and sources of germplasm

A plant population needs genetic variation and diversity, otherwise it will not continue to evolve. Genetic variation is introduced through natural mutation; introgression (naturally occurring cross-pollination) from wild or weedy relatives; the physical mixing of seeds from other varieties; and hybridisation with other varieties (deliberate cross-pollination between stable parents) (Almekinders and Louwaars, 1999:4–5). There are dynamic, constantly evolving processes between the local gene pool, farmers' practices and the environment. Genetic variation and diversity require deliberate maintenance of the gene pool (Almekinders and Louwaars, 1999:6). Materials from outside can be introduced in the form of germplasm (unfixed varieties) that can be mixed with local varieties in a deliberate process of variety improvement. Sources of this material could be from other farmers or from the formal system.

An important source of parent material is farmer germplasm. In the formal system, farmer involvement in the collection of varieties ends with germplasm going to

BOX 3: Germplasm ownership and access

There may be ownership rights on genetic materials used in PPB. In most cases, materials come from farmers and from public sector and CGIAR collections. In most of these cases, where IP rights exist, these are waived. However, there are still rules and procedures on accessing these materials, and on benefit sharing, if improvements are commercialised.

The germplasm introduced through the formal system is governed by international and national policies, laws and regulations on ownership and use of materials. For signatories, there are obligations related to the legally binding international agreements concerning germplasm, in particular the Convention on Biological Diversity (CBD) and its Nagoya Protocol, and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). Being a signatory to these agreements also implies having or creating national procedures for effective implementation (Vernooy et al., 2016a). Some countries are not members and then rules differ from place to place. In some cases, germplasm may be fairly easily exchanged through farmer-to-farmer means, including community seed bank networks. These are often 'exempt' from (not regulated by) national access and benefit sharing laws. Elsewhere, international and national laws must be followed to access materials, especially from the formal system. This applies to materials from CGIAR, national gene banks, ARIs and commercial breeders/seed companies.

The CBD encourages bilateral negotiation on access and benefit sharing. Terms of access must be written in a contract, with national state mechanisms for tracking, monitoring and enforcement. Under the ITPGRFA, member countries agree to create a multilateral system (MLS) for facilitated access to a limited number of agricultural crops (64 are listed in Annex 1 of the ITPGRFA) and multilateral benefit sharing arrangements (Vernooy et al. 2016a:52). Accessing materials from the MLS can be an effective means to bring new diversity to breeding programmes and ultimately to farmers' fields. Benefit sharing deals with the division of any benefits deriving from the use of the genetic resources between the provider and receiver of the genetic material, according to rules and regulations set out in the ITPGRFA.

These international agreements have agricultural biodiversity conservation as their objective and promote the role of farmers as custodians of biodiversity. They sit alongside prevailing obligations in the World Trade Organisation (WTO) Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement, as well as the International Union for the Protection of New Varieties of Plants (UPOV). TRIPS requires signatory countries to have some kind of plant breeders' protection, which has to cover certain basic protections, but it is ultimately up to the individual country to decide how to formulate these.

There is a lot of pressure on countries, especially in the global South, to adopt UPOV 1991 as the standard. This particular model is historically based on commercial developments in Europe that favour private breeders' rights over the rights of farmers. Every revised version of UPOV has progressively restricted breeder exemption (to allow other breeders to freely use protected materials for further research and development) and so-called 'farmers' privilege' to recycle and use protected seed on their own holdings. This 'privilege' is optional and excludes exchange of these materials between farmers (Visser, 2015). Farmers' rights to recycle, use, exchange and sell seed are included in Article 9 of the ITPGRFA, but the way in which signatories 'domesticate' this Article is not defined, and in practice few countries have incorporated it into national policy and/or legislation.

A question for a breeding programme is what the laws and regulations say about access, use and benefit sharing of germplasm that is sought for use. Usually, farmer materials are not covered by IP protections and can be put forward by farmers, without any problem.

Signatories of the ITPGRFA and CBD/Nagoya Protocol will have contact people or national focal points for enquiries about access to materials registered in the formal system. Information on member states, laws, regulations, contact points, etc. can be located on the ITPGRFA, CBD/Nagoya Protocol and FAO websites.[9] Public sector organisations, such as the gene bank and the ARIs will be able to provide information about access and benefit sharing. For accessing materials in the multilateral system, there will usually be a Standard Material Transfer Agreement (SMTA) specifying terms and conditions of use. The SMTA protects the genetic resources of plant species listed in Annex 1 of the ITPGRFA against IP rights and assures continuous and free availability (Haussmann and Parzies, 2009:111). In some instances, use of materials obtained from the multilateral system could lead to 'royalty' payments if derived materials are commercialised. This whole story will generally be left to formal sector institutions to deal with, especially since it applies to access and benefit sharing of materials only from the formal sector. But there should be discussions with farmers if there are any IP considerations. Vernooy et al. (2016a) provide further detail of what is required to access materials from formal collections governed by the multilateral system.

Creative alternatives to exclusive plant breeders' rights are being tested, including the Open Source Seed Initiative (OSSI), formed in 2012 by a group of breeders from the public sector, small seed enterprises, farmer breeders and activists.[10] Originally OSSI was based on efforts to create a licensing framework for germplasm exchange that preserves the right to unencumbered use of shared seeds and their progeny in subsequent use (Kloppenburg, 2014). The General Public License (GPL) is one specific mechanism proposed by the Centre for Sustainable Agriculture (CSA) in India. CSA coordinates the Apna Beej open source seed network, which includes breeders, farmers and CSOs. CSA says use of the GPL can prevent or impede patenting of plant material, bioprospecting/ biopiracy and use of farmer materials in private breeding programmes. GPL can also develop a legal/institutional framework recognising farmers' collective sovereignty over seed: allowing farmers to freely exchange, save, improve and sell seed; enabling farmers and plant scientists to work together to develop new varieties; and allowing the marketing of seed that is not patented or use-restricted (CSA, 2014:8–10).

However, OSSI abandoned the idea of a license when it became apparent that many farmers and organisations do not want to adopt a licensing framework. Licensing was pulling OSSI in a policing and bureaucratic orientation. Instead, OSSI has adopted a pledge, which may not be legally binding, but which is easily transmissible and is an uncompromising commitment to free exchange and use (Kloppenburg, 2014). OSSI also supports plant breeding, PVS, value for cultivation and use (VCU) testing, seed multiplication and distribution activities based on the open source materials developed and selected with farmers. It supports activities in India and the US, and start-up activities in East and Southern Africa. Bioversity International and HIVOS (a Dutch NGO) are collaborating on an open source seed system initiative in Eastern Africa with a strong policy component.[11]

9. ITPGRFA www.planttreaty.org, CBD Nagoya Protocol www.cbd.in/abs/nagoya-protocol; and CBD ABS Clearing House https://absch.cbd.int/ and FAOLEX http://faolex.fao.org/ for laws.
10. Thanks to Sabrina Masinjila at ACB for inputs on this section on OSSI.
11. https://www.hivos.org/sites/default/files/options_for_national_governments_to_support_smallholder_farmer_seed_systems_the_cases_of_kenya_tanzania_and_uganda_0.pdf

gene banks for use by formal breeders. PPB is significantly different, in that collected/identified materials are identified and used by farmers together with breeders for further development. Farmer varieties may be limited to local controls based on identified preferences to compare with new varieties. However, farmers could also have a much more central role in identifying materials, not just as a control for testing against external materials, but for enhancement.

Aside from farmer materials, germplasm and variety collections are maintained in different places, including the national ARIs and CGIAR institutions, gene and seed banks and private/corporate collections. CGIAR institutions are prime movers in the history of PPB and continue to provide materials for practical work. CGIAR material is usually new material brought in from outside the country that has been bred for traits that have been identified as priorities. The material may still need to be adapted for use in specific local contexts. Some of this material may already earlier have been crossed with local varieties from the area, especially if local ARIs were involved in breeding.

There are a series of national, regional and global gene banks that aim systematically to collect germplasm and data on agricultural biodiversity and to make this available on a public interest basis for development. Breeders, including farmers, may approach national gene banks and ARIs for germplasm and request for assistance for repatriation/revival of specific varieties/plant materials. CGIAR plant breeding programmes are structured to have a centralised breeding platform linked closely to a world germplasm collection. Regional breeding programmes draw on support from the central unit. There is differentiated regional support to national breeding programmes, depending on capacity and resources (Lynam, 2011:40). CGIAR institutions relate directly to government departments and ARIs, but farmers can also approach the CGIAR centres directly.

Germplasm entries will be screened in the pre-adaptive phases of research, to find cultivars most closely meeting important identified characteristics, such as maturity, plant height, agro-ecology niche, product

quality, resistance to biotic or abiotic stresses, receptivity to artificial inoculation; or to deal with high incidence of natural infection or pest challenge in 'hot spot' locations (Ceccarelli, 2009:65). Materials may also be screened for diseases. Breeders will then propose materials for introduction to cross with farmer varieties for the desired traits. There are cases of farmer involvement in pre-breeding selection of introduced breeder materials at on-station experimental plots.

Crossing

Once the materials are assembled, some crossing may take place prior to selection and testing in the field. Crossing involves combining genetic material of selected parents with the objective of producing progeny with combined traits. Inbred lines (for example, from CGIAR or gene banks) have been bred for specific traits and are uniform, giving the option to be specifically adapted. The breeding objective can vary from specifically and locally adapted to only one or several environments, with more or less similar features (Hardon et al., 2005; Ghaouti et al., 2008). Crossing with local varieties is one way to do this. Crossing with wild relatives may be possible, although there may be technical restrictions (Ceccarelli, 2009:64). Crossing is not a necessary element of a breeding/crop improvement programme. Inbred lines could simply be introduced into an environment and tested and locally adapted over time. There may be some comparison with the performance of local varieties, but without crossing the materials. Over time, the materials may cross naturally in the fields, allowing farmers to select their preferred materials. In this way, the materials do get integrated into ongoing processes of selection and enhancement of seed. So the materials do ultimately cross, but not necessarily through a controlled process.

Farmer varieties, landraces and wild relatives harbour large amounts of genetic variability. If this material is to be used, it simply involves the collection of the plants as parents for the next stage (Ceccarelli, 2009:65). PPB can still take place using this genetic material, through in-field crossing, selection and experimentation. In-field crossing is rare as a systematic intervention, mainly because of the technical complexity. However, approaches such as evolutionary plant breeding create greater space for natural processes of genetic intermingling in the field, with farmers selecting from a diverse pool of materials that is continually evolving to specific conditions through natural processes.

Systematic crossing will be necessary for the creation of hybrids with the desired trait mix (Box 4). This is not very common in PPB programmes, but there are cases where hybridisation takes place as part of the programme. Some breeders consider systematic crossing to be the essence of breeding.[12]

In any breeding programme, the degree of participation in generating genetic variability is determined by who selects the parental materials. Given the complexities of crossing, it may be less important for farmers to be involved in the actual physical process of crossing if they have participated in the processes of selecting the parent materials (Ceccarelli, 2009:66). Most authors reviewed agree that crossing is a technically difficult task and farmers can rather be brought in at the assessment and evaluation stages (Trouche et al., 2012). Technical methods for generating variability are provided in various chapters in Ceccarelli (2009).

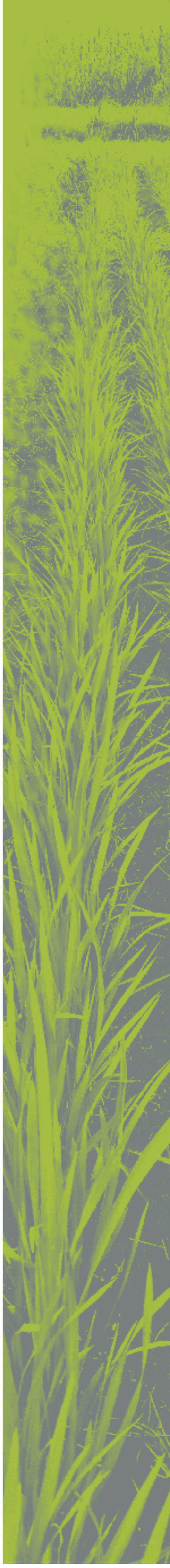
In defining PPB, we may want to include the requirement that there should be some use of farmer and local varieties in the experiment beyond merely as a control, even if the programme also includes the introduction of other materials from outside. This roots material ownership with farmers. According to de Boef and Ogliari (2008:182), "in the case of self-fertilizing crops, this means that at least one parent in the PPB programme should be a landrace or locally adapted cultivar. In the case of cross-pollinating crops, local varieties should contribute to the development of composite populations". This involvement should extend beyond just inclusion of farmer varieties, to farmers themselves actively participating in selecting the materials they want to work with in partnership with researchers (Hellin et al., 2008). Otherwise it is just farmers testing outside material, for example, PVS. This testing may be participatory, but if farmer involvement is restricted to this activity, it cannot be considered a fully-fledged PPB process.

