The Impacts of Food Legume Research in the CGIAR: A Scoping Study

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1. Introduction

The Standing Panel on Impact Assessment (SPIA) of the CGIAR has expressed concern that there are few ex-post impact assessments available for the legume crops that are the mandates of four CGIAR Centres (CIAT, IITA, ICARDA, and ICRISAT). In preparation for a stripe impact assessment on legumes beginning in 2011, SPIA has commissioned an initial study of the status of legume uptake and impact in the CGIAR. This paper reviews the literature, summarizes available documentation on estimated levels of adoption, discusses a framework for future legume impact studies, and provides suggestions and possible research themes that could contribute to the wider review.

The paper is based on an analysis of literature found on the shelf, available electronically, and supplied by correspondents in the CGIAR and elsewhere. The review is fairly superficial and there is surely additional relevant documentation (e.g. in national institutions) that would provide further insight. The review was done without in-depth technical knowledge of many of the disciplines that impinge on legume impact, thus this review must be considered as simply a first step.

With respect to technology uptake, the focus was on significant instances of change in the past 15 years. The terms of reference envisaged a review of nine legume species, but this study discusses information on the uptake of only seven (common bean, cowpea, groundnut, chickpea, pigeonpea, lentil and faba bean). No relevant information could be located for grass pea or soybean (despite significant earlier success for the latter crop in central Nigeria). The terms of reference also contemplated a range of legume technology, but the majority of the discussion and all of the uptake studies focus on the adoption of modern varieties (MVs), although crop management implications are discussed.

Following this introduction, Section 2 provides a brief review of some of the factors that make assessment of legume technology uptake and impact particularly difficult. Section 3 (and the Annex) summarizes the information that is available on the uptake of legume MVs. Section 4 discusses the factors that should be considered in defining possible impact pathways for legume technology. Section 5 is a discussion of possible cases and themes that might be appropriate for impact studies or assessments.

2. Legume Impact

There are several factors that can help explain why the uptake and impact of legume technology is less well documented than is the case for some other major staples. Some are related to the relative importance of legumes and hence the absolute contribution of changes in legume technology and the importance that farmers may accord to opportunities for innovation. A second set of factors is related to the mechanisms for promoting legume technology and particularly the limitations of national seed systems for diffusing new varieties. A third set of factors relates to the way that statistics are collected about legume technology use.
2.1 Legumes in cropping systems
Legumes are vital elements of many cropping systems but they occupy niches that are varied and subject to modification, substitution or even abandonment. It is impossible to provide a succinct summary of the various cropping patterns involving legumes around the world. There are important instances where they are planted as a major sole crop, often as a component of a rotation, but many more examples involve various types of intercropping, mixed cropping and relay cropping, taking advantage of complementarities in growth habits and farm labour profiles. Woolley et al (1991) describe six major classes of cropping system involving common bean. Beans are mostly intercropped in sub-Saharan Africa, with the major exception of southern Africa where nearly half are monocropped (Kimani et al, 2005). Groundnut is often grown as an intercrop in West Africa but there are parts of Mali where they are mostly grown as a sole crop (Ndjeung’a et al, 2008). Pigeonpea has been traditionally grown as an intercrop in India, but new short-duration genotypes are included as sole crops in rotations (Ali, 1990). More than half of the lentil grown in Bangladesh is planted under mixed cropping (Sarker et al, 2004).

Legumes are often seen as insurance or risk-reducing crops, in part because some of them have deep rooting systems. But many legumes are prostrate growers and sensitive to competition for light, and the relative abundance of N in the plants makes them particularly susceptible to insects and diseases (Breman and van Reuler, 2002). Their susceptibility to biotic and abiotic stresses leads one reviewer to characterize legume production as ‘unpredictable and unreliable’ and to observe that if legume performance were the subject of a school report the assessment might read ‘could do better’ (Smartt, 1990:9). Yield improvements in legumes in the past several decades have often been much less than those for cereals. Pigeonpea and chickpea yields have increased only modestly (Parthasarathy Rao et al, 2010), while groundnut yields in developing countries have increased by about 2% per year (Birthal et al, 2010). In the past half-century the yield of pulses in India has increased by 25%, compared to 211% for cereals (Srivastava et al, 2010). Legumes’ ability to fix atmospheric nitrogen is an important attribute but it is dependent on the appropriate *Rhizobium* bacteria and adequate environmental conditions. Cowpea is a common intercrop in much of semi-arid West Africa, but it is susceptible to drought and pests and its total production is only about 10% of the cereals it is grown with (Mortimore et al, 1997). A study in India found that chickpea yields were more variable than those of wheat (Kelly and Parthasarathy Rao, 1994, cited in Gowda et al, 2009).

The broad range of legume cropping systems provides valuable flexibility, but also makes it difficult to target and develop new technology. Different cropping systems often require different varieties and even within one system farmers may plant several varieties with different agronomic or food preparation characteristics. Mortimore et al (1997) found between 5 and 9 different (local) cowpea varieties in the villages they surveyed in Nigeria; Rwandan bean farmers plant mixtures with an average of five varieties (CIAT, 2008). Legume variety performance will vary under different management regimes and there has been some attention to the implications for breeding programmes in crops such
as cowpea (Blade et al, 1997) and common bean (Woolley and Rodriguez, 1985). Because legumes are often a ‘secondary’ crop, farmers may not provide the management attention and inputs accorded to cereals. Farmers are likely to manage intercrops in ways that favour the cereal; fertilization of a cowpea-cereal intercrop will shift production to the cereal, for instance (Blade et al, 1997). Much was made of the fact that the advent of productive, early-maturing wheat and rice varieties led to the displacement of legume acreage in the Green Revolution (Lipton with Longhurst, 1989).

Legumes make a significant contribution to diets, but are rarely the major focus of attention. They are often referred to as ‘poor man’s meat’ and with few exceptions direct legume consumption tends to drop or at best remain stable with increases in income. (This does not necessarily apply to the use of soybean and other legumes in industrial food products.) Statistics show bean consumption in Africa remaining relatively constant over the past 15 years with the exception of significant declines in several countries where beans are a more important element of the diet (Rwanda, Burundi and Kenya) (Kalyebara et al 2007). A review found per-capita pulse consumption in developing countries dropping by 6% from 1980 to 1995; in 1995 pulses contributed 4g (7%) of the total 56g of protein consumed per capita in developing countries (Kelley et al, 2000). Although legume protein provides a good balance to cereals in many traditional diets, there is often a preference for alternatives, particularly animal products. It has been argued that the traditional Mesoamerican diet based on maize, beans and squash was brought about by the relative absence of domesticated animals (Albala, 2007).

In summary, while legumes make an important contribution to crop production and local diets, there are a number of factors that make the development of productive technology, and farmers’ interest in pursuing such technology, a considerable challenge. Legumes are subject to various biotic and abiotic stresses and are often managed as complementary crops. The wide range of cropping systems involving legumes is a testament to farmer ingenuity, but new technology must either fit the conditions of these specific systems or be developed by innovative researchers and farmers who are willing to look for new management options for crops that often receive less attention than grain staples or other cash crops.

2.2 Technology diffusion and seed systems
Despite the challenges to legume improvement, there have been many successes in legume breeding. However, these have not always been matched by widespread diffusion of the new varieties, and legume seed systems play a large role in the explanation. Although there is some variation, legumes tend to share certain characteristics that make formal seed production efforts less attractive. Most of the legumes we are examining are essentially self-pollinating, meaning that farmers can maintain home-saved seed. (The major exceptions are faba bean and pigeonpea which are partially insect-pollinated.) In addition, legumes tend to have higher seeding rates and/or lower multiplication rates than many major cereals, leading to higher seed prices and relatively higher seeding costs, which again makes farmers favour home-saved seed. Added requirements of threshing and conditioning some legume crops may further increase the seed cost. One seed
technology expert has called groundnut ‘the worst seed crop in the world’ (M. Turner, personal communication).

These factors explain why the commercial (public or private) seed industry for legumes has often been slow to emerge in both developing and industrialized countries. Bishaw et al (2009) surveyed six CWANA countries and found that formal legume seed production was little more than one percent of that for cereal seed. Our focus is on public legume varieties and many public research systems are less aggressive than they could be at promoting new varieties to seed producers. A study in three states of India in the mid-1990s found that the weighted average age of varieties indented for breeder seed was 15.3 years for groundnut and 12.9 years for chickpea, compared to 9.3 years for wheat and 11.5 years for rice. Two groundnut varieties released in 1940 together accounted for 14% of demand and the most popular chickpea variety had been released in 1960 (Witcombe et al, 1998). (In the US, public bean breeding faces increased competition from the private sector and is seeing its proportion of the seed market decline (Maredia et al, 2010)).

In addition, many public research systems in developing countries have to face variety release procedures which do not prioritize legumes. For instance in Kenya the variety release system charges a fixed fee for a crop trial; maize breeders can share the trial cost among many varieties (and companies), while bean breeders, with fewer entries, face higher per-variety costs. The length of the variety release process has led to cases where the same groundnut variety has been released many years apart in two neighbouring sub-Saharan African countries. In addition, the location-specificity of some legume varieties means that a relatively large number of varieties, each with a limited market, may be competing for attention in the release and promotion processes.

