International Crops Research Institute for the Semi-Arid Tropics

Beyond 'the major growing areas' – targeting pigeonpea research to maximize global impact

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About ICRISAT

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market- Oriented development (IMOD).

ICRISAT is headquartered in Patancheru near Hyderabad, Andhra Pradesh, India, with two regional hubs and five country offices in sub-Saharan Africa. It is a member of the CGIAR Consortium. www.icrisat.org

CGIAR is a global agriculture research partnership for a food secure future. Its science is carried out by 15 research Centers who are members of the CGIAR Consortium in collaboration with hundreds of partner organizations. www.cgiar.org

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Abstract

The agricultural sector remains the driving force in most of the developing world and thereby the major factors affecting the livelihoods of the global population especially those that are food insecure. Agricultural research is one of the most important means to reduce food insecurity and elevate the living standards of the rural, but also urban poor. Investments in agricultural research aim at improving the wellbeing of farmers and consumers by reducing costs, increasing output, improving product quality or introducing new products (Arndt et al. 1977). Making these improved technologies available to the people who need them and who can utilize them is one of the core parts of the work in agricultural research for development. Therefore, it is important to recognize where a newly developed technology is likely to be applicable as the technologies developed generate new knowledge which could disseminate far beyond the location where the research is conducted and even beyond the location the research targeted. Based on the global mandate of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to produce international public goods, the global applicability and dissemination of technologies developed is of crucial importance to fulfill its mission. With limited distribution of released varieties beyond country boundaries, this work provides the basis for increasing the limited utilization of the benefits that could emerge from the applicability of crops beyond country and ecoregion boundaries.

This ex-ante assessment of the global distribution of welfare benefits is based on Davis et al. (1987) and explicitly accounts for spillover effects that occur between the different ecoregions. The main determining factors used in the model are: 1. the homogenous zones (HZ), 2. current production and consumption levels, 3. producer prices, 4. elasticities of supply and demand, 5. cross homogenous zone applicability, 6. production proportions, 7. research focus, 8. capacity of the national programs, 9. ceiling level of adoption, 10. unit cost reduction and 11. adoption pattern. Starting from a sound analysis of the environmental factors affecting applicability of pigeonpea varieties, global homogenous zones are introduced which serve as a base layer of the quantitative analysis. With pigeonpea being a niche crop which is mainly grown in South Asia and parts of East and Southern Africa the harnessing of all potential benefits is even more crucial to convince people to invest in the development of appropriate varieties and technologies. The underlying question is whether a centralized or a regionalized breeding program is better suited to maximize the benefits to the target countries.

The concept of applicability and spillover effects is very useful for every organization working on an international level and especially working on global public goods. The HZ mapping and therefore the assessment of applicability allows better targeting and resource allocation aiming at the dissemination of technologies and its benefits. Utilizing modern GIS facilities and the huge amount of open source data available, it is possible to create HZs with limited resources. When the original data is still included, these HZs can even be adjusted to specific tasks and problems in order to assist breeding institutions and other stakeholders in partnering even after varieties are finalized. A crucial precondition for the successful implementation is the collaboration among scientists from all relevant fields as only this will ensure the acceptance of the final output as well as make sure all relevant factors are considered and the HZs do reflect the reality. Furthermore, the process itself leads to insights and interest from various scientists based on the discussions and the

different views on the core business.

First and foremost the comparison of ex-ante assessment with ex-post experiences shows the need for an increased effort in making the already released varieties available to all countries within one zone; harnessing the full potential direct effects much better than in the past would already boost the overall benefits considerably. Though the applicability of pigeonpea is limited across homogenous zones, making a systematic effort to move varieties to countries they could potentially be applicable to could even further increase the results in terms of welfare improvements.

When trying to answer the question of regionalization or centralization for pigeonpea breeding, generally the answer has to be regionalization. However, these regional programs should still collaborate closely and exchange material as there are possible spillover effects that could be utilized even though they are more limited as compared to other crops like Groundnut (Mausch and Bantilan (2012), Mausch et al. (2013)).

The results also highlight the potential that efforts like zone-wise/regional release policies could have by making the movement of improved varieties across country borders easier and quicker. Those efforts to ensure wider spread of varieties could be enhanced using a more focused set of international trials to include not only new promising varieties but also several released varieties that already proofed to be successful. This may force scientists to rethink their efforts in dissemination and gives them a basis for choosing collaboration partners across the globe.