Selection

Once the preferred genetic materials are selected and generated, the next step is narrowing down of the large diversity of genetically different breeding material to a number of preferred lines that will eventually produce true to type with the desired bundle of traits. "To unite as many genes or favourable alleles as possible in a single cultivar requires a large number of generations of selection and testing of the best plants" (Federizzi et al., 2012:67).

There are many different possible ways of doing selection, with greater or lesser farmer participation. There are different views on the feasibility of farmer involvement in early stage selection, possibly depending

12. Greybill Munkombwe, Director: National Genetic Resources Centre, Zambia, pers. comm., 10 September 2017



BOX 4: Hybrids and open pollination

Hybrids

Hybrids are crosses involving at least one inbred line. Inbred lines are individuals of a particular species that are nearly identical to each other in genotype, due to long inbreeding. This is often the form of materials that will be used in a breeding programme from a CGIAR centre or the gene banks.

Hybrid seed has to be reconstituted each generation by crossing the parents while avoiding self-pollination. Farmers generally cannot produce hybrid seed themselves because the parent lines are normally not available. Hybrid varieties are, therefore, the main asset of the seed company producing the hybrid seed.

In hybrid crosses, the original parental plants are the P generation. They are of diverse origin and genetic make-up.

The hybrid offspring of the parents are the F1 (first filial) generation. This gives a genetically diverse population, a "heterogenous population of recombinant genotypes" (CENESTA, 2013:8). F1 will have the characteristics of the dominant parent for a particular trait.

F1 fertilisation with itself or with one another produces the F2 generation. Both alternatives of each parental trait reappear. Self-pollination over generations will reduce the number of individuals with mixed traits (heterozygous); 90–95% of genotypes will be homozygous (uniform) for a trait after 6–9 generations.

(Almekinders and Louwaars, 1999:8–9, 12)

Open pollination

In the case of open pollination, pollen release from the anthers and depositions are not controlled. It may be self- or cross-pollination. Hand pollination is possible but it is time consuming.

In self-fertilising crops, 95% of pollination is from self-fertilisation. Modern varieties have one homozygous pure genotype. Improved self-pollinating cultivars consist of a small number of very similar genotypes. It is relatively easy to isolate the material genetically, so deterioration is slower if the seed is properly managed (Danial et al., 2007). Examples of self-pollinating crops are wheat, rice, finger millet, bean, cowpea, soya, groundnut, sesame, chickpea and tomato.

For cross-pollinating crops, in natural conditions 50% or more of pollination occurs through cross-fertilisation (insects or wind). Selfing often results in in-breeding depression, which expresses itself in the general weakening of the plant. Examples of cross-pollinating crops are maize, pearl millet, sunflower, canola, onion and most fruits. Isolation is the major concern for the crossing of these crops. Improved cultivars of cross-pollinating crops consist of a narrowed gene pool with high frequencies of desired characteristics. Maintenance is through mild but continuous selection for desirable plant types. Without this, the improved cultivar will gradually lose it character because it is not possible to isolate the plant genetically from other varieties (Danial et al., 2007:388). Farmers cannot easily maintain cross-fertilised varieties true to their original characteristics and may have to purchase seed if they want to produce relatively uniform varieties. However, cross-fertilising crops are more adaptive to local conditions than self-fertilising crops.

Open pollination with random mating and no selection pressure results in a constant percentage of the different genotypes.

(Almekinders and Louwaars, 1999:11)

Vegetatively reproduced crops

Improved cultivars of vegetatively reproduced crops (for example, potato, cassava, vines) consist of a single genotype. These are easy to maintain and multiply true to type, but are susceptible to pathogens carried by the propagules used for reproduction (Danial et al., 2007:388).

on the type of crop. For example, in self-pollinating or vegetatively reproduced crops, where individual plants are easy to recognise, involvement of farmers in early stages of selection may be feasible. There is an argument that in crops such as wheat and barley, where it is difficult to distinguish between plants, this is not advisable (Danial et al., 2007). However, Ceccarelli (2009), for example, shows that farmers are experts in selecting the best plants of these crops. Methods will depend on the mating system of the crop and the genetic control of the traits under selection. Field trials are expensive compared with on-station trials and this should be considered when structuring the selection and testing stages of the programme (Ceccarelli, 2009:66–67).

In the early stages of selection there are still many segregating lines[13], which are later reduced to only a few nearly finished lines. At each new round of selection, seed selected from the previous round may need to be multiplied for further selection. This may take place on-station, in parallel with the PPB (Ceccarelli, 2009a:215).

There is no standard methodology for assessing materials, with different selection processes for different crop types (for example, self-pollinating, cross-pollinating, or vegetatively reproduced). Mass selection is the simplest, most common and oldest method of crop improvement, in which large number of plants with similar observable characteristics (phenotypes) are selected and their seeds are harvested and mixed together to constitute the new variety. Evolutionary plant breeding follows this model. Mass selection is important for cross-pollinating crops but has only limited application in self-pollinating crops.[14] Selection of self-pollinated crops is about reducing genetic variance within families and increasing variance between families (Ceccarelli, 2009:66).

If crossed materials are used, early stage selection is a very structured process. Between F1–F6 generations, plant materials undergo segregation and are characterised by high genetic instability. There are large numbers of segregating lines (that is, characteristics are not stable in reproduction on next planting), and this may pose management challenges for farmers who will need to manage hundreds of lines, sometimes with only small plots available. For this reason, farmers may participate through selection from on-station trials, or may be involved only in later stage selection, when there are fewer lines and management is more feasible.

Where materials are going through a formal sector breeding process, farmers may not typically be invited to evaluate materials until after they have stabilised at F6 generations and above (Humphries et al., 2005:12). Farmer participation in early selection requires farmers to have some understanding of selection from unstable materials, where phenotypic characteristics are unlikely to express themselves consistently in early generations (Humphries et al., 2005). It is a tedious and difficult process for farmers to evaluate a large number of entries, while the pay-off for the farmer may be in the distant future (Danial et al., 2007; Ceccarelli, 2009).

Materials are gradually honed down to a final line that may undergo multi-locational trials. This completes one cycle of breeding/crop improvement. Where farmers were not involved in early stages of selection, a small number of almost finished lines may be introduced to farmers for PVS. According to de Boef and Ogliari (2008:179), "PVS is the term used for selection from among advanced or genetically stable populations and lines in self-pollinated species, or among populations in open-pollinating species, while PPB denotes selection from within segregating populations" (that is, early stage selection). For our purposes we understand PVS as an integral part of broader PPB programmes that cover other elements of breeding as well.

Farmers may evaluate lines in trials conducted at the research station (for example, Kamau et al., 2011), or farmers may

13. Mendel's law of segregation: During gamete formation, the alleles for each gene segregate from each other so that each gamete carries only one allele for each gene, https://en.wikipedia.org/wiki/Mendelian_inheritance
14. Agriinfo (n.d.) Method of plant breeding in self-pollinated plants – mass selection. http://www.agriinfo.in/default.aspx?page=topic&superid=3&topicid=1750

be actively involved in the production as well as the selection process. Technically speaking, selection usually occurs at two stages of the plant production cycle. First, an evaluation is done at flowering, and then, at or after harvest. More frequent evaluation becomes costly and does not significantly improve the outcome (Danial et al., 2007). Selection for processing and cooking characteristics, palatability, poundability, food quality, etc. may take place after harvesting and at storage.

PVS is quite commonly used in conventional breeding programmes, even if only on-station. Stable lines developed at the research institution are taken to farmers to test in the field, followed by discussion with researchers about which varieties they prefer, then the breeder finishes the process. There is growing recognition of its value in conventional systems for adapting varieties to specific local conditions; especially marginal, high-stress environments, together with low input systems (Dawson et al., 2006; Laurie and Magoro 2008:672). Often ARIs produce new cultivars but face the challenge – especially in the global South – of lack of capacity or resources to do local evaluations or multiply and distribute these varieties. PVS offers an opportunity to introduce these materials into local contexts. PVS can assist in widening the range of available genetic material available for local use and increase agricultural biodiversity. It may be faster and more cost effective than the longer PPB process in identifying farmer-preferred varieties if a suitable choice of varieties exist (Witcombe et al., 1996).

Certainly a minimum element of PPB must be farmer in-field experimentation, trials and selection. Therefore, if PVS is limited to farmer days to select from amongst formal breeder varieties at on-station trials, this can't really count as PPB. In PPB, on-station evaluations and selections usually will be conducted parallel to PVS in farmers' fields for comparison and as a backup in case field trials fail. Even where farmers are only involved in PVS, it can serve as an important starting point for longer term PPB processes (for example, de Boef and Ogliari 2008; Laurie and Magoro 2008; Trouche et al., 2012). PVS is contained and allows farmers to build up their technical skills before engaging in other parts of the breeding process. In some cases, PVS is even viewed as a necessary precursor. For example, there is a view "in PCI [participatory crop improvement] that

PPB only commences after several years of successful PVS implementation, as farmers first need to learn to work with genetic diversity and gain some experience in formal experimentation" (de Boef and Ogliari, 2008:182). PVS is considered a "logical step before PPB" (Laurie and Magoro, 2008:672).

At the end of the selection process, which is at the heart of the breeding programme, farmers will have a number of experimental cultivars with selected traits fixed in them and that reproduce true to type.

Testing of experimental cultivars and relation to registration

Once cultivars are selected for recommendation, these may be compared with favoured local varieties to see if they do indeed perform better in localised contexts based on the prioritised characteristics (Ceccarelli, 2009). If cultivars are to be spread to different agro-ecological regions, wider adaptation will be required (Aguilar-Espinoza, 2007). Plants or varieties may perform differently in different environments. Breeders know this as genotype x environment interaction (GxE). Direct selection in the target environment is always the most efficient means of selection. Selection in an environment different from the target leads to a decrease in selection efficiency. Parent selection should include local materials to overcome this (Wakjira et al. 2008:188).

As with the selection process, there are usually two check points (Ghaouti et al., 2008:260):

- Scoring at the onset of flowering on plant height, disease incidence, lodging, biomass yield, end of maturity, visual estimation of yield at maturity, and personal appreciation of material through visual score;
- After harvest (for grain) – measure of grain yield, thousand grain weight, and grain status (health).

Generally speaking, all stages will follow formal protocols if the objective of the breeding programme is to produce cultivars for official registration and release. This is necessary if they are to be used for commercial production and sale. Parental materials may need to be registered; certain agronomic practices, monitoring and data collection and analysis processes must be followed; and formal VCU and distinct, uniform and stable (DUS) tests will be required. These usually occur simultaneously for a period of 2–3 years.

VCU trials are multi-environment trials (METs) to test the reaction of the materials to a multitude of environments, for example, location, years, different types of agronomic management. The aim is to have as many locations as possible. In PPB programmes, the main limiting factor is the availability of seed. These trials have limited precision, so it is mostly negative selection, discarding obviously inferior breeding material. METs allow the subdivision of GxE into genotype x location (GxL) and genotype x year (GxY) interactions. It allows for identification over time of appropriately-adapted high-yielding, stable genotypes (Ceccarelli, 2009:71). Tests must show added value for farmers of the new variety over existing available materials (Kaimenyi, 2017).

VCU may be under centralised control of a breeding institution or may be decentralised, with tests in numerous environments through voluntary farmer participation. If decentralised, recommended cultivars are distributed to farmers for testing and comparison with locally favoured varieties. Advantages of a decentralised approach are: i) there is an increase in the number and range of test environments; ii) The costs of VCU testing are reduced, because decentralised institutions can be responsible for only one or a few locations; iii) control cultivars (usually the best in cultivation) are defined previously; iv) rules for inclusion, continuity of test lines and release of new cultivars can be decided in a collective manner; v) it gives breeders an opportunity to test their best lines with other lines from other breeding programmes. Disadvantages are: i) there is a lack of control over how the trials are performed by the participating institutions and the quality of experimental data, and ii) the new lines will be available to third parties (which is only an issue if exclusive ownership is sought) (Federizzi et al., 2012:69–70).