The near absence of formal seed production for many legumes has meant that new varieties face greater challenges. The idea that ‘a good new variety sells itself’ is only very partially true. New legume varieties do spread from farmer to farmer (Grisley and Shamambo, 1993; Kormawa et al, 2004; Alene and Manyong 2006b), and grain markets, which are a very important seed source for many legumes, can help diffuse a new variety (Jones et al, 2001; Tripp et al, 1998; David, 1997). But there are limitations on the degree to which informal diffusion of a new variety can be expected (Sperling and Loevinsohn, 1992; Masangano and Miles, 2004) and additional methods must be used to promote the technology.

Some of the more successful instances of legume variety diffusion have taken place in the context of an aggressive seed distribution programme (e.g. Mather et al, 2003). The most effective modalities for promoting new varieties through seed interventions have yet to be fully worked out. Some efforts are quite comprehensive, such as the programme to promote bean seed in sub-Saharan Africa (Rubyogo et al, 2010), while others are more dispersed. Beye and Margiotta (2008) describe a wide range of donor projects aimed at promoting the seed of new groundnut varieties in West Africa.

The wide range of seed efforts that still characterize many legume variety promotion efforts (seed loans, seed villages, seed banks, community seed enterprises, seed exchange
programmes, farmer research groups, seed fairs, small seed packs, etc) indicates that we still need to learn what should be done to make seed available in the most efficient way possible while promoting the eventual emergence of a sustainable commercial seed system. This paper is not the place to explore that question, but certainly part of the reason for lower than expected impact from legume research is the seed bottleneck. At the very least it may be necessary to acknowledge that in many variety development situations the budget must include a line for technology promotion through sensible seed delivery if any reasonable cost/benefit ratio for legume research is to be expected, and that the costs of seed delivery may need to be considered in impact assessments.

2.3 Legume statistics
A further impediment to the assessment of legume technology diffusion is the availability of accurate statistics. Legumes often do not receive the same attention in farm surveys that staple cereals attract, and because legumes are often intercropped or planted in ‘minor’ seasons they may not be accurately reported. Langyintuo et al (2003) review the various ways that cowpea statistics are collected and reported and Johnson et al (2003) discuss the problems in finding accurate statistics on beans (at one time FAO had India, which grows little common bean, as the world’s largest bean producer).

In addition, the large number of legume varieties sometimes makes it difficult to identify the movement of new varieties. Farmers in Malawi may use different names for the same bean variety (CIAT, 2007) and in various countries it is not uncommon to find a legume MV known by the name of its promoter, such as an NGO or extension agent, rather than by its official name. A recent survey in northern Nigeria found MV names such as ‘World Bank’, ‘Liberia’, and ‘Kanada’ (Ellis-Jones, 2008). In Uganda farmers grew a groundnut MV developed by a nearby research station but did not know its name or origin (referring to it as ‘India’) (Longley et al, 2001). As with many other crops, the distinction between ‘local’ and ‘modern’ varieties is not always recognized by farmers, making it more difficult to assess variety uptake.

3. The Use of New Legume Technology
The focus of this review is to summarize what is known about the uptake of legume technology and to use this information to identify opportunities for impact assessment. As mentioned in the introduction, virtually the only legume technology described in any detail (or assessed beyond very location-specific situations) is new crop germplasm, hence the discussion in this section is related entirely to studies on legume MVs. (Section 4 returns to offer some information on crop management.)

There is virtually no recent national-level data on the uptake of legume MVs, nor was it possible in the course of this review to organize any expert surveys that might estimate national adoption levels. The most recent multi-country, multi-crop estimates of MV adoption and impact are found in the studies from the mid- and late-1990s reported in Evenson and Gollin (2003). This data deficiency (which is not confined to legumes) is
one of the reasons for new BMGF projects (DIIVA and TRIVSA) that will develop such data.

The studies that were available and relevant are summarized in tables in the Annex to this paper. Many of these were suggested by correspondents at the Centres and they were supplemented by further literature search. It was only possible to find studies on seven target legume species. The tables report the most recent studies available and do not try to follow historical trends. In the cases of common beans, groundnut and lentil some comparative figures from the earlier Evenson and Gollin (2003) studies are also presented.

The studies were done for a variety of reasons, under various types of sponsorship. It is well to be aware of this context, especially when considering further studies, because it is important to seek synergies and opportunities for collaboration among sources of funding to promote legume technology. Some of the major past and current efforts that help document legume technology uptake (project, Centres, crops/regions, donor) include:

- **PABRA** (Pan-African Bean Research Alliance): CIAT; beans in E and S Africa; multiple donors.
- **PRONAF** (Projet Niébé pour l’Afrique): IITA; cowpea in W. Africa; IFAD.
- **PROFRIJOL** (Programa Cooperativo Regional de Frijol para Centro América, México y El Caribe): CIAT; beans in Central America and the Caribbean; SDC.
- **Treasure Legumes**: ICRISAT; legumes in Ethiopia, Kenya, Malawi, Tanzania; IFAD.
- **Nile Valley Project**: ICARDA; legumes in Egypt and Sudan; IFAD.
- **Tropical Legumes 2**: ICRISAT, CIAT, IITA; beans, cowpea, groundnut, chickpea, soybean, pigeonpea in Africa and India; BMGF.
- **Pulse CRSP**: various collaborators; beans and cowpea in Africa and Latin America; USAID.
- **Peanut CRSP**: Various collaborators; groundnut in Africa, Latin America and Asia; USAID.
- **DIIVA** (Diffusion and Impact of Improved Varieties in Africa): New project to estimate grain, legume and root and tuber variety uptake and, in some cases, impact in Africa; BMGF.
- **TRIVSA** (Tracking Improved Varieties in South Asia): Similar to DIIVA, for South Asia; BMGF.

The last five of these all have plans for future assessment of variety uptake and are possible sources of collaboration for some impact studies, although specific funding commitments are not yet available.

The patterns of legume MV uptake described in the Annex tables are quite varied and no attempt will be made here to summarize them, although relevant cases are discussed in subsequent sections of this paper. But some comments are in order on the nature of the studies that produced the uptake estimates.
The studies described in the Annex do not represent a complete accounting of the adoption data available for legume varieties. They are only the studies suggested by Centre staff or found in the course of a brief literature search. There are, for instance, surely a number of other studies available with national research entities. The lack of country-level, or even more local-level adoption data may not be too surprising. The organization of a competent adoption study takes time and resources and Centres are currently pulled in many directions. On the other hand, basic adoption data are necessary for Centres to monitor how their primary products, new crop varieties, are performing in the market.

The studies that are reported were carried out for a variety of reasons, but in many cases they were baselines or assessments required by particular projects. In some cases the adoption figures reported in the Annex are drawn from documents that summarize several such studies that are apparently unpublished, and the summaries give relatively little detail on the nature of the study. Few of the studies provide much information that would be useful to biological or social scientists who might be interested in refining the technology or addressing specific bottlenecks, the type of monitoring that should be part of technology development. Many of the detailed adoption studies appear to see journal publications as the priority audience and feature analysis that concentrates on parameters that are found in traditional, academic technology diffusion studies rather than focusing on a more practical monitoring role. In a few cases the adoption data was used in an impact assessment.

Many of the studies report relatively high levels of MV uptake and the sample is obviously biased by the fact that such studies are rarely undertaken in situations where low adoption rates are expected. Almost none of the studies attempt nationwide estimates although many cover substantial areas of a country where the crop is most important. No attempt is made in the tables to specify the details of the sampling, but in many cases the studies have been done in areas that have profited from substantial technology promotion, often through the projects sponsoring the study, so some degree of over-estimation is likely in these cases. The nature of ‘adoption’ is rarely specified, so it is often unclear what proportion of an adopter’s field is planted to MVs; the area in MVs is also reported when available. The yield advantage of the MVs is recorded in the tables only when it is reported in the study, and as explained in Section 4 such estimates may be of limited relevance in some cases of legume MV uptake.

4. Possible Impact Pathways

4.1 Types of impact
In trying to delineate distinct hypotheses related to the impact of legume technology (‘impact pathways’) it is useful to consider both the type of technology being examined and the breadth and nature of its effects.

With respect to technology type, we have already seen that most of the likely current candidates are based on new germplasm, although there are often important crop
management implications. Byerlee (1994) used the distinction between Type A variety change, when MVs replace older or traditional varieties (typical of the Green Revolution for rice and wheat); and Type B changes where further generations of MVs are adopted as part of a more conventional variety improvement and delivery system. This division is useful and has been employed by a number of other authors, but it has some limitations. There can be some confusion between chronology and size of impact (earlier introductions of MVs are not necessarily the ones that have the largest effect). Perhaps more important, impacts may derive not only from the fact that an MV is high-yielding but also from its ability to change production patterns (e.g. double cropping or other types of intensification). Thus the following discussion will not attempt any strict classification of the legume technology but will instead focus on a range of relatively recent varietal introductions, some of which also have important crop management consequences.