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Introduction

Agricultural research is an investment aimed at improving the well-being of farmers and consumers by reducing costs, increasing output, improving product quality, or introducing new products (Arndt et al. 1977). Identifying the correct target population and target location(s) has to be the first step in each research process and is often overseen or done less rigorous than desireable. Furthermore, targeting 'the major production areas' as often done in project development, might not always maximize the impact on the indicator desired.

Besides the initial targeting, making these improved technologies available to the people who need them and who can utilize them is one of the core parts of the work in agricultural research for development. Firstly, it is important to recognize where a newly developed technology is likely to be applicable as the technologies developed generates new knowledge that could disseminate far beyond the location where the research is conducted. Based on the global mandate of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to produce international public goods, the global applicability and dissemination of many technologies developed is of crucial importance to fulfill its mission. Secondly, besides the direct applicability, international dissemination could happen in the form of spillover effects. Spillover effects refer to a situation in which a technology that is generated for a specific target region or product is also applicable to other locations or products that are not targeted during the research process. They are generally categorized in three groups. First, across-location spillovers occur when a technology designed for a specific target region is also applied in other regions. Second, price spillovers occur when the technology change for a specific crop does change the supply of that product and therefore influences the price. If that product is internationally traded this change in price will affect the world price and therefore other regions in which no research was undertaken. Third, across-commodity spillovers refer to a situation in which a technology designed for a specific crop is also applied to other crops (Deb and Bantilan 2001). Utilizing and explicitly exploiting both, applicability and spillover effects, could improve technology delivery and uptake which has been slow in the past decades especially across most African countries.

ICRISAT, as member of the CGIAR, has a mission that is based on serving a broad set of countries and their resource poor farmers with agricultural technologies that improve their standard of living and eventually enables them to get out of poverty. It is important to note here the role of spillovers to the world's poorest countries of technologies from industrialized countries both individually and through their collective action via the CGIAR. Until recently, much of the successful innovative effort in most of the world's poorer countries applied at the very last stage of the process of selecting and adapting crop varieties and livestock breeds for local conditions using materials developed elsewhere. Relying on these sources used to be reasonable, given an abundant and freely accessible supply of suitable materials, at least for the main temperate-zone food crops, but now changes taking place in the emphasis of 'rich'-country research, combined with new intellectual property rules and practices and an increased use of modern biotechnology methods, have already begun to spell a drying up of the public pool of new varieties. The reduction in technologies from these traditional sources means that less developed countries will have to find new ways of meeting their demands for new varieties. Against this background, increased efficiency in the technology development and especially its dissemination to the potential beneficiaries becomes even more crucial.

This paper is organized in five sections. The first gives an introduction of the topic and outlines its relevance. The second introduces the theoretical framework and defines key terms used before the application of the model is described for the case of pigeonpea in section three. In section four the model results are given and implications for research planning are highlighted before in section five conclusions are drawn and some future outlook is outlined.

Theoretical framework

In the context of breeding for smallholder farmers, the concept of spillover effects and the results of ex-ante modeling of global impacts can be utilized to better assess the potential outcomes of the research and maximize the impact on the desired outcome. In a setting where several projects or project ideas are competing for funding within an institute or across institutions this framework can assist by allowing to judge on the global impact and thus maximize the intended effects. Besides targeting the optimal environment it is also possible to judge on a more aggregate and long term level if breeding for a crop should be done in a centralized facility or needs to be regionalized.

In contrast to most technology spillover effects from industrial research and development, agricultural innovations are not applicable in all environments. While, in the context of technology spillovers, trade and foreign direct investment are the main determinants of spillover potential, environmental similarities are much more important in the investigation of agricultural research spillover benefits. Therefore, these conditions have to be incorporated in the assessment of the applicability and spillover effects that might then be much lower as compared to other technologies. Within the debate of the movement of agricultural technologies two basic types have to be distinguished: the movement within one ecozone and the movement across the boundaries of ecozones. In an ideal world without country boundaries, governmental regulations, or transport/availability restrictions the movement within one ecozone would be the norm as the same environmental factors are present and thus any variety would express the same positive characteristics in other locations within one ecozone. However, based on the adaptability of crops and varieties, technologies might also move across the boundaries of ecozones and outperform the varieties in other zones. This movement would then be called spillover effect. In the first case, within one ecozone, the applicability of the variety is close to 100 % whereas in the latter case, the spillover effect, the applicability is significantly lower than 100 %.