DUS testing is done to establish the unique character of a variety for IP and certification purposes. The requirement for a variety to be distinct and new primarily is an IP issue. A variety must be distinct from an already registered variety, so that ownership can be conferred for a period. It must also not be genetically the same as a variety previously registered. Uniformity and stability contribute to providing a distinct identity in comparison to other varieties (Hardon et al., 2005). In addition, uniformity and stability test that the variety meets certain user requirements. Uniformity refers to the progeny of the seed having the same characteristics as one another. This is important for large-scale agro-industrial production, but local markets may at times also prefer some level of uniformity, for example, grain/meal colour. 'Stable' means the advertised traits must be faithfully replicated in the progeny, the seed must breed 'true to type', at least for the first crop planting. With hybrid seed, these characteristics disintegrate with further plantings. DUS is not always appropriate for farmer needs, especially the need for diversity and dynamic evolution (CENESTA 2013:16).

Even if cultivars are not going through the formal process, VCU-type testing can be of value to farmers, to test the materials in practice, to see if they do outperform other available varieties in specific contexts. In PPB, materials may already have cycled into farmer systems at numerous points in the process, and final release of a cultivar is not a necessary outcome.

Formal variety release requirements may include (Manu Aduening et al., 2006):

- Description of the breeding procedure used, origin of germplasm, etc.;
- Phenotypic characterisation of the accessions, including resistance to common pests and diseases;
- Performance of the accessions in on-station and on-farm trials across the agro-ecological zone(s) targeted for release (VCU);
- An inspection plot (generally on-station), where the potential variety can be inspected and where sufficient planting material is available to demonstrate that release is feasible in practice; and
- A description of post-harvest attributes.

Not all registered varieties have plant variety protection (PVP). A variety that is registered but not protected may allow anyone to multiply and sell that variety (conditional on meeting certification requirements). However, registration on its own, including of farmers' varieties, can open the way for biopiracy by making visible the genetic resources held by farmers, and opening these to appropriation, using existing agreements and laws. There are technical and cost barriers to registration and seeking protection in the PVP and registration laws. These may pose challenges if farmers want to register their varieties, since, from the outset of the PPB programme, farmers must keep in mind the certification and variety release requirements. Once a variety is registered, the registered owner can apply for protection, allowing exclusive use for a period specified in PVP laws and regulations, and the right to license use to others. Commercial enterprises usually apply for protection of varieties to prevent others from using them without payment.

In most countries, farmers may recycle protected varieties for own use on their own landholdings, although this is being narrowed with new PVP laws. Legally speaking (in the standard case), farmers are not supposed to exchange these seeds with others, but in practice this is almost impossible to monitor because it is part of daily human interaction. Protection of their varieties may provide farmers with some legal protection against biopiracy, because anyone wanting to use the variety will need to enter into an agreement with the rights holders. Farmers' and their organisations will need to decide their approach to registration and protection, and perhaps to consider other possible methods to protect genetic materials as a common pool. OSSI suggests one alternative, although they have moved away from a licensing process as it is too time consuming, bureaucratic and politically unpalatable for some.

An underlying principle of PPB is that farmers' contributions should be recognised if property rights are attributed to finished materials (Sperling et al., 2001:447). Benefit sharing may include financial benefit but also other practices and mechanisms, such as community biodiversity management funds, or seed banks with multiple functions supported technically and financially by national government (Vernooy et al., 2016a:57). Taiwan has an access and benefit sharing contract model that provides an alternative to arrangements based on exclusive rights and compels the balancing of interests between public sector, commercial entities and farmers. The model requires recognition by name of any farmer who makes a contribution, as well as the creation of an enforceable fair benefit arrangement agreed by all the named parties, before a license for seed release is granted (Song et al., 2016:22).

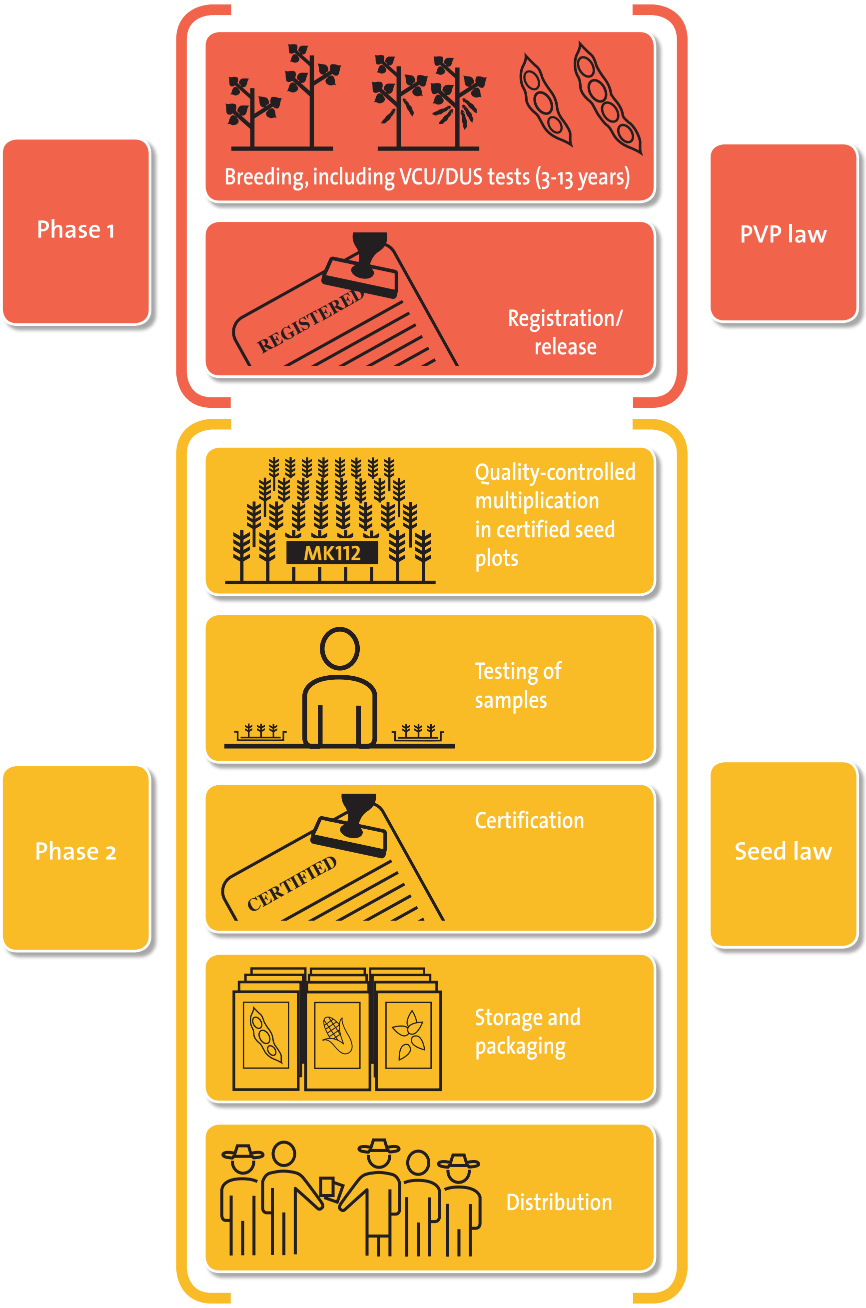
Multiplication and dissemination of cultivars following breeding

Although not the focus of the paper, we must say something about multiplication and distribution, because, if varieties are developed but not shared, it is a wasted opportunity. Once breeding is completed and new cultivars are produced, there are different routes to share. Many PPB programmes share genetic materials with participating farmers throughout the selection process. Farmers can keep and propagate and otherwise use the materials as they wish. Farmers are encouraged to share materials with others who may benefit from it. This free and informal dissemination of germplasm and enhanced materials is at the core of decentralised approaches, where the objective is the development of locally adapted varieties for local use.

However, these practices may fall foul of laws on the dissemination of genetic materials that are common in many countries, including in Africa, and that follow UPOV and International Seed Testing Association (ISTA) standards and procedures for variety registration and release, and for seed multiplication, storage and distribution. These laws are mainly designed to provide an official guarantee that seed is of appropriate quality and is identifiable at the time of purchase (Visser, 2015). In most countries, a variety must be registered and certified before it can be sold. There may be exemptions, but in many places the sale of unregistered seed is outlawed. Current proposals in South Africa seek to include any form of exchange as part of the definition of sale (ACB, 2017). Legally speaking, this means farmers may not exchange any materials if the materials are not officially registered and certified. Across the world, farmers do sell unregistered seed (even in the standard definition of sale as exchange for money). Generally, this may be tolerated and is not monitored closely unless scale becomes significant and authorities get to hear about it. If such activities begin to pose a threat to the interests of commercial seed producers, there will be a clampdown.

This illegality of exchange and sharing of unregistered and uncertified seed poses a significant threat to PPB programmes

Figure 4: Getting through the formal registration and certification system



and to public sector involvement in such programmes where the objective of the programme is to produce enhanced varieties that are to be locally circulated. The public sector will not be able to participate in activities that are deemed illegal (such as distribution of unregistered/uncertified varieties). For farmer innovation to be incorporated into breeding, exemptions are required on the sale and exchange of seed, with flexible quality controls based on farmer-user interactions and agreements (formal and informal).

The other route, after variety development, is formalisation, with registration and official release, as discussed above. After this, there will be quality-controlled multiplication, certification processes, and, finally distribution/marketing. The process to follow for formal registration and certification is indicated in Figure 3. There are two phases: the first phase up to registration and release, dealt with above; and a second phase of multiplication, certification and distribution. The first phase is usually covered by PVP law, while the second phase is often covered by the seed law governing production and sale of seed.

Once a variety has been registered, it will be legally eligible for production and commercial sale. The seed that is registered is breeder seed. This must now be multiplied out in successive batches, with quality controls to ensure the seed retains its registered characteristics and to make sure it performs according to claims. Seed is planted in certification plots with quality control inspections, and post-harvest supervision for sealing of raw seed and processing. Seed samples are sent to a registered seed certification authority to verify conformity to standards, including genetic and physical purity (field test), germination rate, moisture content, and to ensure the batch is free of weed seed and seed-borne disease.[15]

If the seed passes inspection, it is certified and the seed lot is released for multiplication or marketing. Previously, public sector seed certification authorities carried out quality controls (inspection, testing and certification). However, structural adjustment and fewer resources have resulted in privatisation of these services, with accredited seed inspectors in private companies. These are the same companies that own and sell the seed; hence, this is a self-regulated system. There may be occasional public sector spot checks in response to consumer complaints. Private inspection services are not set up in all countries and public sector seed certification authorities still play a big role in some countries, though they may lack capacity (for example, insufficient number of inspectors, especially for many dispersed smallholder plots).

Seed laws contain standards and requirements for storage, packaging, labelling, marketing, etc., of seed before it can be legally sold. Many countries have adopted ISTA standards. Again, this is not in every country at this time, but the objective for commercial producers is for a standardised set of criteria for certification that meet the needs of large-scale commercial producers, but that also provide some quality guarantees to the user. As with DUS testing, these laws have been designed for commercial production and not for farmer seed systems, but they might end up regulating farmer seed systems, in the absence of any specific legislation or regulations covering the latter.

The formal standards are fairly onerous for smallholder farmers to abide by, and may not be appropriate, especially when the seed is primarily for local dissemination. Quality control standards may be relaxed, for example, quality declared seed (QDS) for local distribution and sale, but these usually still require certification through formal agencies. Standards could be made more flexible for smallholder farmers, while still ensuring seed quality and seller accountability. In some cases, farmers indicate they are able to meet formal certification standards, but that these are not always necessary because existing social structures are adequate in regulating seed quality (Visser, 2015). Assistance to farmers to produce basic seed may be required for a while to ensure quality production (Aguilar-Espinoza, 2007).

15. Agriinfo (n.d.) Seed certification procedure. http://www.agriinfo.in/default.aspx?page=topic&superid=3&topicid=2303

PPB assessment and lessons

This section considers the lessons from 25 years of PPB practice globally. It draws from published articles and reports on specific cases, as indicated in Annex 1, as well as a number of comprehensive overview studies on PPB. Annex 1 shows that the majority of reviewed case studies were for improvement of grains. There is some diversity here, including maize, rice, millet, sorghum, quinoa, barley, teff and others. There are a much smaller number of case studies on legumes and vegetatively propagated crops. PPB/PVS on legumes is more common in Africa, and, to a lesser extent, in Latin America. Relatively few of the cases covered more than one crop type in a programme, but there were some.