With respect to the nature of impact, there are many possibilities for classification (Maredia, 2009). Walker et al (2008) usefully distinguish between Stage 1 and Stage 2 for ex-post impact assessment. Stage 1 is concerned with the economic returns for a given technology, focusing on the impact on adopters, while Stage 2 extends to broader ‘community-level’ impacts that may include parameters such as consumer prices, market efficiency, or environmental externalities. The two stages are perhaps best seen as a continuum rather than separated by an unambiguous dividing line; the scope, depth and time-scale of an intervention do not necessarily offer opportunities for a simple bipartite division. In addition, there is the question of whether broader ‘multi-dimensional’ impacts can be legitimately assessed in cases where they were not part of the technology planning process.

The following discussion will begin by examining the role of new legume varieties in bringing about changes in crop production and income. It then examines the often important crop management changes associated with legume variety introduction. The rest of the section looks at broader impacts, including effects on poverty, market development, soil quality, other environmental factors, and human nutrition.

### 4.2 Crop production

Probably the most obvious cases of impact from agricultural technology are those instances where a more productive variety replaces an older one. The process for legumes is subject to varying histories. In India and several other Asian countries there is a long history of public plant breeding. In parts of southern Africa there are instances of well-established but quite old groundnut MVs from public research (particularly from South Africa) (Bantilan et al, 2003), while most lentil variety development is fairly recent (Aw-Hassan and Shideed, 2003).

Although variety replacement is relatively easy to measure, assessing the precise nature of a new variety’s superiority and impact is not necessarily straightforward. In some cases the variety may simply be more efficient and higher yielding than the one it replaces. The groundnut variety released as CG 7 in Malawi and MGV 4 in Zambia is significantly higher yielding than its competitors although it is no less susceptible to the major groundnut diseases (ICRISAT, 1994). But there are often other factors that must be
examined in assessing yield advantage. In the case of legumes some of the more important factors are disease or insect resistance, consumer qualities, and the range of variety use. In addition, crop management changes associated with new varieties may be important (and are discussed in section 4.4).

Biotic stresses are among the most important yield constraints for many legume species and are often the major justification for variety change. MVs are generally selected for their resistance or tolerance to disease and this factor is at times crucial to variety uptake. Development of resistance to bean golden mosaic virus (BGMV) was responsible for much of early success in bean breeding in Latin America (Johnson et al 2003); resistance to the root rots that were causing devastating yield losses in western Kenya encouraged farmers to adopt new bean MVs (CIAT, 2004); partial resistance to rosette virus encouraged adoption of groundnut MVs in Uganda (Moyo et al, 2007); several diseases caused chickpea production to plummet in Nepal and led to an integrated crop management effort (Pande et al, 2005); disease resistance was a major key to the success of lentil MVs in Bangladesh (Sarker et al, 2004); developing resistance to ascochyta blight was one of the key factors in promoting winter chickpea in a number of countries (Singh et al, 1997). If a disease is endemic and prevalent, the MV’s yield advantage over a susceptible variety can be estimated with some confidence, but if disease incidence is sporadic or seasonal the estimation of yield advantage is more complex. In Honduras, there was significant uptake of BGYMV-resistant MVs although they showed a yield advantage only in one of the two major bean seasons (Mather et al 2003).

There are also examples where legume breeding has addressed abiotic stress such as drought. A recently released chickpea variety with drought tolerance (Kusumenglou et al, 2006) has been reported to have withstood a serious drought in Turkey (SeedQuest, 2007). A recently released bean variety in Nicaragua is being promoted on the basis of its drought tolerance (S. Beebe, personal communication).

Home consumption and market preferences are often important determinants of MV acceptance. The disease-resistant bean varieties introduced in Honduras were of a size and colour that resulted in a 10-15% price discount, and hence farmers faced a yield-price trade-off (Mather et al 2003). Beans are particularly challenging in this regard (David, 1997; Mooney, 2007) and variety preferences may vary within a limited geographical area. Some haricot bean MVs achieved limited acceptance in Ethiopia because they were not the preferred colour (Negash, 2007). Cowpea preferences vary across West Africa (Langyintuo et al, 2003).

Because legumes are often not the major crop in a farming system, they may be managed in a variety of ways (intercrops, rotations, relay crops, etc) that mean farmers may be looking for various qualities in MVs and thus a range of variety types needs to be considered. This is the case for lentil in Bangladesh, for instance (Sarker et al, 2004). In Rwanda farmers plant a range of bean types, partly as a risk aversion strategy in the face of a range of biotic and abiotic stress and partly for different consumption goals (Sperling et al, 1993). The fact that legumes may be managed in various ways, including a
significant degree of intercropping, adds to the challenges of estimating the yield advantage of an MV.

Another important factor in estimating the yield advantage of a legume MV is the multiple uses for which a legume may be grown. Not only may legumes be harvested and consumed as dry grain or immature pods, but the leaves of several legume species are important vegetables. In Kenya, early maturing pigeonpea varieties are mostly grown as vegetables, while late-maturing types are for dry grain use (Shiferaw et al, 2008). Several legumes are also important sources of oil and other industrial products.

In addition, legume haulms are often used as fodder, and crop management for a new MV may be conditioned by the relative importance of food and feed in the farming system. Some of the semi-erect cowpea varieties that have achieved widespread adoption in Nigeria are an example of such a dual-purpose crop (Kristjanson et al, 2005). Stalks are an important by-product of pigeonpea production and are used as fuel.

### 4.3 Income

The assessment of income changes due to increased legume production needs to take account of the multiple uses for the crop. It is important to understand the destination of production when assessing impact. In some cases a legume may be almost completely a cash crop, such as pigeonpea in northern Tanzania, where an insignificant fraction of the harvest is retained for household consumption (Shiferaw et al, 2007). In other instances there is more of an even division between home use and market sale; slightly over half of pigeonpea production in Kenya goes to home consumption (Shiferaw et al, 2008) while cowpea farmers in northern Nigeria sell about 60% of their production (Lowenberg-DeBoer and Ibro, 2008). In other cases a legume is an essential element in the farm family’s food basket; chickpea farmers in Ethiopia and bean farmers in Rwanda sell less than one-third of their output (Asfaw et al 2010a, CIAT, 2008a). In the latter cases the marketed proportion may of course vary significantly among different classes of farm households in the same production system.

If one is seeking the economic value of the increased production market prices can be used regardless of end use, but it is important to remember that in many cases legume prices differ significantly by variety (e.g. CIAT, 2007). Thus market prices may not tell the whole story in cases where the increased production is particularly important for household food consumption, and it may be that some measure of increases in available calories and protein, for instance, may be appropriate.

Even in cases where home consumption of grain (or other products) may be valued at market prices, an impact assessment may also need to make appropriate assumptions about the elasticity of demand and its effect on the price of the increased supply. There may be cases of production increase of a sufficient magnitude to examine consumer price effects, although it would be important to identify the appropriate counterfactual.

Farmers’ income gains from a new technology must of course include assessment of any changes in production costs. Even if a variety is simply more responsive, there may be
incentives for using additional inputs. Disease- or pest-resistant varieties may allow savings in pesticides (where they were employed before). On the other hand, some legume MVs may require additional insecticide, as is the case for the determinate varieties of cowpea in West Africa (Abatania et al, n.d.; Kristjanson, 2005) and early-maturing pigeonpea in East Africa (Jones et al, 2002), or the susceptibility of chickpea to pod borer when it is grown in warmer, non-traditional areas of India (Gowda et al 2009). Other management changes may also need to be considered, such as the differences between spreading and erect groundnut varieties for weeding and harvesting labour.

4.4 New cropping systems
The preceding discussion assumed the case of a MV simply replacing an older variety under more or less the same management regime. Changes in input and labour use are commonly found in the adoption of MVs for many crops but there are a number of important instances of legume MVs that are associated with more radical changes in cropping systems that need to be accounted for in assessing technology impact. The importance of such cases may be partly due to the fact that legumes are often accommodated in various niches in farming systems and hence elicit a very broad range of management practices.

Most of the legume species we are examining have expanded significantly from their centres of origin, but there are relatively few contemporary cases of the introduction of a new species as a result of a plant breeding programme. Probably the most important example is soybean and the rapid growth of that crop in Nigeria the 1990s is well documented (Sanginga et al, 1999). There are attempts to emulate this success in other parts of Africa (Chianu et al, 2008a, b), but there are relatively few other examples of widespread adoption of new species. Pigeonpea production has increased in some parts of Eastern Africa, mostly as an export crop (Jones et al, 2002). Smartt (1990) discusses the problem of matching new legume species of high biological potential to consumer preferences in Africa.

But some of the most important examples of the uptake of legume MVs are associated with significant changes in production systems.