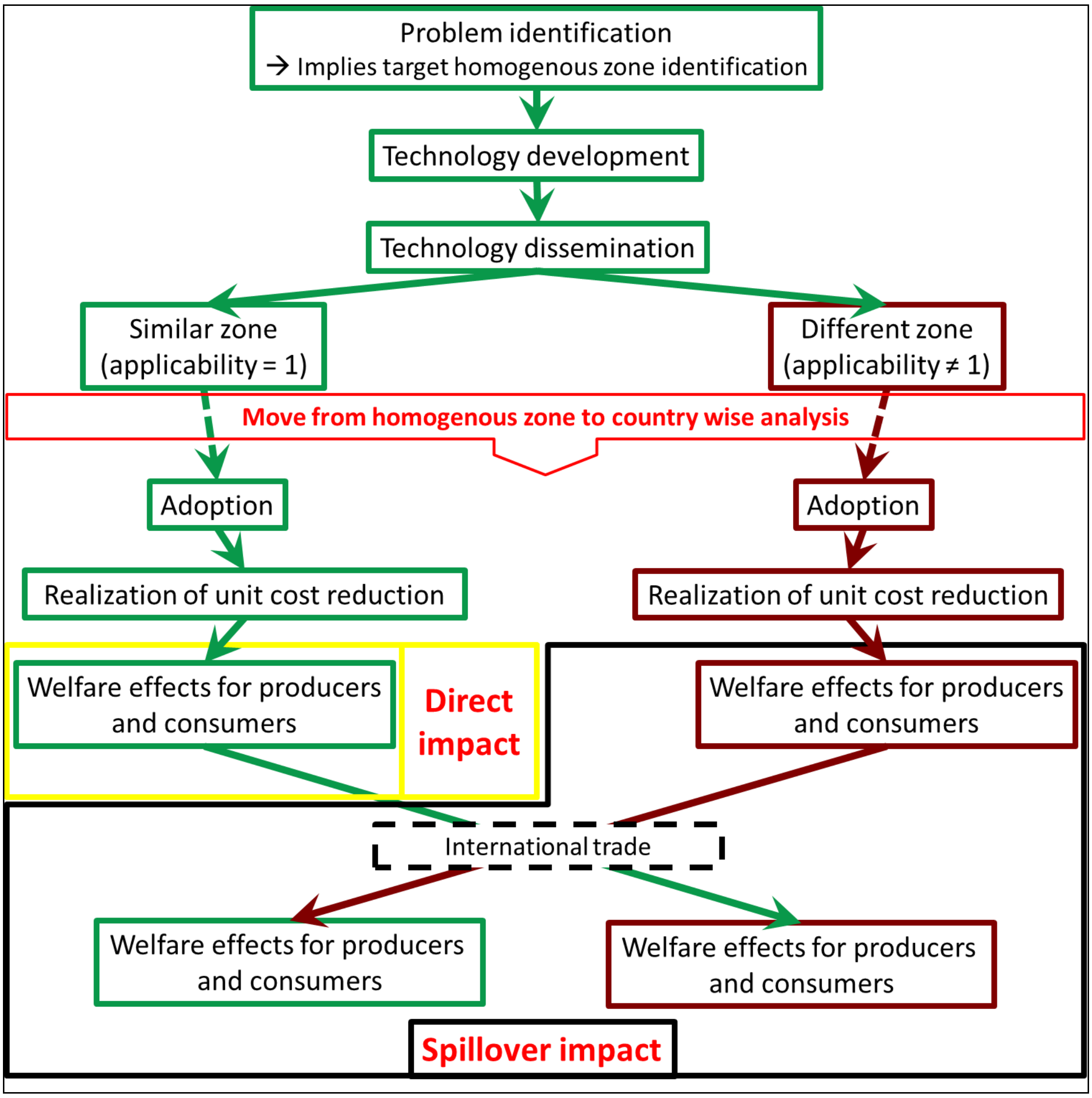

Figure 1: Spillover effects and impact. Source: Own presentation based on Davis et al. (1987) and Mareida et al. (1996).

To measure spillover effects, Davis et al. (1987) base their analysis on these six main steps: 1: Selecting commodities; 2: Defining agro climatically homogenous zones; 3: Identifying the probability of success of research for each ‘Homogenous Zone’; 4: Expected ceiling level of adoption and adoption time lag; 5: Determine spillover effects; 6: Derive prices, transportation costs, and elasticities. (For a detailed overview of spillover literature and measurement and the historic development see Deb and Bantilan (2001) as well as Bantilan and Davis (2013).)