Following the general structure of a plant breeding programme, literature was reviewed to see farmer active participation in the various stages: genetic materials selection; crossing; selection; in situ experimentation; and then the related multiplication and distribution of newly developed cultivars, formally or informally. Farmers' active participation was most prominent for in situ experimentation (all the cases except two), then late stage selection, followed by selection of parent materials and early stage selection (Annex 1). Few farmers were actively involved in crossing, which is a technically demanding activity. Also, not every PPB programme included crossing as part of the activities. Participating farmers usually have free access to materials used through the process and are able to use and share these materials at will. This underscores a primary aim of PPB to generate diverse adapted varieties for use in local socio-ecological conditions.

Different phases of PPB are variously pointed to as core to the definition. Some say that if farmers are not involved in crossing and early selection, then it is not really PPB. Others say that if farmer materials are not included as parents, then it is not real PPB. Certainly, from the evidence of case studies, at the minimum PPB must involve farmer participation in setting objectives and goals, sharing of genetic materials, in situ experimentation, and some active involvement in selection, whether early or late stage.

Not all cases explicitly mentioned whether farmers were involved in multiplication and dissemination of enhanced materials/new cultivars. About a third of the cases specifically mentioned farmer involvement in multiplication, while just under half mentioned farmer involvement in dissemination (Annex 1). Dissemination was often not through formal channels, and often the materials were taken and shared during the process, rather than only at the end, once there was a finished variety. This is one of the major strengths of PPB activities, because it gives farmers access to a wider diversity of materials that they can take and use, based on their specific contexts. In around one third of the cases, farmers sought registration of the PPB varieties in their own name or combined with formal breeders, while in a quarter of cases it was explicitly indicated that farmers were not seeking registration. In the other cases, there was no specific mention of whether varieties would be registered or by whom. In a number of PVS cases, in particular, varieties were registered in the name of formal institutions, such as the ARIs.

In a comprehensive participatory programme, farmers will be actively involved in all stages. However, this may be a phased process, with farmers introduced to a part of the process, and then gradually their involvement expands with their technical knowledge, interests and goals. PVS is widely viewed as a good entry point to build farmer technical capacity and to generate materials that can be used for further enhancement by farmers in their specific contexts.

It becomes evident that plant improvement/enhancement is a cyclical process, also integrating revival/repatriation, and on-farm conservation and use. There is a constant evolution of materials, introduction of new beneficial materials, improved/enhanced materials feeding back into ongoing processes of selection, crossing/mixing of varieties, further trials and testing and feeding back again. This can be contrasted with conventional breeding, based on a linear approach, which sees raw germplasm at one end and a finished, static and decontextualised variety at the other end. The continued evolution and adaptation of a species/cultivar, including adaptation to climate change, depend on continuous on farm management of local crop diversity (Sthapit et al., 2012).

Stages of PPB

Setting priorities and objectives

As indicated earlier, ideally a PPB programme should be demand driven but there may be obstacles to farmers initiating such activities. As a result, there is most likely to be some kind of facilitation, and most reviewed projects were formal-led or initiated by researchers rather than farmers. In many cases, this was an NGO that had a history of working directly with farmers. In some cases, the ARIs, CGIAR institutions or universities initiated engagement with farmers directly. Government departments may be drawn into processes, but in the case studies they were seldom, if ever, the initiators.

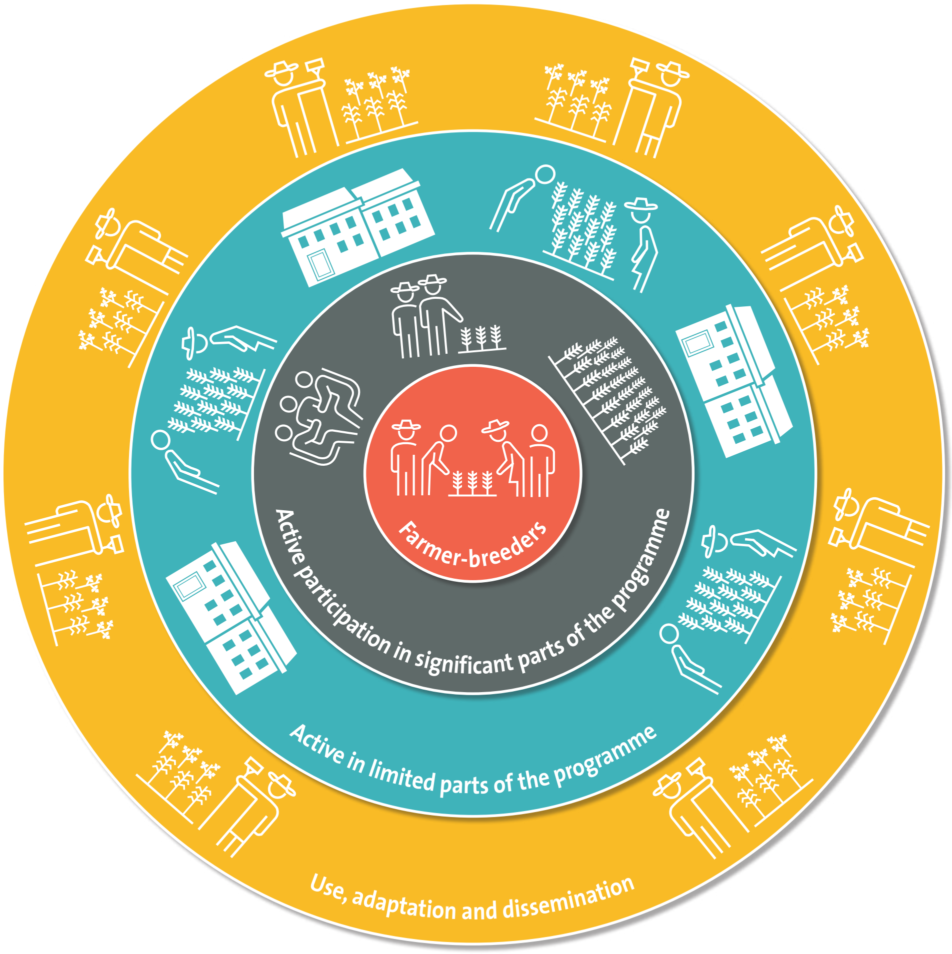
Despite the fact that women smallholder farmers play a major role in maintaining and reproducing agricultural biodiversity, almost universally women were minor participants in reviewed PPB programmes. There were only three cases where women participated in significant numbers (Hardon et al., 2005; McElhinny et al., 2007; Song et al., 2016). Reasons cited for lack of women's participation included gendered decision-making norms, unreflective exclusion from projects, and lack of expressed interest. In an Ethiopian case, men mostly made decisions on the type of variety to grow, and women were mostly responsible for seed storage and processing, with some joint decision-making. There was some joint decision-making on the number of varieties to use, plot allocation for specific crops and on seed selection (Abay et al., 2008:315). In some cases, there was evidence of interest from women but they were not informed about opportunities, or there was an assumption they were not interested (Humphries et al., 2008; Ceccarelli 2016). In a Brazilian case, the project did not seek to involve women because cassava was considered to be grown mainly by men. However, women do tend cassava fields at times, and also do processing (Saad et al., 2005). These are examples of researcher bias. In other places, lack of interest because of no immediate benefits was stated as a reason for the limited involvement of women (Gabriel et al., 2004). In West Africa, women's domestic demands kept them from participating as fully as the men (Jones et al., 2014).

The importance of including women in PPB programmes is recognised. Women and men will have at least some different trait choices and a combination is needed (Danial et al., 2007). Although it sounds very stereotypical, case studies repeatedly showed men favouring in-field and market characteristics, while women favoured culinary and storage characteristics (for example, Rios Labrada, 2005; Asfaw et al., 2012). This reflects a material division of labour in practice.

Wealth and class differentiation are mostly not reported on in case studies. There was some indication that mixed wealth categories participated, while others tended towards wealthier participants. In a couple of case studies where it was mentioned, women participants tended to be poorer (Smale et al., 2003; Hellin et al., 2008). In a related issue, Rios Labrada (2005) indicated that local innovations were not strictly related to literacy levels, indicating that participation need not automatically be limited to those with formal education.

Case studies showed uneven interest amongst farmers in participating in breeding/crop improvement. Not everyone wants to work on breeding and it is better to identify and work with those who are interested (Aguilar-Espinoza, 2007), for example, seed custodians – those who are

Figure 5: Degrees of farmer participation



actively involved in maintaining, enhancing and saving seed, regardless of whether there is a formal programme or not (Abay et al., 2008; Sthapit et al., 2013). For a community to benefit from plant breeding, only a limited number of really motivated and interested farmers may need to participate as a source for improved plant materials. The number of participants depends on the context (Hardon et al., 2005). According to Smolders et al. (2008:221):

> *Three categories of farmers can be generally identified within the participating communities. A few individual farmers who are skilled breeders and run their own rice breeding programmes, select parents and perform crosses. A second category of farmers grow out and evaluate segregating selections, supported by the farmers in the first category. The third category of farmers is not actively engaged but interested in further testing and growing the products of farmer-led PPB.*

While this will depend on the context, it indicates an example of varying involvement by different farmers in plant breeding processes.

Smale et al. (2003) showed a similar situation, with some farmers only participating in field days, others purchasing seed of elite landraces provided by project staff, a smaller number participating in trials of 'elite' landraces alongside a local control, and some participating in training sessions. Some case studies concluded that clearly defined objectives with fewer farmers can prevent the creation of unrealistic expectations. They argued there should not be too many farmers involved in the breeding process, in order to maintain quality control. It is better to involve fewer farmers but design learning activities that enhance farmers' experimental and analytical skills (Aguilar-Espinoza, 2007).

In one case, many farmers took part in initial screening of materials, but in subsequent seasons fewer farmers were involved. Farmers

were selected based on land availability, experience, communication abilities, interest, and influence in the community. In this case, representivity was not considered because of the high biophysical variability (Saad et al., 2005). In another case, selection was run on an individual basis, but with some collective decisions to select a wide range for further work in farmers' fields (Rios Labrada, 2005). If the smaller group of farmer-breeders are part of democratic farmer organisation, the results will be more relevant to the local population.

A clear point emerging from the case studies is the value of involving end users/buyers in the process of establishing priorities and in selection and evaluation of materials being developed, as well as determining the potential and limitations of the available breeding materials (Manu Aduening et al., 2006; Aguilar-Espinoza, 2007; Danial et al., 2007; Gyawali et al., 2010; Kamau et al., 2011). "A variety may perform excellently under varying types of drought stress, but it will not become a successful variety if it is not tasteful or has no market" (Asfaw et al., 2012). Consultations can include farmers and breeders, consumers, millers and other processors at various scales, and retailers. Users may be willing to pay a premium for a set of post-harvest and organoleptic traits over a single trait, such as aroma or taste (Gyawali et al., 2010). Market studies on consumer preferences in the Participatory Enhancement of Diversity of Genetic Resources in Asia (PEDIGREA) programme assisted farmers to better understand the market mechanism and identify niche markets for non-mainstream vegetable crops (Smolders et al., 2008:222).