- In northern Nigeria, the availability of medium-maturity cowpea MVs has brought significant cropping system changes to a region that has traditionally planted (as intercrops with cereals) short-maturing cowpea varieties for food and late-maturing varieties principally for fodder (Mortimore et al, 1997). The MVs have been planted after the main cropping season on residual moisture as a dual-purpose crop (Kristjanson et al, 2002) and as part of intensively managed strip-intercrops with cereals (Ajeigbe at al, 2010; Alene and Manyong, 2007).

- Climbing beans have become increasingly important in Rwanda (Sperling and Muyaneza, 1995) where they offer significantly higher yields than bush beans (in part by escaping some of the moisture problems that cause disease) and provide a way of taking advantage of vertical space on very small farms. But they require more intensive management, the provision of poles, and better soil fertility.
Although this is not a new cropping system (many farmers had previous experience with climbers), it has expanded in a way that surely requires some examination of the management correlates.

- There are several examples of significant change in chickpea technology in India, as the crop shifts away from its traditional production areas in the north of the country (Gowda et al 2009). The availability of earlier-maturity, wilt-resistant MVs has allowed the crop to be grown in warmer climates with shorter growing seasons. Chickpea production has increased significantly in Madhya Pradesh, often grown on previously fallow land, and as a relatively new crop in Andhra Pradesh, where it may replace cotton, tobacco or other crops.

- The development of blight-resistant, cold-tolerant chickpea MVs has allowed a significant expansion of winter-sown chickpea in Syria (Mazid et al, 2009; Singh et al, 1997). Farmers have adopted the new varieties specifically for winter sowing and tend to follow somewhat different sowing and plant protection practices than they use in spring-sown chickpea.

The analysis of the impact of MV adoption associated with significant cropping system changes presents additional challenges in establishing counterfactuals, but these cases may offer some of the most outstanding potential examples of recent impact.

4.5 Other management changes

As discussed earlier, this analysis of potential cases of legume impact focuses almost entirely on germplasm introduction (and often the accompanying crop management change). This is not because other aspects of legume management have not received attention from researchers but because it is difficult to find examples of management change that cover a significant area or number of farmers.

One of the major examples is cowpea storage. Cowpeas are particularly subject to post-harvest loss due to bruchid damage (Murdock et al, 1997). Various crop storage techniques have been tested and promoted. Major success appears to have been achieved in Senegal with the introduction of ‘triple bag storage’, using several layers of thick plastic bags (Boys et al 2007). The method is currently being promoted in other West African countries (Moussa et al, 2009).

Insect control for legumes has been the subject of various IPM efforts, but the extent of uptake has so far been modest. Examples of legume IPM programmes include those for cowpea in Benin (Nathaniels, 2005), groundnut and cowpea in Uganda (Bonabana-Wabbi, 2002), pigeonpea in India (Tripp and Ali, 2001), chickpea in Nepal (Pande et al, 2005) and common beans in Nicaragua (Labarta and Swinton, 2005).

There have also been crop management efforts for disease control in chickpea in Bangladesh (Johansen et al, 2008) and weed control in legumes in WANA (Abang et al, 2007)
4.6 Poverty reduction and equity

When we turn to consider broader impacts of agricultural technology uptake probably the most important task is to examine opportunities for assessing impact on poverty and the equity of the distribution of benefits. Measures of poverty can be complex (Maredia, 2009) and are not examined here, but presumably most major examples of legume technology uptake that are the subject of an impact analysis assessing changes in production and income could include some examination of the poverty reduction or equity implications of the technology change. Alwang and Siegel (2003) provide a proposed methodology for assessing the poverty impact of agricultural technology that uses data from Malawi and show that increases in groundnut production would favour wealthier households. Moyo et al (2007) do an ex-post impact assessment for groundnut in Uganda showing a positive impact on poverty indicators, and a study using adoption from Uganda comes to positive conclusions regarding poverty impact (Kassie et al, 2010). Johnson and Klass (1999) estimated the poverty impact of bean MVs in Honduras using GIS data. Other instances where legume uptake has been examined with respect to poverty impact include a study relating households’ assessment of food security to cowpea technology adoption in northern Nigeria (Alene and Manyong, 2006a), a study relating food security and nutritional status to soybean uptake in Benue State, Nigeria (Sanginga et al, 1999) and a preliminary examination of the relation between poverty status and the use of faba bean technology in Sudan, Ethiopia and Egypt (Amegbeto et al, 2008).

Gender-related issues are particularly important, especially given the fact that many legume crops are women’s responsibility. Women’s priorities for variety characteristics may or may not be addressed in plant breeding programmes (Ashby et al, 1987) and the results will be reflected in the gender equity of the subsequent variety adoption. Changes in crop management may have considerable consequences for women. An examination of adoption of climbing bean MVs in Rwanda showed that women-headed households were as likely to adopt as male-headed households and that adopters were more likely to be on smaller farms and among poorer households (Sperling and Muyaneza, 1995). Tipilda et al (2008) looked at the effect of cowpea MVs in northern Nigeria and concluded that some of the extra income was passed to women, and that some of the extra yield contributed to women’s ability to produce and market bean cakes and other cowpea preparations. In some areas of southern Mali, groundnuts are women’s most important source of income (Diallo, 2009).

The discussion above on income effects mentioned the possibility, in selected cases, of looking at the impact on consumer prices and its effect on poorer households. The importance of this factor would depend on the extent to which legumes are an important item in the food baskets of non-producing or net-purchasing households.

4.7 Market changes

There may be cases where increased legume production has contributed to market development. Whether increased trade is a cause or consequence of increased production would need to be examined, but there are instances where the behaviour of these markets should be included in an impact assessment. Increased market demand is credited with
stimulating the growth in lentil yield and area in Nepal (Neupane et al, n.d.). There is considerable effort at promoting the domestic cowpea market in Nigeria, including the development of new commercial food enterprises (Lowenberg-DeBoer and Ibro, 2008). Examples of important legume export markets include the export of pigeonpea and chickpea from Africa to India (Jones et al, 2002; Simtowe et al, n.d.), haricot bean export from Ethiopia (Ferris and Kaganzi, 2008), and regional West African cowpea trade (Langyintuo, 2003).

4.8 Soil quality contributions
A distinguishing feature of legumes is their ability to fix atmospheric nitrogen through symbiosis with otherwise free-living soil bacteria (rhizobia). A large proportion of the plant’s nitrogen needs are provided in this way, although the exact amount depends on environmental factors and species; for instance common beans are particularly deficient and may only fix half of their nitrogen requirement (Smartt, 1990). Whatever nitrogen is fixed represents a ‘saving’ from externally provided nutrient sources (Graham and Vance, 2003), but such savings are not necessarily the basis for impact assessment.

The contribution of a legume to soil fertility depends on the species and on crop management. Although there have been some studies that propose the transfer of fixed nitrogen to intercropped cereals, the evidence is thin (Giller, 2001). Most of the nitrogen contribution of a legume will derive from the amount of plant matter returned to the system, including roots and nodules, incorporation of crop residues, and the recycling of nutrients by grazing animals or insects (ibid). The precise contributions are obviously difficult to measure but there has been a great deal of experimental work (ibid); some relevant reviews include those for cowpea (Carsky, 2002) and pigeonpea (Rao, 1990). The key to assessing residual effects is the balance between the nitrogen harvested in grain (and other plant parts removed from the system) and that left behind. Species such as soybeans or short-season varieties of cowpea or common bean may remove more nitrogen than they provide to the soil (Giller, 2001; Smartt, 1990). The impact of a higher-yielding legume MV on soil nitrogen status will thus depend on its harvest index and the farmer’s crop residue management and these are subject to various trade-offs. In the case of pigeonpea in Africa, for instance, the best prospects for soil fertility contributions come from long-season, indeterminate varieties, while farmers often favour faster-maturing and higher (grain) yielding varieties (Freeman and Coe, 2002). Other work has examined the various economic and crop management factors that condition farmers’ possible use of legumes in rotations or intercrops (Kamanga et al, 2009; Snapp et al, 2002).

Another factor related to assessing the possible impact of a legume is the cost of the nitrogen fixation, which is an energy-intensive process (Leigh, 2004), although the assimilation of externally applied nitrate also requires considerable energy (Giller, 2001; Stoskopf, 1991). Such energy costs contribute to low yields for legumes compared to cereals, although it must be remembered that legumes have much higher protein (and often lipid) content than cereals, requiring extra energy for synthesis (Smartt, 1990). It must also be remembered that although the legume may provide most of its nitrogen needs and can make some of the nitrogen available for the succeeding crop, an
unfertilized legume crop may remove other nutrients or compete with intercrops (Kimaro et al, 2009).

So while the nitrogen fixation of legumes makes a valuable contribution to cropping systems, the extent to which changes in legume germplasm or management would imply a significant positive impact on soil quality depends on various factors and assumptions. The simple substitution of a new (e.g. higher yielding or disease resistant) variety would be fairly unlikely to qualify. If there are significant management changes (new intercrops, rotations, etc) then there is more possibility of finding a soil-related impact. The case for seeking impact is greatest where legumes are specifically introduced to a system to improve soil quality (Mekuria and Waddington, 2002; Ojiem, 2006).