ICRISAT’s commodities (chickpea, pigeonpea, sorghum, pearl and finger millet) are clearly defined in its mandate; therefore the selection was made from this set of five crops. In this paper, pigeonpea was chosen for the analysis as one of the upcoming export crops from East Africa. The second step - the definition of the homogenous zones/zones - is one of the most important steps. This step is of crucial importance as it is on the basis of this that the applicability matrix will be established. Based on earlier work on the establishment of just these zones (see Mausch and Bantilan 2012) this paper will provide comparative results on global benefit levels for the two crops.

Besides the methodology of Davis et al. (1987), the concept of Maredia et al. (1996)

allows assessing spillover effects from agricultural research and thereby also addresses the issue of priority setting in this line of research. It is based on an econometric approach utilizing international trial data along the example of wheat improvement. Similar to the approach of Davis et al., it builds on the notion that agricultural technology adoption and success depends on the similarity of environmental factors. A matrix of m*m agro-ecological zones with cij spillover coefficients is utilized. The coefficients cij "measure the performance of a technology developed for environment i, in environment j, in relation to the technology developed for environment j" (Maredia et al. 1996, p. 160).

Both of these concepts crucially rely on an accurate classification of homogenous zones across the world. This zoning is the basic precondition for the definition of variety dissemination in target and non-target zones. Additionally, the homogenous zones represent a useful tool to assess technology applicability on a global level and thereby allow us to measure spillover effects. In a situation in which two zones in two different locations across the globe are characterized by identical agro-ecology and climatology, a variety developed and released in one of these two locations is highly likely to perform similar to the other location and the applicability is high. Accordingly, if two zones are characterized as being similar but not fully equal a variety might still be transferable to the other zone but might not lead to the same performance. Then the degree of applicability is different from 1 / 100 % but still there is chance of the variety performing better than any other local variety. This scenario would then be defined as a spillover effect.

Application of an international trade model to asses targeting options in pigeonpea breeding

The model

The model utilized to estimate the ex-ante direct and spillover welfare gains by country is based on the principles of economic surplus and incorporates international trade. It was earlier utilized by the Australian Centre for International Agricultural Research (ACIAR) in an effort to systematize their priority setting for country level support programs and is based the model developed by Davis et al. (1987). During implementation the basic concept was further developed by Lubulwa et al. (2000). The parameters used in the model to estimate the welfare gains are:

1. The homogenous zones
2. Production and consumption
3. Producer prices
4. Elasticities of supply and demand
5. Cross homogenous zone applicability
6. Production proportions
7. Research focus
8. Capacity of the national programs
9. Ceiling level of adoption
10. Unit cost reduction
11. Adoption pattern

Data is available from FAO and other sources for several of these indicators. The production and consumption data are used from FAO (2012) database. In the model the averages over the years 2005 to 2007 are used as the latest reliable estimates for several indicators. For the producer prices (farm gate prices), the FAO (2012) prices in US Dollar were used where available. For the remaining countries the average prices were used. The elasticities of supply and demand were used as estimated by International Food Policy Research Institute (IFPRI) for the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model. These are the most consistent estimates available on a global level.

The remaining parameters had to be estimated from other sources.

The homogenous zones

One of the crucial inputs in the model are the homogenous zones (HZs) across the world for the crop in question. Based on the methodology as described in Mausch and Bantilan (2012) for groundnut, pigeonpea zones were developed using the same methodology. The base layer consists of the agroecological zones (AEZ) developed by FAO (2000). These zones already include the most important features characterizing different environments and thus are a very useful starting point for the customization for different crops. Based on the AEZ, in-depth discussions with pigeonpea experts were held to understand the specific needs of the crop and to further refine the zones.

The most important feature is the photoperiod sensitivity of pigeonpea. This leads to a very limited applicability of a variety across latitudes. However, as the AEZ are already implicitly accounting for this factor as well as the climate variable change along latitudes it was not necessary to incorporate an extra layer for this. Close investigation together with pigeonpea scientists revealed that the photoperiod sensitivity is well taken care of using the AEZ. Furthermore, temperature is a crucial factor for the growth pattern of pigeonpea (Silim 2006). Therefore, the elevation levels were closely investigated as an additional layer after the AEZ which accounted for the major temperature differences. After overlaying the elevation levels of 1500 m, which was mentioned as a cut-off point, it was found that this is also already covered in the AEZs. The warm and cold tropics are delineated along just this line and therefore the AEZ was the sole base layer for pigeonpea.