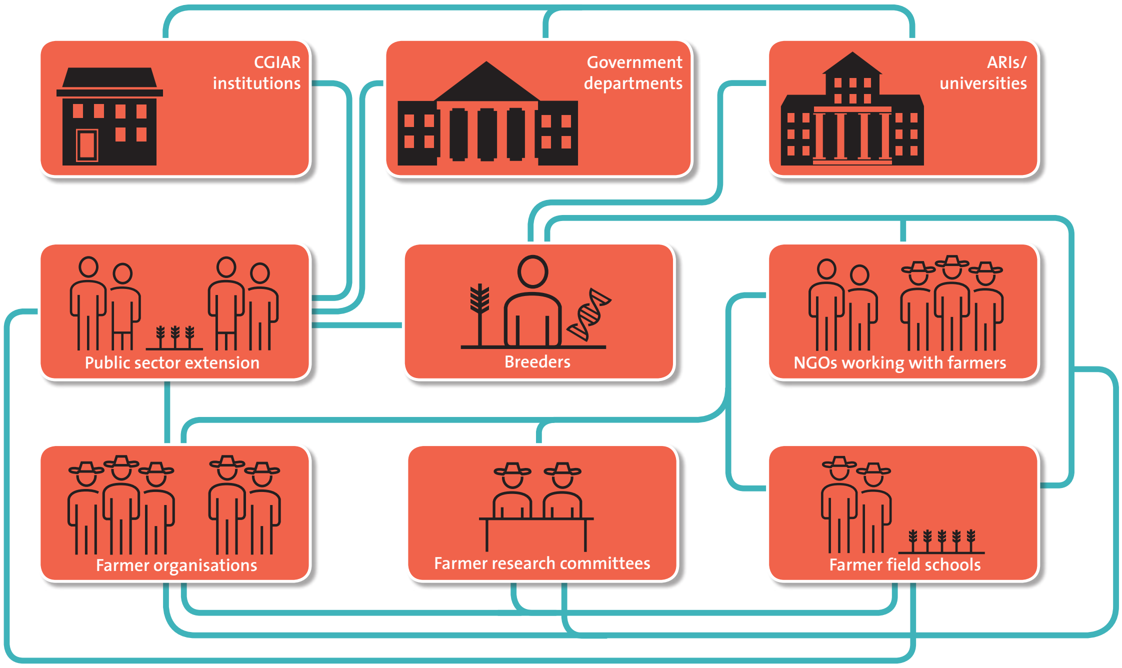
Generally, the evidence shows that farmers seek a diversity of varieties with a diversity of traits, rather than a single dominant trait. In a number of cases, farmers selected for a group of attributes 'on average', rather than for individual traits in isolation (Rios Labrada and Wright, 1999; Hellin et al., 2008; Humphries et al., 2008; Asfaw et al., 2012). This is a notable feature of PPB over conventional breeding, which usually focuses on the development of a single trait, usually associated with yield/productivity.

Farmer organisation

Reviewed cases show that farmer organisation is very important to facilitate participation and knowledge sharing, and that it is better to work with groups of farmers than with individuals (Saad et al., 2005; Danial et al., 2007; Sthapit et al., 2012). The stronger farmer organisation is, the deeper the participatory process can be. A limiting factor in the scaling out of PPB programmes is weak farmer organisation on the ground. It is generally accepted in the literature that it helps if there is some kind of pre-existing farmer association that expresses interest in participating in a programme. The aim is to carry the process institutionally at local level and to ensure farmers are driving and shaping the process. Farmers and farming communities will need knowledge and leadership capacity to evaluate the benefits of a conservation or breeding programme. Activities may be designed to strengthen and empower local communities to maintain and reproduce resources at their disposal.

In a number of cases, PPB projects were introduced through existing community meetings and organisations. These include co-operatives, farmer research committees (the CIALs in Latin America) and FFS, especially in Asia and Latin America. In some of these cases, farmers already had some experience with doing systematic research,

Figure 6: Institutional structure



farmer-to-farmer learning and sharing, and participation in technical skills building processes (for example, Rios Labrada and Wright, 1999; Hardon et al., 2005; Saad et al., 2005; Smolders et al., 2008). In other cases, farmer organisations were established as part of the PPB project, often with NGO support. In one instance, farmers formed a co-operative after the start of the project, specifically to register their varieties in order to produce certified seed for sale (Aguilar-Espinoza, 2007). In other projects, no specific efforts were put into forming farmer organisation (Hellin et al., 2008).

Farmer research committees bring farmers and researchers together in a process of joint experimentation and learning. They establish a direct link between locally organised farmers and research institutions, including but not limited to plant breeding. The CIAL concept was developed by CIAT in Colombia and spread to other countries. It reduces the need for extensive coverage by research institutes and extension services, because farmers take on the task of testing and adapting technologies for themselves (Vernooy, 2003; Humphries et al., 2005). Local innovation groups amongst farmers can assist in introducing and adapting appropriate genetic materials for their contexts (Rios Labrada, 2005).

A lot has been written on FFS as an effective institutional approach for PPB. BUCAP (2002) and PEDIGREA (Smolders and Caballeda, 2006) in South East Asia, and more recently CTDT in Zimbabwe (Callo et al., 2015), have published field guides on PPB implementation in farmer field schools, and a framework for PPB in FFS has been developed (Smolders, 2006). In farmer field schools:

> *Farmers get together in weekly or bi-weekly meetings for the duration of one full cropping season to study particular topics in the curriculum. Basic topics in the curriculum on PPB include understanding genetic diversity and crop improvement, baseline assessments, participatory variety selection, and variety rehabilitation. When possible, crop hybridization and selection in segregating populations are included. After the first season, small groups of interested farmers are formed who continue with variety selection and breeding per crop under the guidance of an experienced farmer, extensionist or NGO trainer. (Smolders et al., 2008:218)*

CIALs and FFS facilitate farmer networks for learning and sharing knowledge and resources, with farmer facilitators placed with the FFS. Both farmers and extension workers indicated a preference for FFS,

since it is a planned series of interactions rather than occasional field days. It offers a more equitable basis for interaction with extension, and farmer empowerment and a sense that farmer views are being taken seriously. Farmers are partners in developing technologies (Hardon et al., 2005). A related approach is farmer-led extension (Islam et al., 2011) and exchanges or cross visits between participating farmers are common (Abay and Bjørnstad, 2008; Jones et al., 2014). Such exchange visits are viewed positively and contribute to building group cohesion (Hardon et al., 2005). One proposal is for farmer extension agents to be trained through the FFS (Hardon et al., 2005).

Challenges identified include organisational weaknesses at farmer level and maintaining active and stable farmer participation over a number of years (Humphries et al., 2008). Co-operatives may be structured specifically to engage with an external project and there may be uneven buy-in. As indicated earlier, women's participation is often limited, despite their actual centrality to seed practices (Aguilar-Espinoza, 2007). Humphries et al. (2008) suggest that farmer groups involved in PPB should be representative of the user community, otherwise their variety selection and development may not be appropriate for local requirements, and that inclusivity is important, even if it may slow the uptake of new ideas and technologies to begin with.

Technical and institutional support

In reviewed cases, NGOs played a very important role in connecting farmers with scientists in formal institutions, facilitated ongoing multi-disciplinary rigorous participatory research (Humphries et al., 2008; Humphries 2016), and, in some instances, provided technical agronomic support. Participating NGOs are mostly rooted with farmers, with a long history of working with farmers on different aspects of agriculture and development. PPB as an issue has tended to arise from these ongoing interactions. NGOs are mostly in a better position than farmers to make links to formal institutions. Having said this, case studies suggested seeking ways to strengthen direct links between farmers and scientists in the formal institutions. NGOs should not be gatekeepers to this process, but facilitators to enable it to happen. NGOs can also bring farmers into contact with other national and regional networks (Aguilar-Espinoza, 2007). NGOs contribute a social sensibility, bringing socio-ecological considerations into a process that may otherwise be limited to decontextualised technology development (Humphries et al., 2008).

Hellin et al. (2008) say that participatory processes led by formal researchers may not have sustainable impacts on farmer capacity and organisation. They recommend breeders teaming up with development institutions, with a presence on the ground, and longer-term contact with farmers. This includes NGOs, the ARIs, extension services and farmer organisations. In some cases, partnerships extended to university students (for example, Hardon et al., 2005) or universities integrated their research programmes with farmer experimenter networks, with the eventual inclusion of the process in educational curricula (Rios Labrada, 2005). Decentralisation, a greater role for social scientists, and involvement of a wider range of actors are recommended from a case study in Ghana (Manu Aduening et al., 2006). Hardon et al. (2005) say it is important to have local ownership of a project, but also for external support to increase understanding and confidence in what is a new approach to breeding.

Ideally relevant government departments and agencies should be involved at least at the planning stages. Public sector extension was involved in a number of cases, and this proved to be of value (Saad et al., 2005; Aguilar-Espinoza, 2007). In some cases, agriculture departments were involved in partnerships but were not often very active. In Nicaragua, PPB was linked to the national Zero Hunger programme (Aguilar-Espinoza, 2007). A number of challenges were experienced with involving government departments. There was mostly limited involvement at policy and management levels, with projects coming about as a result of interest from individual extension workers and breeders and not taken up institutionally. Sensitisation is needed at higher levels, especially once a project has started (Hardon et al., 2005). In practice, government departments did not always show a good understanding of participatory approaches (Hardon et al., 2005).

In the reviewed cases, formal sector breeders in the ARIs, universities and NGOs usually provided training. As farmers become more adept over time, they can take over more of the process themselves. In Honduras, the coordinating NGO provided technical support for the first years, until a team of para-professional farmers or local facilitators had been identified and trained from amongst the membership. After that, farmers mostly only needed support from a local facilitator and occasional agronomic backstopping for field trials (Humphries et al., 2008). Farmer-to-farmer exchanges are widely used to share knowledge and skills amongst farmers and researchers in partnership, with FFS as a successful example of this in many places, as mentioned.

In Syria, training was provided on experimental design and data analysis in conditions where the research process is not under scientists' control (Vernooy, 2003:22). In Mexico, a training module on seed selection and storage was provided, based on farmer requests (Hellin et al., 2008). In Honduras, farmers were trained in formal agricultural research methods. Tools and methodologies may be required that can enable farmers to replicate processes within their organisations (Aguilar-Espinoza, 2007). Prior support and training in PVS played a big role in the success of the collaboration. The project involved a formal comparison between conventional and participatory breeding approaches. Comparative and verification trials were carried out, farmers employed the use of controls and replicates, learned how to work with segregating materials, and managed negative selections, etc. Intense technical support was provided to farmers (Humphries et al., 2008). This may raise costs in the short term, but the long-term benefits are the flourishing of technical capacity amongst farmers, a seedbed for creativity and innovation. In a project in a number of Asian countries, farmers requested simple learning materials with lots of visuals, and simple written information on FFS and the breeding process (Hardon et al., 2005).

Bob Brac[16] highlights the need for more discussion on the multiplicity of actors and the asymmetry of information and power among them inside a PPB programme. This includes elaboration of the governance mechanisms among researchers and farmers in research programmes as a starting point for dissemination, and multi-stakeholder dialogue for public policy decisions. This

16 Bob Brac, pers. comm., 13 December 2017.

is a major issue in different international research programmes. For example, EU research programmes offer grant agreements that are not easy to follow for farmer organisations participating in PPB projects (European Commission, 2017). Currently they are trying to negotiate more suitable contracts.

Sources of germplasm and generating genetic variability

In the reviewed case studies, germplasm for PPB mostly came from a combination of CGIAR and national gene bank/ARI materials and farmers' materials. There was only one case of private sector involvement in the reviewed cases, a recently launched global consortium on evolutionary plant breeding with quinoa, with genetic materials from the USDA and private companies (Murphy et al., 2016). Gene bank materials include past accessions of local landraces (for example, Gibson et al., 2011), but also crossed material including hybrids (for example, Gabriel et al., 2004; Laurie and Magoro, 2008; Kamau et al., 2011; Campanelli et al., 2015).

There may be a wide diversity of source material. In Syria, for example, activities started with experimentation with farmers in their fields to compare local barley varieties with other varieties. These included fixed lines; F3 (third generation) segregating populations from crosses between fixed lines unrelated to landraces; landraces; and crosses including landraces. This increased farmer interest in their own materials because of the opportunity to systematically compare their own materials with exotic germplasm under local conditions. A second phase on PPB was then carried out. In this phase, farmers requested more of their own landraces to begin with, using materials selected from the previous round (Ceccarelli, 2016).

As Annex 1 indicates, there was limited involvement of farmers in the crossing stage. In quite a few cases there was no crossing done, just the use of existing materials for experimentation and comparison in the field. Crossing is mostly left to formal researchers, even if farmers participated in prioritising traits and identifying parent materials (Hardon et al., 2005; Humphries et al., 2008). In a few cases, farmers were involved in crossing/hybridisation in the field. Farmer participation in crossing proved to be challenging in the reviewed cases. Based on experiences in Asia, Hardon et al. (2005) suggest that institutional plant breeders may be better placed to make initial crosses, possibly at the request of farmers, and then release the resulting breeding populations in more advanced generations (F4–F5). However, they also indicated that involvement in crossing increased the understanding of farmers and both options were valuable. Although crossing is a tedious and difficult process, farmers liked to do it themselves and gained greater confidence in their local varieties as parent material. Although a case of farmer participation in crossing in their fields in Bolivia did not work, backup materials from the ARI were distributed to farmers to continue the experiment (Gabriel et al., 2004).

As mentioned earlier, evolutionary plant breeding adopts a different process. In Iran, a large number of wheat and barley lines were selected down by farmers to a few locally adapted varieties for their own use. There was some introduction of crossed materials from ICARDA as part of the genetic mix at the outset, but otherwise crossing takes place 'naturally' within the mixture (CENESTA, 2013).