The introduction of legumes to a cropping system may of course make other contributions to soil quality, such as controlling erosion, reducing water or nutrient loss, and increasing access to nutrients such as P from deep soil horizons (Giller, 2001; Shapiro and Sanders, 2002; Adu-Gyamfi et al, 2007). Legume rotations may also play an important role in weed control (DeGroote et al, 2010). But the measurement of such impacts related to technology change is most defensible when there has been conscious design and introduction of the new cropping patterns.

4.9 Other environmental factors
There are other instances of potential environmental impact from changes in legume technology. These include pesticide management and the fuel wood and related demands of legumes.

We have already discussed that new disease- or pest-resistant legume varieties may save on the use of pesticides while some legume MVs may imply additional pesticide (e.g. when a determinate variety replaces an indeterminate one). In cases where a legume is a new introduction (as with chickpea in southern India), the pesticide balance depends on which crops it replaces (e.g. chilli or sorghum in this case).

Many legumes require considerable cooking time, which has significant implications for fuel wood demands. The importance of this factor varies among species; lentil, for instance, is valued partly because of its relatively short cooking time (Aw-Hassan and Shideed, 2003). Cooking time is indeed one of the important factors that farmers consider in choosing new varieties, although there is not much documentation on the introduction of MVs specifically for firewood saving. One of the important constraints to the spread of climbing beans, which are generally much more productive than bush beans, is the requirement for staking material and the potential environmental consequences.

4.10 Human nutrition
Legumes are widely recognized for their contribution to human diets. The assessment of protein quality is fraught with difficulties, and while it has been recognized that the lysine deficiency of most cereal proteins is usefully balanced by legume protein (itself deficient in sulphur-containing amino acids), legume protein has often been considered of relatively low quality. But recent revisions in protein quality measures have seen legume
protein achieve a higher rating (Messina, 1999). Legumes are also a good source of fibre and some other nutrients; legumes are important sources of zinc and (sometimes) calcium, but relatively poor sources of iron. One exception is mungbean, and a study estimates the nutritional impact of the widespread adoption of mungbean MVs, which have a higher iron content than local varieties, in Pakistan (Weinberger, 2005). The presence of oilgosaccharides in many legumes can lead to some digestibility problems and in some cases there are anti-nutritional factors that may be important (Messina, 1999).

While the focus is on the protein in legume grain, it is well to remember that some legumes may be eaten green or provide leaf protein. In some cases the leaves may make a nutritional contribution that rivals that of the grain; it has been estimated that cowpea leaf production may contribute up to 15 times more protein than the grain from the same field (Bittenbender et al., 1984). The exact balance of the contribution in this case would depend on how the leaves are harvested (excessive leaf harvest will affect grain yield) and dietary customs (e.g. cowpea leaves are a more important part of the diet in northern Ghana than in northern Nigeria). The timing of legume’s contribution to the diet is also important. For instance, cowpeas and leaves may fill the hunger gap before cereal harvest in West Africa.

Similar to the case of legumes’ impact on soil nitrogen, the significant contribution of legumes to dietary protein does not necessarily imply opportunities for assessing the nutritional impact of changes in legume technology. An increase in legume production may or may not find its way into the producers’ diets. If it does, then overall dietary changes during the intervention period would need to be assessed. The best opportunities would seem to be in situations where legumes are an important part of the diet, or a new legume (such as soybean) has been introduced. A fairly complete analysis of cropping and consumption trends would be required. In a contrary example, the Green Revolution in northern India saw farmers shift away from growing legumes and there was considerable concern about dietary implications, but Ryan and Asokan (1977) show that there was a net gain in both dietary calories and protein. Ideally, the demonstration of nutritional impact of a crop variety intervention should be part of a research programme in which nutrition was explicitly addressed (e.g. Low et al., 2007).

Another opportunity for examining the nutritional implications of changes in legume technology is where the shift brings higher income from legume crop sales, assuming the legume component of income could be clearly identified. Demonstrating relationships between diet or nutritional status and relatively modest changes in income is often challenging and must take account of household characteristics as well (Kennedy and Peters, 1992) so any candidate cases would need to be carefully screened. There may also be cases where significant increase in legume production has affected the prices paid by poorer consumers who may be more dependent on legumes as a protein source.

4.11 Summary
Box 1 presents a summary of the factors that have been discussed in this section. The factors are in only a rough sequence of feasible assessment and complexity of analysis.
Box 1. Summary of Potential Impacts of Introduction of New Legume Variety

Yield and yield stability (simple variety substitution)

Assessment may need to account for:
- Cases where multiple varieties, uses, cropping patterns
- Cases where yield advantage (e.g. from disease resistance) may vary by season, year
- Uses of the harvest (grain, vegetable, fodder, etc)

Income
- Income from occasional sale of excess production or as cash crop
- Home-consumed product may be valued at market price, but often considerable variation by variety (grain, vegetable, fodder)
- For fodder value additional animal products may be considered
- Varieties of higher grain quality may increase income
- Even simple variety substitution may imply changes in crop management costs (labour, pesticides, etc)

Changes related to significant modification in crop management
- Requires a more complete assessment of alternative cropping systems for yield, income
- May imply major changes in labour, input use
- May require analysis of use of previously fallow land, a replacement in a rotation, or entirely new rotation

Poverty status

Various parameters might be considered, including:
- Measures of household poverty
- Distribution of benefits by wealth or social class
- Distribution of benefits by gender (within or between households)
- Consumer price changes

Agricultural markets

Relation of increased legume supply to:
- Domestic markets
- Export markets
- Food processing industry

Environment
- Soil quality (various parameters) may be affected by increased legume production or (more likely) introduction of a legume to a crop system
- New legume varieties or systems may increase or decrease pesticide use
- Other potential impacts (e.g. fuel wood, staking material)

Human nutrition

Direct consumption effects may include estimation or measurement of differences in:
- Supply of protein (and perhaps other nutrients)
- Dietary consumption
- Nutritional status

Indirect effects (related to increased income):
- Impact of additional income on household food supply, diet, nutrition
The importance of any of these factors will depend on the particular case and the nature of the cropping system, consumption and marketing changes entailed.

Given that there are relatively few impact assessments of legume technology, and legumes are rarely the dominant component in a cropping system, it is possible to argue that initial emphasis should be given to the basic production and income impacts of legume technology. There may, however, be particular cases where there are opportunities to examine broader impacts, but the primary impacts would still need to be carefully measured. Assessment of many of the broader impacts would require fairly clever specification and estimation of counterfactuals, even when there might be clear ‘adopter’ and ‘non-adopter’ populations available.

Another factor related to the breadth of impact assessed is the extent to which the outcomes being measured were contemplated in the original research programme. While it is legitimate to consider unintended consequences of a research programme, when impact assessment is related to the accountability of the research enterprise it is best to concentrate on telling a coherent story of planned technological change. The choice of factors should of course be related to the interests of the audience and hence the evaluator’s knowledge of the ‘impact of impact studies’. But the choice of documenting unintended consequences should probably concentrate on the examples where lessons can be learned to guide future technology development, rather than on presenting some serendipitous, unplanned outcome as an example of impact.

5. Possible cases for impact assessment

The information presented in this report only provides some preliminary ideas for the organization of a stripe review on legume impact. Such a review will need to take as broad a view as possible, assessing major trends in legume technology change; but it may have to be bolstered by some original research on uptake and impact in specific localities. These latter cases may be at a regional, national, or sub-national level, depending on the resources available, the possibilities of confidently sampling from wider trends, and the value of illustrative case material. Detailed decisions would have to be taken in consultation with the appropriate Centre and national researchers.

Given the significant resource implications for any extensive impact assessment, it is very important that the review be planned in conjunction with the various legume-related projects that are also interested in developing uptake and impact data. DIIVA, for instance, will be organizing data collection of great value in Africa. For legumes in a number of countries it will be seeking expert opinion on the uptake of MVs; such data may provide further guidance on deciding which countries or crops might offer appropriate case studies and, on the other hand, it may be that a stripe review study could help to ground-truth such analyses. In a smaller number of cases, DIIVA will support country-level farm surveys that will assess farmer variety use, and the prospects for using such data (or even contributing to the questions asked on the survey) for impact assessment are obvious. It appears that there will only be one case of a DIIVA-sponsored
impact assessment on legumes (beans in Rwanda and Uganda), and the stripe review would of course want to pay close attention to this. There may be similar opportunities for South Asia with TRIVSA, but plans are less far along in that project. Several other legume projects at least expect uptake data to be developed on the technologies they sponsor and collaborative efforts with a stripe review may be feasible in some cases.

The following discussion is organized by legume species (although in some cases assessments of several legumes in the same environment may be appropriate). Most of the examples were developed in correspondence with Centre staff but their inclusion here does not signify any kind of official endorsement. Given the very modest amount of data currently available on legume impact, and considering the challenges of measuring some of the broader outcomes sometimes attributed to legume production, it is probably best to concentrate most effort on the more basic impact parameters related to production, income and the distribution of that income (i.e. the top rather than the bottom of Box 1).

The choice of research areas and specific cases for a stripe review on legume technology impact will have to pay attention to a number of themes, including:

- **The spread of new varieties.** There are many cases where MVs are either replacing traditional varieties or older MVs in existing production systems. In some cases the new MVs owe their superiority to a combination of factors, while in other cases they represent the outcome of research aimed specifically at a particular biotic threat that had severely reduced legume production.

- **Crop management changes.** Because legumes are often accommodated in niches in the principal staple production systems, new legume technology may lead to significant crop management modification. In most of the cases reviewed, such change is led by the introduction of a new variety rather than by crop management research, but there may well be significant instances of the latter. Assessing the impact of such change is both important and challenging, and it would need to assign appropriate credit for innovation to research, extension and farmers.

- **Subsistence production.** In a number of farming systems legumes are an indispensable item in subsistence production and the description of major instances of technology change in these cases is important.

- **Legume cash crops.** There are several cases where market demand (domestic or export) has contributed to the movement of new legume technology, and representatives of these cases should be described.

- **Delivery mechanisms.** Given the exceptional challenges in delivering seed of legume varieties, an impact assessment should at least keep its eye on cases of successful, cost-effective legume seed provision.

### 5.1 Common beans
Annex Table 1a indicates that there has been significant progress made in the diffusion of bean MVs since the mid-1990s in a number of countries in sub-Saharan Africa. Given the high levels of poverty and dependence on beans in Rwanda, technological progress there would be an important example of impact, and it is appropriate that DIIVA is supporting a full impact assessment in Rwanda (and in Uganda). A stripe review should take account
of the results of that analysis, but there is probably not much additional to be done on that case.

The data in Table 1a show quite high adoption rates for other countries (Kenya, Tanzania, DR Congo, and especially Malawi), but these figures come from summary documents and the nature of the surveys that provided this data is not clear. Given that DIIVA will support expert surveys on variety uptake in all of these countries, it might be best to wait for those results before deciding whether one or more of these countries deserves particular attention for impact assessment.

One possible case of interest is beans in Western Kenya. In the late 1980s bean production in Kenya began to decline because of the spread of root rot. Many farmers abandoned planting beans. By the mid-1990s five varieties each of bush and climbing beans resistant to root rot had been developed and introduced (Odendo et al, 2005). Beans are grown as a sole crop and intercropped with maize. The major change was simply the substitution of disease-resistant MVs. Estimates for levels of adoption range from 35-80% in one summary (CIAT, 2004) to 76-100% in another paper (Kalyebara et al, 2008). The area is apparently confined to Vihiga and Kakamega districts in Western Kenya (W. Kenya comprises several other districts and grows about 125,000 ha of beans). Although the area is relatively small, it is an example of efficient research response to a particular threat. A broader look at beans in Kenya (over 900,000 ha) might also be possible.

Another very specific case that may deserve more attention is the uptake of white beans in Ethiopia for export markets. If there were a significant interaction between new varieties and market growth (and data to confirm this are not immediately available) then it would be an interesting case in a country that is struggling to support market-oriented agriculture (Ferris and Kaganzi, 2008).

In various African bean cases, impact assessment could look at the relative effectiveness of seed provision mechanisms for new varieties, a subject that CIAT has thought about quite carefully (Rubyogo et al, 2010).

Annex Table 1b also shows progress for bean varieties in parts of Latin America. The Pulse CRSP is currently planning to do expert surveys for a number of countries in LAC to update MV adoption data and as a basis for some impact assessments. Communication between the stripe review and CRSP could provide useful synergy for describing the impact of bean research in the region. It would appear that much of the progress in Central America is the steady replacement of older MVs by more recent ones.

The instance that is best described is Honduras, which grows approximately 100,000 ha of beans. All of Central America was subject to the spread of Bean Golden Mosaic Virus (BGMV) in the 1970s, seriously affecting yields. New BGMV-resistant varieties were developed and introduced by CIAT, which won the King Badouin Prize for this work in 1984. Studies in the early 1990s indicated increasing adoption rates. An impact study was done in 2001 (Mather et al, 2003). Since that time newer varieties have been released and promoted and there is evidence of widespread adoption of some of these (B. Reyes,
Further analysis would be needed to identify the yield advantages of the new generation of MVs and to decide how to estimate this. It is not known if the market price discount of MVs over traditional varieties has been overcome. The Mather (2003) study reports that a little over half of bean production is marketed. (In the early 2000s Honduras was essentially self-sufficient in beans and exported some to its neighbours). There is a large government programme that subsidizes the distribution of MV bean seed and the costs (and benefits) of this could be included in an impact study.

5.2 Cowpea
Cowpea is largely an African crop and 85% of Africa’s cowpea area is found in Nigeria and Niger. The annual production of those two countries is over 2 million mt (Langyintuo et al, 2003). IITA has been involved in developing and promoting new cowpea varieties with various traits (Singh et al, 2002); erect and semi-erect varieties of medium and early maturity, some of which are dual purpose (food-feed), seem to be the most important. The only evidence available on significant adoption (Table 2) comes from Nigeria, and given that this is the leading producer it would make sense that an impact assessment should concentrate here (and perhaps across the border in southern Niger). (There are also instances in West Africa where cowpea is not a traditional crop but cowpea MVs have been taken up as a cash crop; no recent adoption data were available.)

A recent, informal analysis estimates that 38% of the cowpea in Nigeria is MVs (Alene, personal communication). Despite a number of adoption studies, there has been no concerted effort at estimating the impact of cowpea MVs in this region. A precise inventory of the most important cowpea varieties for northern Nigeria and southern Niger is not immediately available. There has been a ‘pipeline’ of new varieties, although apparently some of the MVs promoted since the mid-1990s have only been officially released in Nigeria in the past few years.

In many cases the new varieties imply changes in management. In some areas there has been significant promotion of MV use as part of intensive strip intercropping with cereals (with variations in the details of intercropping by agro-climatic zone), although this is apparently not relevant in other areas, where relay cropping is practiced. Some of the varieties are also promoted for dry-season cultivation. There is a tendency for higher insecticide use on the MVs and many farmers have to contract people to do the spraying.

Cowpea is important both as a cash crop and for home consumption, so impact assessment might include market parameters or an examination of the growth of cowpea markets. Northern Nigeria has been the focus of most of the studies, but southern Niger is also important and exports a large amount of cowpea to Nigeria and other countries. Studies have shown MV uptake negatively correlated with distance from markets (Alene and Manyong, 2006a; Kristjanson et al, 2005). There has been one study correlating self-assessed household food security with MV uptake (Alene and Manyong, 2006a) but the exact contributions (consumption vs income) are not specified. Fodder use should be considered as a parameter, but needs further clarification.
IITA will try to estimate the use of MVs in Nigeria and Niger under DIIVA (using expert interviews) and the Pulse CRSP is also interested in this type of assessment. There might be possibilities to attract support for a more comprehensive study from other cowpea projects, including Tropical Legumes 2, PRONAF, and the Gatsby Charitable Foundation (which has been promoting the technology in northern Nigeria and southern Niger).

5.3 Groundnut
Annex Table 3 does not show a large amount of data on which to base decisions for impact assessment of groundnut. For East Africa, Uganda shows a significant increase in MV use and the adoption data was used as the basis for an impact study (Kassie et al, 2010). In Southern Africa there has been considerable effort at promoting groundnut MVs, but no recent uptake data was available for this paper. In West Africa, preliminary discussion with ICRISAT staff indicated that Mali might be a particularly interesting example. Groundnut is an important cash crop in Mali and in some areas is women’s most important income source (Diallo, 2009). New varieties have been tested and promoted, including some seed production and distribution activities. It is also important to note that there will be a farm-level groundnut MV adoption study carried out in Mali under DIIVA. A farm-level survey in Tanzania on several crops for DIVA will include groundnut.

Groundnut is also an important crop in certain parts of south Asia. Table 3 indicates that there were a number of adoption studies done in the 1990s, but little recent information is immediately available. An ICRISAT paper on groundnut in India (Deb et al, 2005) does not seem to go far beyond the earlier data. The ICRISAT website gives a brief summary of progress in groundnut in Asia, but little specific detail. Recent baseline studies for the Tropical Legumes 2 project in Karnataka and Tamil Nadu indicate that older groundnut varieties still predominate (Lokesha et al, n.d.; Karunakaran and Bantilan, n.d.). ILRI is currently conducting an impact study on dual purpose groundnut in southern India (N. Teufel, personal communication).

5.4 Pigeonpea
Pigeonpea is traditionally important in Asia (which grows nearly 90% of the crop), but there are also several important instances of pigeonpea cultivation in Eastern and Southern Africa (which accounts for most of the rest of world area).