There is limited, if any, specific discussion on IP for incoming parent materials in the reviewed cases. Generally, it seems to be that materials were made available to the programmes without cost. Even materials in formal PVS processes generally did not appear to be tightly controlled by breeders. By this time, breeder material has gone through adequate quality controls to reach the stage of sharing with farmers, and is considered to belong to the farmers, who are entitled and encouraged to work on it further, or multiply and distribute the materials (Laurie and Magoro 2008; Smolders et al., 2008). Ownership claims on cultivars developed through a PPB process is a different issue. Providers of the initial germplasm, whether farmers or formal breeders, may want to stake a claim in ownership of these cultivars, if they are to be registered, certified and produced for sale. Theoretically, this stake will allow them to get financial benefits from sales. This aspect of ownership is considered later in the discussion on what happened to improved cultivars in the reviewed case studies.

Formal breeding processes may have annual registration fees for breeding materials being used, which may vary in individual country PVP laws. These fees may be waived for materials coming from public sector and CGIAR gene banks, but this would need to be checked on a case-by-case basis. In Nicaragua, the supporting NGO covered the registration fee on breeding materials, but eventually farmers would be required to take over these costs (Aguilar-Espinoza, 2007).

Selection

Challenges for involving farmers in early stage selection arising from field experience include lack of identity of the entries, as they are still fairly heterogeneous; lack of sufficient plant material; and small plots, which may reduce selection efficiency with a large number of entries (Danial et al. 2007). This has led to recommendations that trials with smallholder farmers should have fewer lines or replications to avoid farmer fatigue during evaluation (Hardon et al., 2005; McElhinny et al., 2007) or that conventional processes are used for initial materials preparation and then selected genotypes go to farmers for selection and evaluation (Gabriel et al., 2004). Diseases are not always immediately apparent in the seed. Farmers have shown some capacity to be able to select for disease resistance, but not always. It may be necessary for researchers/ pathologists to remove non-resistant lines before late stage trials, which may require laboratory screening (McElhinny et al., 2007; Gyawali et al., 2010).

Despite these challenges, farmers participated in early selection in quite a number of the reviewed cases (Annex 1). There is some evidence from the field that farmers are able to handle large numbers of entries and, therefore, could be involved in earlier stages of selection (Vernooy, 2003; Ceccarelli, 2016). In Ghana, farmers were consistent in their selections, even amongst large numbers of seedlings, and could select effectively throughout the breeding cycle (Manu Aduening et al., 2006). In Honduras, in the early stages of the programme, CIALs members learned to handle unstable genetic materials and became "familiar with conducting controlled experiments and are generally regarded by others in their communities as leaders in innovation and

research" (Humphries et al., 2008:210). In a programme in Cuba and Mexico, scientists initially doubted farmers' capacity to manage four or five trials simultaneously, but, over time, realised that farmers have a deep understanding of their farming systems. The lesson was not to underestimate farmer knowledge (Rios Labrada, 2005). "Decentralized selection in farmers' fields [also] avoids the risk of useful lines being discarded because of their relatively poor performance at experimental stations (where conditions are almost certainly more favourable, through fertilization or irrigation for example)" (Vernooy, 2003:21).

Generally, where farmers participated in selection, materials were grown by farmers in communal or individual fields with parallel plantings on-station, both for comparison and as a backup (for example, Saad et al., 2005; McElhinny et al., 2007; Gyawali et al., 2010; Campanelli et al., 2015). However, there were some cases where experimental plots for early stage selection were on-station, with farmers going to the station to evaluate the materials (for example, Rios Labrada, 2005; Kamau et al., 2011). In one of these cases, seeds from the preferred five lines were given to farmers for further experimentation in their fields (Rios Labrada, 2005). On-station plots means risk of crop failure is not carried by the farmer, but it is also often not in the same environment as farmer production (McElhinny et al., 2007). If farmers are selecting from on-station trials they may not have a chance to develop any sense of ownership of the material they select (Ceccarelli, 2009a:199).

In reviewed case studies, where experiments were done on-station and in-field, selection choices sometimes differed between farmers and researchers, as well as amongst farmers, and there were also some differences amongst researchers. This shows a diversity of needs (Campanelli et al., 2015; McElhinny et al., 2007). Farmers generally had diverse priorities for selection. Varietal choice is influenced by household preferences and existing natural resources (soil type, rainfall) (Abay et al., 2008).

There are significant gendered differences in selection criteria and it is important to understand the basis of these differences (Vernooy, 2003; Rios Labrada, 2005). As indicated, men tend to orient towards productivity and in-field traits, while women also take into account organoleptic and post-harvest characteristics. In Ecuador, women were reticent to categorise any seed as 'poor' because all seed has some value. More accurate reflections may be achieved with a wider range of choices for evaluation than just three (good, medium, poor) (McElhinny et al., 2007). Men tend to dominate group discussions and it is useful to maintain separate evaluation groups (McElhinny et al., 2007). In reviewed studies, women played a central role in selection at post-harvest stage to evaluate processing, cooking and food quality characteristics, even if they were actively involved in the breeding programme to this point (Manu Aduening et al., 2006; McElhinny et al., 2007; Abay et al., 2008; Laurie and Magoro, 2008; Jones et al., 2014). Other lessons from practice are that plot sizes should be kept to a minimum, in order to avoid a large burden on farmers who dedicate land for research (CENESTA, 2013) and that a heterogeneity of sites is of value to cover the real conditions facing farmers, although this will require more testing sites (McElhinny et al., 2007).

Testing of experimental cultivars and relation to registration

In some cases, official registration for newly developed cultivars was sought. This is the objective of conventional breeding processes (whether with PVS or not), although some formal-led processes may not aim for official variety release (see Ceccarelli, 2015; Trouche et al., 2011; Almekinders et al., 2006 for cases). In conventional processes with PVS, varieties will usually be under the control of the breeders, who will register in their own name (although the materials may also be shared with farmers as a separate process). In Zimbabwe, farmers in a formal PVS project will not be able to claim full ownership of varieties produced because they only contributed to the development of the cultivars but did not have ownership claims on the starting material (Makumbe and Wing-Davies, pers. comm., 19 April 2017).

Aside from PVS in conventional breeding, in some cases of PPB and evolutionary breeding farmers may also want to register cultivars. One of the reasons PPB farmers wanted to go through the process, in particular early on in PPB programmes, was to gain recognition for PPB and farmers' expertise. It had nothing to do with the notion of making money out of the new variety.[17] Annex 1 indicates that in just under a third of reviewed cases, farmers sought official registration of their cultivars with some possibility of co-ownership, depending on farmer contributions, especially to the parent material. In one case,

17. Ronnie Vernooy, pers. comm.s, 9 January 2018

authors recommended that variety release requirements can and should be included within participatory breeding programmes at the outset (Manu Aduening et al., 2006). There was an example where farmers only decided to register PPB varieties after the breeding programme had started, so this is possible (Aguila-Espinoza, 2007). In other cases, farmers were not looking to register enhanced varieties. There are challenges with institutional frameworks in some cases. For example, in Syria, after farmers had tested the material in their own fields for four years, this was not recognised in the formal process and there was still a requirement for another three years of on-farm trials, from scratch (Ceccarelli, 2016).

Farmers may want to register cultivars because government will not support breeding/crop improvement programmes or purchase and dissemination of varieties, unless they are registered and certified. This will restrict the dissemination of farmer cultivars developed through PPB programmes (for example, Manu Aduening et al., 2006; Gibson et al., 2011). In Syria, for example, the agriculture department was told to stop working with ICARDA on a PPB project and government even tried to close down the project because varieties were not officially released and therefore could not legally be cultivated, exchanged or sold. Failure to secure registration meant the programme could not use government facilities to produce and distribute seed. This was despite there being no evidence in the law that exchange of unregistered seed is prohibited. Farmers were given intermediate technologies to clean and treat the seed themselves and some commercialisation of the seed resulted (Ceccarelli, 2016). In Honduras, the municipal government was involved in the PPB programme and had the authority to recognise varieties emerging from the process as belonging to the regional CIAL Association. However, the farmers lacked the capacity (including land size) to multiply the variety, resulting in others doing multiplication for sales and distribution without any benefit to those who had done the work on enhancing the seed (Humphries et al., 2008).

Multiplication and distribution

In almost all cases, farmers gained access to genetic materials at any stage of the process, including the cultivars they had contributed to developing. It is generally accepted that participating farmers should have free access to the materials they would like to use. This facilitates local biodiversity and availability of improved genetic materials (for example, Humphries et al., 2008). In South Africa after the trials, planting material of new sweet potato varieties was established in nurseries and farmers had access to cuttings (Laurie and Magoro, 2008). Farmers in Uganda were already distributing sweet potato clones being used in participatory trials four years before official release (Gibson et al., 2011:631).

Genetic materials and cultivars are often exchanged and distributed through informal channels beyond the sites, although this may be relatively limited in geographical range, mainly short distances (for example, Dorward et al., 2007; Gyawali et al., 2010; Gibson et al., 2011). According to Baloua Nebie at ICRISAT Mali (pers. comm. 19 November 2017), "farmers themselves are efficient actors for variety diffusion in their zones as the adoption of these varieties is more based

on trust. They can also easily reach others farmers even in the remote areas, where seed companies and extension services cannot go". For varieties developed for the specific local context this is fine, especially if farmers did a lot of the work and there is no pressure to commercialise or scale up. The use of any materials throughout the process, not only the final cultivars, was actively encouraged in most reviewed programmes, notwithstanding occasional national government opposition, as indicated in the Syrian case above. One of the key objectives of farmer involvement in PPB is access to a wider diversity of genetic materials, so it defeats the purpose if farmers are restricted from freely using and sharing the material. This is clearly an area where the legal framework needs to be adjusted to accommodate these practices and not criminalise them.

In most of these cases where multiplication was explicitly mentioned, there was an overlap with farmers having registered the cultivars, although this was not always so. Sometimes individual farmers (for example, Rios Labrada, 2005) and sometimes farmer seed production groups were established for the purpose of multiplication of new PPB cultivars. In Nepal, for example, community seed production groups were established to maintain and multiply the seed, with a seed network connecting village seed production groups, and providing foundation seed to village level. The network was led by one producer group that was formally registered with district agriculture, and there was NGO and public sector support (Gyawali et al., 2010). In Zimbabwe, a farmer-owned company with subcontracting arrangements with smallholder farmers is contracted to produce seed from participatory processes (pers. comm. Makumbe and Wing-Davies, 19 April 2017; pers. comm. Mushita, 27 October 2017). Generally, reviewed cases did not touch on the question of certification. As previously mentioned, officially farmers are not meant to sell uncertified seed but may still do so, especially when there is limited access to certified seed (Rios Labrada, 2005). In other cases the certification process may have been followed, but there was no explicit mention. In an Asian programme, farmers did not feel certification was necessary because return customers are enough incentive to sell good quality seed (Hardon et al., 2005).

PPB successes

Reviewed PPB projects showed a number of tangible successes, including superior performance of PPB varieties over conventionally bred and local varieties; a shorter and less costly process; increased availability and earlier access to genetic materials and consequent expansion of biodiversity; farmer empowerment and building organisation amongst farmers.

A large number of projects show evidence that PPB is more effective than conventional breeding in producing varieties with enhanced yields and traits in the specific local contexts in which they were developed. Research has also shown that farmers often prefer local varieties over certified varieties and imported genotypes, especially in stress-prone and marginal conditions (Rios Labrada and Wright, 1999; Abay and Bjørnstad, 2008; Laurie and Magoro, 2008; Humphries et al., 2008; Humphries 2016). In Ghana some local land races simply being used as controls were selected ahead of certified varieties (Manu Aduening et al., 2006). Farmer controls also outperformed introduced materials in a PVS project in Asia, even though researchers were primarily concerned with the performance and acceptance of their own varieties (Hardon et al., 2005).

Local adaptation and buffering capacities meant local varieties and landraces performed more predictably than registered cultivars (Abay et al., 2008). In Germany, polycross progeny performed better on yield than inbred lines (Ghaouti et al., 2008). In Italy, selected varieties exhibited strong GxL interaction of cross-over type, fully justifying decentralized selection and testing (Campanelli et al., 2015). For wheat in Iran, there were aroma and quality benefits from evolutionary populations (CENESTA, 2013). In Brazil, a PPB variety was the best performing for nitrogen use efficiency in comparison with local varieties and commercial hybrids (Machado and Fernandez, 2001).