The adoption studies for pigeonpea (Table 4) are all from Africa. The adoption data do not show particularly high rates of MV uptake (there is a considerable gap between the two figures provided for Kenya), but ICRISAT will be estimating pigeonpea MV use in Kenya, Malawi and Tanzania for DIIVA. Based on that assessment, further decisions can be made about the feasibility of looking further at impact.

If it appears that there is significant technology uptake, the cash crop aspect in SSA may deserve specific attention. Pigeonpea is valued for home consumption in many of these African cases, but perhaps a more interesting focus is the interaction with commercial markets. A very specific case that might be interesting is northern Tanzania. In Babati District farmers rank pigeonpea as their most important cash crop. Tanzania exports
pigeonpea to India and there has recently been considerable activity to supply a European
export market (R. Jones, personal communication). Tanzania has also exported across the
border to Kenya, which may be more important under the new East African Community.
The major MVs in Tanzania are indeterminate, long-duration varieties (similar to local
varieties) that are resistant to fusarium wilt. They have been introduced and promoted
under various projects and do not imply any significant modification in crop
management. ICRISAT will do a farm-level survey under DIIVA to estimate pigeonpea
MV use in Tanzania (also chickpea, groundnut and sorghum). Economic impact in
northern Tanzania was estimated about 7 years ago (Shiferaw et al, 2007; 2008a).

For Asia, it would probably be best to focus on India, which produces more than 80% of
Asia’s pigeonpea. It was not possible to locate any recent adoption studies on pigeonpea
MV in India, although there had been earlier success in short-cycle pigeonpea (Bantilan
and Parthasarathy, 1999) and recent innovations such as very short-duration varieties and
the development of hybrid pigeonpea.

5.5 Chickpea
An obvious focus for looking at chickpea impact would be India, which accounts for
nearly two-thirds of the world’s production (5.65 million mt) and imports an additional
0.23 million mt. Two-thirds of it is produced under rainfed conditions. In the past several
decades there has been a significant shift in production from the northern states to central
and southern semi-arid tropic regions. Between 1985 and 2004 chickpea area, production
and yield grew at annual rates of 2.13%, 3.94% and 1.77%, respectively in central and
southern India (Gowda et al, 2009). Much of this shift has been made possible by the
availability of wilt-resistant, earlier- maturing varieties. The increased cultivation of
chickpea has occasioned significant modifications in some cropping systems.

There are a number of MVs (of different grain types and maturities) available for
southern India although a variety released in 1999 seems to maintain dominance
(Parthasarathy Rao, personal communication). Data on current chickpea variety use in
Andhra Pradesh and Karnataka is available in baseline studies done for the Tropical
Legumes 2 project (Suhasini et al, n.d.; Kiresur et al, n.d.) although more interpretation
would be needed to capture the adoption of recent MVs. The adoption of MVs and the
expansion of chickpea area take place in the context of various cropping systems. In some
cases chickpea is planted in previously fallow land but it is also replacing other crops,
including tobacco, cotton and post-rainy season sorghum. In some areas chickpea
cultivation is entirely mechanized. It would take additional enquiry to identify the most
appropriate cropping systems and areas to investigate chickpea impact in India. There is
the possibility that TRIVSA might support an assessment of chickpea MV adoption in
India and chickpea in India is also a focus for the Tropical Legumes 2 Project.

There are several other instances that may deserve attention in considering chickpea
impact. ICARDA has helped promote winter-sown chickpea in Syria, largely through the
availability of disease-resistant, cold-tolerant varieties (Mazid et al, 2009), and the winter
sowing system is also promoted in other Mediterranean countries. Recent reports indicate
very significant uptake of a drought-tolerant chickpea variety in Turkey (SeedQuest,
2007).
Although chickpea is not a major crop in Bangladesh, it is one of half-dozen legumes that have been promoted through a well-organized extension effort demonstrating new varieties (Afzal et al. (2004); Uddin et al. (2005)). It may make sense to look at this effort across several legumes; lentil (see below) and mungbean are among the most important, but black gram, grass pea and chickpea have also been promoted.

5.6 Lentil
The major example of documented uptake of lentil MVs is Bangladesh, which grows about 150,000 ha of lentil and has traditionally imported more than half of its consumption. Lentil research developed a number of new lentil varieties and evidence from 2002 showed quite high adoption rates (60% among farmers in blocks where demonstrations were carried out). The new varieties are generally higher yielding, in part because of rust resistance and (in one case) blight resistance. Lentil is grown in the post-rainy season, about half as a sole crop and half intercropped with wheat, oilseeds or other crops. It does not appear that the MVs require any change in crop management, but they are found (and preferences among them vary) in a range of cropping systems. There is no information to date on TRIVSA activities in Bangladesh. An adoption study was carried out in 2002 (Sarker et al., 2004) and there is an impact analysis based on this data (Aw-Hassan et al., 2009). As mentioned in section 5.5, Bangladesh has actively promoted a range of legume species and might be a focus of investigation for several of these.

There may be other cases for lentil. There is a study from Ethiopia (Aw-Hassan et al., 2009) and there has been interest in using it to assess impact, but no further information is immediately available on the scope or breadth of the technological change. Lentil is the most important pulse in Nepal and yields and production have increased significantly; no statistics are available to document the contribution of new lentil technology to that change but ICARDA varieties are said to be popular (Neupane et al., n.d.).

5.7 Faba bean
Available information on the uptake of faba bean technology is limited to a brief summary of three country studies done in Egypt, Ethiopia and Sudan examining the outcome of a regional faba bean programme (Amegbeto et al., 2008). The results show quite high use of recommended varieties in Egypt and Ethiopia and generally lower adoption of some of the crop management recommendations. Further information would be required before identifying any possible cases for additional study.
Acknowledgements

It would not have been possible to write this paper without the extensive help provided by many people who are familiar with legume research. While they are not responsible for any of the conclusions or interpretations in the paper, they deserve thanks for their patience in the face of intrusive and often uninformed questioning: Hakeem Ajeigbe, Dawit Alemu, Arega Alene, Robert Andrade, Aden Aw-Hassan, Cynthia Bantilan, Steve Beebe, Boris Bravo-Ureta, David Cummins, C.L. Laxmipathi Gowda, Richard Jones, Alpha Kamara, Genti Kostandini, Mywish Maredia, Jupiter Ndjeunga, Bonny Ntare, George Norton, P. Parthasarathy Rao, Byron Reyes, Said Silim, Franklin Simtowe, Louise Sperling, Nils Teufel, Tom Walker, Tim Williams, and Jonathan Woolley. Several Centres also provided useful comments on an earlier draft of this paper.
Annex. Uptake of Legume MVs

The following tables summarize the results of recent studies documenting the uptake of legume MVs. The tables concentrate on the most recent studies available. Where possible, comparative data from earlier studies (reported in Evenson and Gollin, 2003) are provided. (*These comparative data are shown in italics.*)

### 1a. Common Beans, sub-Saharan Africa

<table>
<thead>
<tr>
<th>Location, year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethiopia</strong>, Alaba District 2005</td>
<td>160 farmers</td>
<td>~15% of bean area</td>
<td>21% (survey data)</td>
<td>Negash (2007)</td>
</tr>
<tr>
<td><strong>Kenya, Kakamega and Vihiga Districts, 2001</strong></td>
<td>383 farmers</td>
<td>35-80% (depending on location, variety)</td>
<td>81% (survey data)</td>
<td>CIAT Highlights 18 (2004); Kalyebara et al (2008)</td>
</tr>
<tr>
<td><strong>Tanzania, northwestern and northeastern, 2004</strong></td>
<td>306 farmers, 3 cropping systems</td>
<td>MVs 54% “of all farmers’ seed”</td>
<td>13% (survey data)</td>
<td>CIAT Highlights 42 (2008c); Kalyebara et al (2008)</td>
</tr>
<tr>
<td><strong>Uganda, six districts, 2003</strong></td>
<td>529 farmers</td>
<td>Average 51% (20%-80%)</td>
<td>41% (survey data)</td>
<td>CIAT Highlights 43 (2008b); Kalyebara et al (2008)</td>
</tr>
<tr>
<td><strong>Rwanda, nationwide, 2004</strong></td>
<td>383 farmers</td>
<td>94% for climbing beans (26% for bush beans)</td>
<td>10% (climbing beans) 30% (bush beans) (survey data)</td>
<td>CIAT Highlights 41 (2008a); Kalyebara et al (2008)</td>
</tr>
</tbody>
</table>
1b. Common Beans, Latin America

<table>
<thead>
<tr>
<th>Location, year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mexico,</strong> 3 states, 2001</td>
<td>455 farmer interviews and postal survey</td>
<td>71%, 42%, 8%</td>
<td></td>
<td>Gonzalez-Ramirez et al (2005)</td>
</tr>
<tr>
<td><strong>Ecuador,</strong> Imbabura and Carchi Provinces, 2006</td>
<td>132 farmers</td>
<td>For red mottled beans (which account for 80% of bean area), 45% MVs</td>
<td>40% (experimental, under disease pressure)</td>
<td>Mooney (2007)</td>
</tr>
</tbody>
</table>
## 2. Cowpea

<table>
<thead>
<tr>
<th>Location, year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria, Kano and Jigawa States, 1999</td>
<td>462 farmers in villages with known adoption</td>
<td>38% of cowpea area</td>
<td>~60% grain yield (crop models)</td>
<td>Kristjanson et al (2002, 2005)</td>
</tr>
<tr>
<td>Nigeria, Kano and Kaduna States, 2003/04</td>
<td>480 farmers</td>
<td>72% of farmers “adopters”; ~80% cowpea area in MVs</td>
<td></td>
<td>Alene and Manyong (2006 a,b; 2007); Tipilda et al, n.d.</td>
</tr>
<tr>
<td>Nigeria, Bauchi and Gombe States</td>
<td>130 farmers</td>
<td>56% of farmers plant an MV</td>
<td></td>
<td>Agwu (2004)</td>
</tr>
<tr>
<td>Nigeria, Borno State, 2007</td>
<td>150 farmers</td>
<td>40% of cowpea land in MVs</td>
<td></td>
<td>Gadbo and Amaza (2010)</td>
</tr>
<tr>
<td>Senegal, 2004</td>
<td>90 farmers, some chosen from project villages</td>
<td>&lt;4% of farmers</td>
<td></td>
<td>Boys et al (2007)</td>
</tr>
<tr>
<td>Ghana, Northern and Upper West Regions, 2007(?)</td>
<td>169 farmers from project villages</td>
<td>16% of cowpea area in MVs</td>
<td></td>
<td>Abatania et al (n.d.)</td>
</tr>
</tbody>
</table>

## 3. Groundnut

<table>
<thead>
<tr>
<th>Location, year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uganda, 7 districts, 2006</td>
<td>945 farmers, 4 farming systems</td>
<td>53% of groundnut area in MVs</td>
<td></td>
<td>Kassie et al (2010)</td>
</tr>
<tr>
<td><strong>Uganda, nationwide, 1999</strong></td>
<td><strong>Expert survey</strong></td>
<td><strong>0% (ICRISAT) 10% (other)</strong></td>
<td></td>
<td><strong>Bantilan et al (2003)</strong></td>
</tr>
<tr>
<td>Malawi, 4 districts, 2006/07</td>
<td>594 farmers</td>
<td>26% of farmers at least 1 MV; ~33% area</td>
<td></td>
<td>Simtowe et al (2010)</td>
</tr>
<tr>
<td><strong>Malawi, nationwide, 1999</strong></td>
<td><strong>Expert survey</strong></td>
<td><strong>10% (ICRISAT)</strong></td>
<td></td>
<td><strong>Bantilan et al (2003)</strong></td>
</tr>
<tr>
<td>Zambia, nationwide, 1999</td>
<td><strong>Expert survey</strong></td>
<td><strong>15% (ICRISAT) 5% (other)</strong></td>
<td></td>
<td><strong>Bantilan et al (2003)</strong></td>
</tr>
<tr>
<td>Zimbabwe, nationwide, 1999</td>
<td><strong>Expert survey</strong></td>
<td><strong>2% (ICRISAT) 50% (other)</strong></td>
<td></td>
<td><strong>Bantilan et al (2003)</strong></td>
</tr>
</tbody>
</table>
### Mali, Koulikoro and Kayes Regions, 2007(?)
- 343 farmers (in areas of seed project)
- 4 MVs occupy 43% of groundnut area
- 23%*
- Ndjeunga et al (2008) ; *ICRISAT website

### Nigeria, Kano, Jigawa and Katsina States, 2007(?)
- 470 farmers (in areas of seed project)
- 32% of groundnut area in MVs
- 31%*
- Ndjeunga et al (2008) ; *ICRISAT website

### Niger, Dosso, Zinder and Maradi Regions, 2007 (?)
- 370 farmers (in areas of seed project)
- 13% of groundnut area in MVs
- 43%*
- Ndjeunga et al (2008) ; *ICRISAT website

### India, AP and Maharashtra, 1997
- 485 farmers, various localities
- 4-98% depending on locality, variety
- Deb et al, 2005

### India, 1997 (selected examples)

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanded (Rabi)</td>
<td></td>
<td>0% (ICRISAT)</td>
<td>94% (other)</td>
<td></td>
<td>Bantilan et al (2003)</td>
</tr>
<tr>
<td>Nanded (Kharif)</td>
<td></td>
<td>32% (ICRISAT)</td>
<td>49% (other)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guntur (Kharif)</td>
<td></td>
<td>98% (ICRISAT)</td>
<td>0% (other)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4. Pigeonpea

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malawi, 4 districts</td>
<td>2006/07</td>
<td>594 farmers</td>
<td>Under 15% adoption of MVs</td>
<td>~15% of area</td>
<td>Shiferaw et al (2009)</td>
</tr>
<tr>
<td>Tanzania, nationwide</td>
<td>2007</td>
<td>600 farmers</td>
<td>17% adoption of one MV</td>
<td></td>
<td>Shiferaw et al (2009)</td>
</tr>
<tr>
<td>Tanzania, Babati District</td>
<td>2003</td>
<td>240 farmers, but with some bias towards those participating in promotion</td>
<td>35% farmers growing new varieties. (Estimate 8% district-wide.)</td>
<td></td>
<td>Shiferaw et al (2007, 2008a)</td>
</tr>
<tr>
<td>Kenya, Mbeere and Makueni</td>
<td>2005</td>
<td>400 farmers</td>
<td>55% of farmers plant MVs; 51% of pigeonpea area in MVs</td>
<td>50-80%</td>
<td>Cited in Shiferaw et al (2008b)</td>
</tr>
<tr>
<td>Kenya, Mbeere and Makueni</td>
<td>2006/07</td>
<td>411 farmers</td>
<td>24% of farmers plant at least one MV</td>
<td></td>
<td>Simtowe (n.d., draft)</td>
</tr>
</tbody>
</table>
5. Chickpea

<table>
<thead>
<tr>
<th>Location, year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia, four districts, 2003</td>
<td>323 farmers</td>
<td>18% of farmers plant an MV</td>
<td></td>
<td>Dadi et al (2005)</td>
</tr>
<tr>
<td>Ethiopia, three districts, 2006/07</td>
<td>700 farmers</td>
<td>32% of farmers planted an MV; ~33% of area</td>
<td></td>
<td>Asfaw et al (2010a,b)</td>
</tr>
<tr>
<td>Myanmar, 2007</td>
<td>National statistics (?)</td>
<td>82% area in new (&lt;6 years old) varieties</td>
<td></td>
<td>Than et al (2007)</td>
</tr>
<tr>
<td>Syria, 2004/05</td>
<td>470 farmers growing winter chickpea</td>
<td>66% using new MVs</td>
<td></td>
<td>Mazid et al (2009)</td>
</tr>
<tr>
<td>India, Andhra Pradesh, 3 districts, 1995</td>
<td>310 farmers</td>
<td>27% of chickpea area</td>
<td></td>
<td>Joshi, et al (2005)</td>
</tr>
<tr>
<td>India, Andhra Pradesh, 2 districts, 2007</td>
<td>?</td>
<td>60% of chickpea area</td>
<td></td>
<td>SAT Trends No.87 (2008)</td>
</tr>
</tbody>
</table>

6. Lentil

<table>
<thead>
<tr>
<th>Location, year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh, 13 districts, 2002</td>
<td>250 farmers</td>
<td>63% of block farmer area and 24% of non-block area in MVs</td>
<td>30%</td>
<td>Aw-Hassan et al, 2009; Sarker et al 2004</td>
</tr>
<tr>
<td>Ethiopia, 4 districts, 2004</td>
<td>289 farmers (10% of land in lentil)</td>
<td>19% of farmers adopt MVs</td>
<td>37%</td>
<td>Aw-Hassan et al, 2009</td>
</tr>
</tbody>
</table>
7. Faba Bean

<table>
<thead>
<tr>
<th>Location, year</th>
<th>Data collection</th>
<th>MV adoption</th>
<th>Yield advantage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sudan</strong>, Dongola Governorate, 2007(?)</td>
<td>Project participants and non-participants, 312 farmers</td>
<td>8% of farmers plant an MV</td>
<td>8%</td>
<td>Amegbeto et al, 2008 ; ICARDA, 2008</td>
</tr>
<tr>
<td><strong>Ethiopia</strong>, Arsi Region, 2007(?)</td>
<td>Project participants and non-participants, 198 farmers</td>
<td>71% of farmers plant an MV</td>
<td>42%</td>
<td>Amegbeto et al, 2008 ; ICARDA, 2008</td>
</tr>
<tr>
<td><strong>Egypt</strong>, Beni Mazar District, 2007(?)</td>
<td>Project participants and non-participants, 80 farmers</td>
<td>100% of farmers plant an MV</td>
<td>18%</td>
<td>Amegbeto et al, 2008 ; ICARDA, 2008</td>
</tr>
</tbody>
</table>
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