In Nicaragua, in six out of seven trials, farmer assessors selected varieties derived from farmer-breeders over those derived on-station from professional breeders. Farmer assessors were not told which lines came from which process. However, breeder-selected varieties did provide superior lines for grain yield and also produced some varieties favoured by farmers. This indicates an important role for breeders, and the key issue is working closely with farmers (Trouche et al., 2012). In Uganda, cultivars that involved farmers met a wide range of positive characteristics, while those involving researchers were ranked very well on specific characteristics. Researcher-bred (improved, certified) varieties scored best on top three traits ('specialist') but PPB and local varieties scored better than researcher varieties on a wider number of traits overall ('all-rounder') (Gibson et al., 2011). This reinforces the argument that farmers seek a bundle of traits, whereas breeders prefer to focus on a single trait or a few traits.

Very limited work has been done on calculating the financial costs and benefits of PPB, compared with conventional breeding. In one study in Mexico, net financial benefits of participation were shown (Smale et al., 2003). In Ghana, farmer involvement added little to costs and provided economic benefit in some aspects (Manu Aduening et al., 2006). A different study in Ghana concluded that lower cost programmes will be conducted largely by farmers and local organisations (Dorward et al., 2007). In South Africa, participatory approaches served the needs of more marginalised farmers, and proved to be a rapid and cost effective way of assessing and selecting potential varieties (Laurie and Magoro, 2008:675). Grassroots breeding is considered to be relatively easy to scale up, as it requires fewer resources than PVS or PPB and can also serve as a precursor to PPB (Sthapit and Ramanatha Rao, 2007).

Others have indicated that training and active farmer participation may increase costs. This is especially because it includes identifying and selecting communities, preparation of training materials, and doing training and capacity building. It is not just production of a new variety, so costs are not directly comparable with conventional breeding (Gabriel et al., 2004). However a full cost-benefit analysis should also consider adoption of the varieties over time, after the project, not only immediately at the conclusion of the breeding process (Humphries et al., 2008). If the participatory process is successful, the benefits will accrue more generally over time, as other farmers adopt the PPB varieties and as the varieties are cycled back into ongoing on-farm selection and enhancement processes.

Crowdsourcing methodology is considered to be up to 80% more cost effective than conventional PVS.[18]

Another area of success for PPB is increased farmer access to genetic diversity and clean planting material, earlier access and adoption of new materials and generally more rapid development and delivery of varieties in the local context (Machado and Fernandez, 2001; Saad et al., 2005; Manu Aduening et al., 2006; Aguilar-Espinoza, 2007; Gibson et al., 2011; Campanelli et al., 2015). More time spent on involving farmers in early stage selection can be recouped at the stage of adoption. Early involvement of farmers may facilitate early release, an important factor in cost effectiveness (Gabriel et al., 2004; Manu Aduening et al., 2006). Access to fresh planting materials may be a key motivator for farmer participation. According to Smale et al. (2003) participation in training did not translate into changed practices for most farmers and "by all appearances, farmers wanted the seed more than the practices" (Smale et al., 2003:269). In cases in Cuba and Mexico, involvement in PPB was the first time farmers had access to genetic diversity, and seed production was integrated into farming systems (Rios Labrada, 2005). In many places ARIs no longer have dissemination capacity and PPB can be a local alternative (Aguilar-Espinoza, 2007).

Some related benefits of PPB highlighted in case studies include the medium-term impact of farmers adopting a more integrated approach to conservation, breeding, seed production, crop production, and consumption, which are separated in conventional programmes. Diversity in the field is one of the most important risk mitigation strategies for farmers (Rios Labrada, 2005). Some cases indicated that participation led farmers to realise the importance of local varieties, and farmers also expressed interest in expanding to other crops (Hardon et al., 2005; Danial et al., 2007). Decentralised selection leads to a wider range of diverse varieties being adopted across target environments, with a positive impact on agricultural biodiversity (Campanelli et al., 2015).

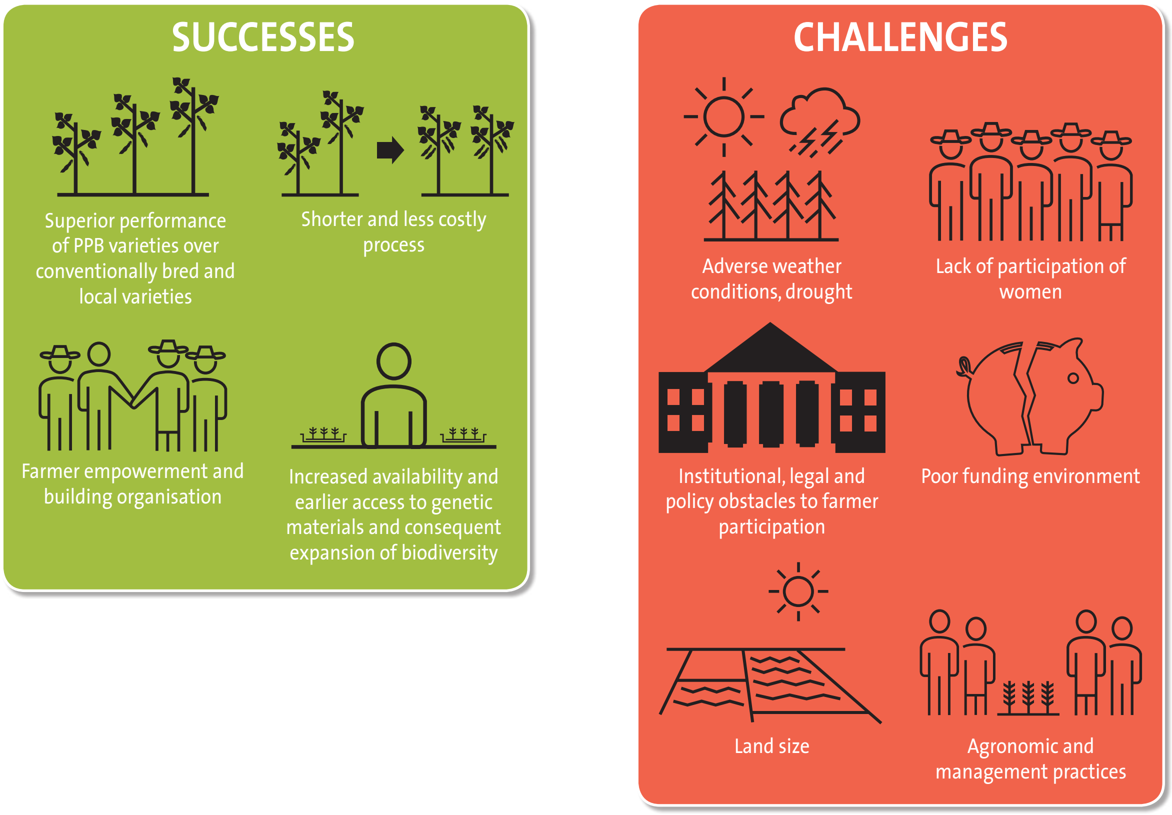
PPB projects can be a conduit for building organisation and collective action amongst farmers (Aguilar-Espinoza, 2007). PPB has a generally recognised empowerment effect on farmers, increasing confidence and motivation to engage in breeding activities (Smolders et al., 2008). In Honduras, learning to do research gave poor women and men self-confidence. Self-confidence allowed women to use their liberty effectively and empowered them to make important household decisions (Humphries 2016). In Cuba and Mexico, experimenter farmer networks were supported through the project after selection and four agrobiodiversity centres established between farmers and scientists. The programme also expanded into others parts of the two countries (Rios Labrada, 2005). PPB in Asia stimulated interest from communities around the sites (Hardon et al., 2005). In West Africa, collaboration with technicians and scientists opened space for farmers to develop their own peer learning network (Jones et al., 2014).

Challenges

However, participatory breeding is not all plain sailing. Projects may encounter ecological, social, institutional and technical challenges. Ecological challenges encountered include regular adverse weather conditions and drought (Humphries et al., 2008; Smolders et al., 2008; Asfaw et al., 2012; Rahmanian et al., 2014). Social challenges included lack of participation of women in many of the projects, as indicated earlier, and illiteracy amongst farmers (Humphries et al., 2008). Some projects showed a decline in participation over time (for example, Gabriel et al., 2004; Hardon et al., 2005). Farmers may need to spend a great deal of energy and resources on maintaining quality and production, especially for sale, as well as obtaining administrative and technical capacity in their organisations. As a result, developing more varieties or spreading the experience may not be feasible in all conditions (Aguilar-Espinoza, 2007). Some studies raised the question of what the incentives are for farmers to invest in the process (Manu Aduening et al., 2006).

18. https://www.bioversityinternational.org/innovations/seeds-for-needs/crowdsourcing/

Figure 7: PPB successes and challenges

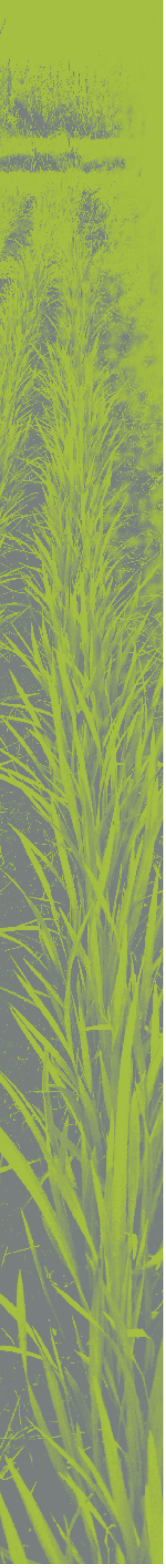


Farmers already use their own seed and cost is not a major issue. Going through the hard work of improving varieties, including cost of registration, certification, maintaining the variety, etc. may reduce the incentives. Is participatory breeding justified in terms of recouping costs of production through sales (Aguilar-Espinoza, 2007)?

This relates to institutional challenges, which make it difficult for farmers to navigate their way through the statutory requirements for registration and certification of varieties. These are onerous and do not accommodate decentralised and diverse processes and products; they favour uniform and standardised procedures and outputs. Not all farmer materials conform to the specific and tight definition of a variety found in the law. This has been discussed elsewhere in the paper. Even where farmers do follow the procedures, bottlenecks in multiplication, dissemination and promotion may limit greater adoption (Gabriel et al., 2004).

PPB is a long-term undertaking, requiring stable funding for the different partners and continuous dialogue between researchers, NGOs and farmers (Humphries, 2016; Trouche et al., 2012). Donor projects have short time frames, and this may restrict farmers to PVS. PPB is possible but because it is a long-term process that needs resources, it must be situated in government for the long term. Few donors see the intrinsic value of PPB (pers. comm. Makumbe and Wing-Davies, 19 April 2017). Decentralisation is a key to PPB, but includes decentralisation of resources, incentives and decision-making (Manu Aduening et al., 2006).

Specific technical challenges mentioned include lack of uniformity of trial plots (variation in soil fertility, watering) and management of trials (gaps in plots, poor weeding and damage to plants as a result of late weeding) (Laurie and Magoro, 2008), seed storage (Hardon et al., 2005) and, for cassava, slowness to mature and few cuttings generated were major limiting factors to replication and maintaining farmer interest (Manu Aduening et al., 2006). For evolutionary plant breeding, very small plots of land may not be enough for farmers to grow their own evolutionary populations (Rahmanian et al., 2014).



Key issues and way forward

PPB can have a positive impact

- The primary aim of PPB is to generate diverse adapted varieties for use in local socio-ecological conditions.
- At the minimum, PPB must involve farmer participation in setting objectives and goals; sharing of genetic materials; in situ experimentation; and some active involvement in selection, whether early or late stage.
- Reviewed case studies suggest that PPB can produce positive results for farmers. Recorded successes include superior performance of PPB varieties over conventionally bred and local varieties; a shorter and less costly process; increased availability and earlier access to genetic materials and consequent expansion of biodiversity; and farmer empowerment and building farmer organisation.

Farmer organisation

- Farmer organisation is very important to facilitate participation and knowledge sharing. Successful forms of farmer organisation include co-operatives, and farmer research and experimentation groups. The aim of the farmer organisation is to carry the process institutionally at local level and to ensure farmers are driving and shaping the process.
- Farmer-to-farmer learning and sharing, and especially the farmer field school (FFS) methodology, appear to be very successful.
- Support is required to build independent smallholder farmer organisation to articulate farmer interests in seed and biodiversity conservation and maintenance, breeding and crop improvement, seed production and distribution.

Multidisciplinary research teams

- PPB is best carried out as a multidisciplinary research process, involving farmers and their organisations, NGOs, public sector breeders and research institutions, as well as end users. These could even be formalised in the form of research consortium agreements that have been negotiated with farmers.
- Involvement of government departments and extension creates a higher likelihood of processes being institutionalised.
- Participation of women should be encouraged and supported – case studies reveal the importance of both men and women being involved in deciding on traits and selection, for example, because there are gendered dimensions to the criteria.

Decentralisation

- Decentralised selection and comparative testing is usually more effective than centralised, on-station processes. It increases the number and range of test environments reduces costs by decentralising tests to different institutions/farmers, who can take responsibility just for their own tests; allows for collective decision-making; and allows for testing against other varieties. The main potential downside is lack of quality control.
- This requires decentralisation of resources, incentives and decision-making. Changes in the organisation and execution of national breeding and extension will be needed.

Germplasm ownership and access

- Farmer ownership of the process and products will be enhanced if farmer materials are used as parent materials. Germplasm should be made available to farmers at any stage in the process. In conventional systems, rejected lines are usually discarded. But individual farmers may favour lines that are rejected in the programme and should be able to take this material for their own use and dissemination to others. Final cultivars should also be available to farmers to use, multiply and distribute without constraint. One of the key benefits of PPB is availability of diverse materials to farmers.

Linking conservation, breeding, seed production and dissemination

- It is important to acknowledge that PPB is only one part of a bigger picture. Plant breeding on its own, no matter how democratically and inclusively it is done, is not going to resolve all the ills and challenges facing smallholder farming communities. PPB should be situated in a wider agenda of agro-ecological programming and support.
- For the purposes of analysis, we have

made conceptual distinctions between conservation and maintenance, repatriation and rescue of varieties, variety enhancement, multiplication, dissemination and use. In reality, these are or can be parts of continuous and integrated processes of crop and seed production cycling through the seasons. Wider agricultural biodiversity is a necessary basis for PPB, and pre-breeding activities to build this base may be required. The work of Bioversity International is a good example of such activities that shade into participatory breeding and selection as they develop. A key feature of PPB is a more overt recognition of the cyclical and continuous character of these processes, as opposed to a conventional linear process, which starts and ends with a defined product.
- Raise awareness on the importance of smallholder farmers' ongoing activities and varieties in conserving, maintaining and enhancing genetic diversity.

Seed laws and policies
- PVP and seed laws and regulations, as they are currently formulated, pose a significant obstacle to systematic participation of farmers with their own varieties in PPB, as well as to government participation and upscaling.
- There should be an immediate exemption to allow public sector entities to work through approved programmes to support farmer seed production and distribution that is not required to go through the existing formal registration and certification process.
- It is up to farmers whether they want to officially register and certify their varieties. However, technical requirements may be onerous and not always relevant to their situation, and there are costs attached.
- Advocacy is required to carve out space for PPB within the legal and policy frameworks, to allow the flexible registration and certification requirements that suit the specific contexts facing farmers as breeders and users of seed.

DUS, VCU and registration
- DUS needs to be relaxed, depending on the purpose of the seed. It may apply for large-scale commercial production, but is not equally relevant in farmer seed systems. Because there is a policy vacuum on farmer seed, the commercial standards bleed into farmer systems.
- Spaces should be opened for crowdsourcing, evolutionary plant breeding models and other innovations, without imposing unnecessary constraints on the use and distribution of materials.
- There is lack of official recognition of farmer testing, even if this is rigorous. Even where farmers do follow the procedures, bottlenecks in multiplication,

dissemination and promotion may limit greater adoption of varieties they have produced.

- PVS could be made a statutory requirement in formal sector/conventional breeding, with the objectives of ensuring seed is appropriate to the context, and to build farmer capability in crop improvement. PVS is a good entry point for farmers to acquire technical skills/ knowledge on selection and breeding/crop improvement.
- Provide blanket protection of registered farmer varieties from biopiracy, even if the varieties are not protected under PVP laws, as a condition for engagement in registration processes.

Quality controls and certification

- ISTA standards and requirements for storage, packaging, labelling and marketing are designed for commercial production and not for farmer seed systems. However, they end up regulating farmer seed systems in the absence of any specific legislation or regulations covering the latter. The formal standards are fairly onerous for smallholder farmers to abide by, and may not be appropriate, especially when the seed is primarily for local dissemination.
- There is need for a set of flexible and context-driven quality standards and controls, based on farmer-user interactions and agreements (formal and informal). There are some existing practices. More investigation is required and ACB has been doing some background research on this.
- The scope of QDS could be expanded to incorporate farmer-based quality assurance and control processes and geographical expansion for distribution beyond the locality. Shared codes could be facilitated through farmer-to-farmer exchanges.
- Geographical expansion of QDS would require the development of quality control processes, including across agro-ecological zones and administrative and legal borders. The vision is for farmer-based processes. But external agents could also enter, with partial approaches and work with farmers to expand these together, in the same way that PPB can start in fairly narrow ways and expand outwards to encompass more complexity over time.

Abbreviations

ACB	African Centre for Biodiversity
AGRA	Alliance for a Green Revolution in Africa
ARI	Agricultural research institute
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CBD	Convention on Biological Diversity
CGIAR	Consultative Group on International Agricultural Research
CIAL	Comité de Investigación Agricola Local
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CSA	Centre for Sustainable Agriculture
CSO	Civil society organisation
CTDT	Community Technology Development Trust
DUS	Distinct, uniform and stable
EOSA	Ethio-Organic Seed Action
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FFS	Farmer field schools
FIPAH	Foundation for Participatory Research with Honduran Farmers
GPL	General Public License
GxE	Genotype x environment
GxL	Genotype x location
ICARDA	International Center for Agricultural Research in the Dry Areas
IDRC	International Development Research Centre
IP	Intellectual property
IRRI	International Rice Research Institute
ISTA	International Seed Testing Association
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
LI-BIRD	Local Initiatives for Biodiversity, Research, and Development
MET	Multi-environment trial
MLS	Multilateral system
NARS	National agricultural research systems
NGO	Non-government organisation
OSSI	Open Source Seed Initiative
PEDIGREA	Participatory Enhancement of Diversity of Genetic Resources in Asia
PIAL	Program for Local Agricultural Innovation
PPB	Participatory plant breeding
PRGA	Program on Participatory Research and Gender Analysis Programme for Technology Development and Institutional Innovation
PVP	Plant variety protection
PVS	Participatory variety selection
QDS	Quality declared seed
R&D	Research and development
SD=HS	Sowing Diversity, Harvesting Security
SDC	Swiss Agency for Development Cooperation
SMTA	Standard Materials Transfer Agreement
SSA	Sub-Saharan Africa
TRIPS	Trade Related Aspects of Intellectual Property Rights
UPOV	International Union for the Protection of New Varieties of Plants
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VCU	Value for cultivation and use
WECARD	West and Central African Council for Agricultural Research and Development

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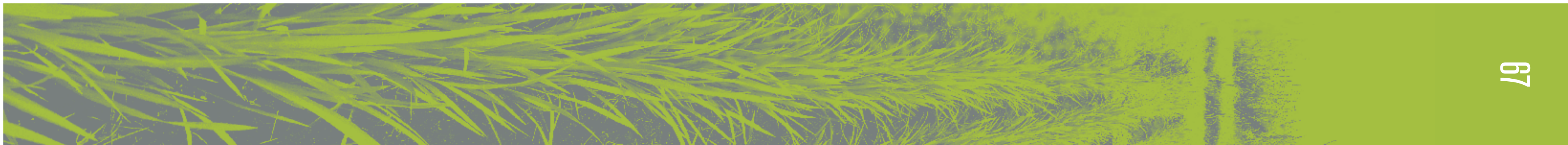
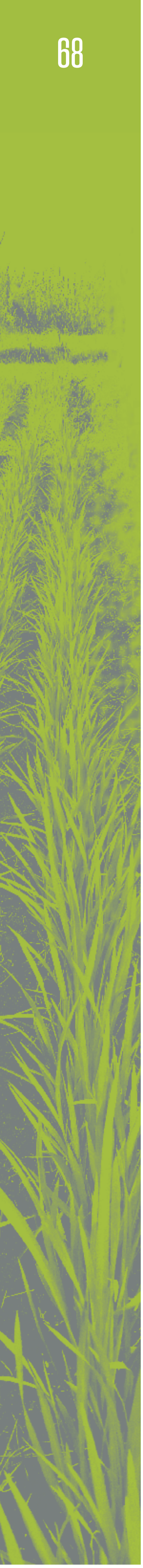
Annex 1: Selected PPB case studies

Region/ country	Crop				Farmer active participation							Farmer variety registration		Source
	Grain	Legume	Vegetative	Other hort	Materials selection	Crossing	Early selection	PVS	In situ exp	Multiplication	Dissemination	Y	N	
Americas														
Honduras		x			x		x	x	x	x	x	x		Humphries et al., 2005; Humphries et al., 2008
Nicaragua		x			x				x	x	x	x		Aguila-Espinoza, 2007
Nicaragua	x				x	x	x	x	x	x	x			Trouche et al., 2012
Cuba, Mexico	x	x			x		x	x	x	x	x	x		Rios Labrada and Wright, 1999; Rios Labrada, 2003
Mexico	x				x			x	x					Smale et al., 2003
Mexico	x				x				x				x	Hellin et al., 2008
Brazil	x				x			x	x					Machado and Fernandes, 2001
Brazil			x					x	x		x			Saad et al., 2005
Ecuador	x							x	x					McElhinny et al., 2007
Andes	x	x	x		x			x	x			x		Danial et al., 2007
Bolivia			x		x	x	x	x	x	x	x	x		Gabriel et al., 2004
US	x						x		x					Murphy et al., 2016
Sub-Saharan Africa														
Kenya			x		x		x	x					x	Kamau et al., 2011
Ethiopia		x			x		x	x	x				x	Asfaw 2008; Asfaw et al., 2012
Ethiopia	x	x	x		x		x	x	x	x	x			Wakjira et al., 2008
Ethiopia	x				x			x	x					Abay and Bjørnstad, 2008
Uganda			x		x		x	x	x		x	x		Gibson et al., 2011
Malawi		x						x	x	x			x	Dakishoni, pers. comm., 2017
South Africa			x					x	x				x	Laurie and Magoro, 2008

Region/ country	Crop				Farmer active participation							Farmer variety registration		Source
	Grain	Legume	Vegetative	Other hort	Materials selection	Crossing	Early selection	PVS	In situ exp	Multiplication	Dissemination	Y	N	
Zimbabwe	x	x						x	x				x	Makumbe and Wing-Davies, pers. comm., 2017
Zimbabwe	x	x			x		x	x	x	x		x		Mushita, pers. comm., 2017
Zimbabwe	x	x						x	x	x	x	x		Mupetesi, pers. comm. 2017
Madagascar	x						x	x	x	x	x	x		Vom Brocke, pers. comm., 2017
Ghana			x				x	x	x					Manu-Aduening et al., 2006
Ghana	x							x	x		x			Dorward et al., 2007
Mali, Niger, Burkina Faso	x						x	x	x					Jones et al., 2014
Mali, Burkina Faso	x				x	x	x	x	x	x	x	x		Nebie, pers. comm., 2017
Benin		x			x				x		x		x	Dena and Brac, pers. comm., 2017
Middle East and North Africa														
Syria	x				x		x	x	x			x		Ceccarelli 2016
Iran	x				x				x		x		x	CENESTA 2013; Rahmanian et al., 2014
Asia														
India	x						x	x	x	x	x	x		Virk et al., 2003
India	x				x		x	x	x					GVT 2002
India	x				x			x	x					Witcombe et al., 2003
Bhutan	x							x	x				x	Hardon et al., 2005
Vietnam	x					x	x	x	x		x	x		Hardon et al., 2005
Lao PDR	x					x	x	x	x				x	Hardon et al., 2005
Nepal	x				x		x	x	x	x	x	x		Gyawali et al., 2010
Indonesia, Cambodia and Philippines	x			x	x	x	x	x	x	x	x			Smolders et al., 2008





Region/ country	Crop				Farmer active participation							Farmer variety registration		Source
	Grain	Legume	Vegetative	Other hort	Materials selection	Crossing	Early selection	PVS	In situ exp	Multiplication	Dissemination	Y	N	
Europe														
Italy				x			x	x	x					Campanelli et al., 2015
Germany		x						x	x					Ghaouti et al., 2008
Portugal	x				x			x	x					Vaz Pato et al., 2008

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