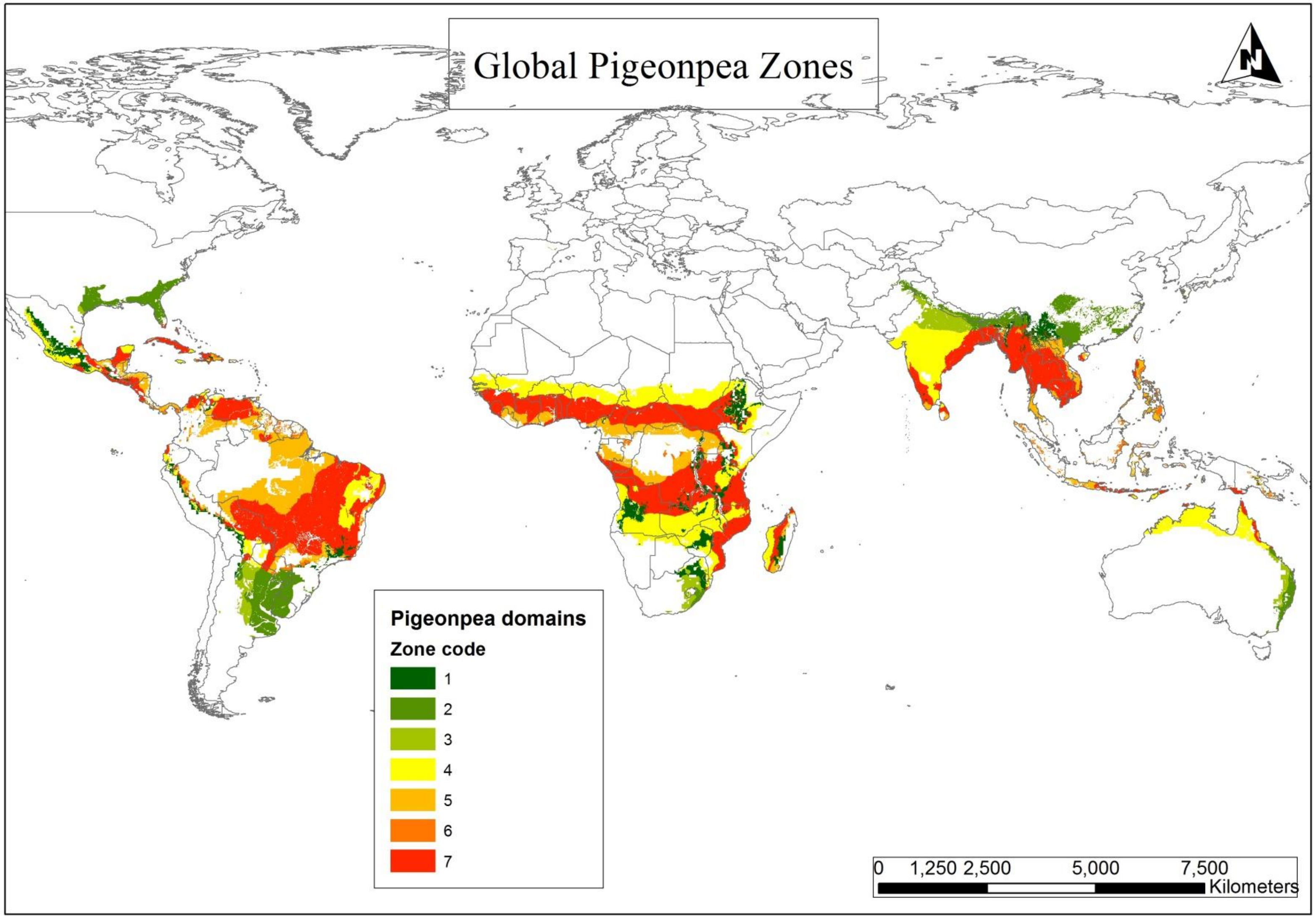

Figure 2: Global pigeonpea homogenous zones.

After accounting for climate, the areas that currently grow pigeonpea (Monfreda 2008) or are suitable for legume production (FAO 2000) were overlayed to separate out the relevant areas from the rest of the AEZ. Finally, all areas with less than 90 days length of growing period (LGP) were excluded to make sure that only zones that can grow pigeonpea under rainfed conditions are included. For the final HZs, see Figure 2.

Production proportions

The production proportions represent the share of the total production in each HZ. These proportions were calculated using the Monfreda (2008) dataset as the alternative Harvest Choice (2009), which was previously used as additional check, aggregates pigeonpea into 'other legumes'. Figure 3 shows the production proportions across all homogenous zones.

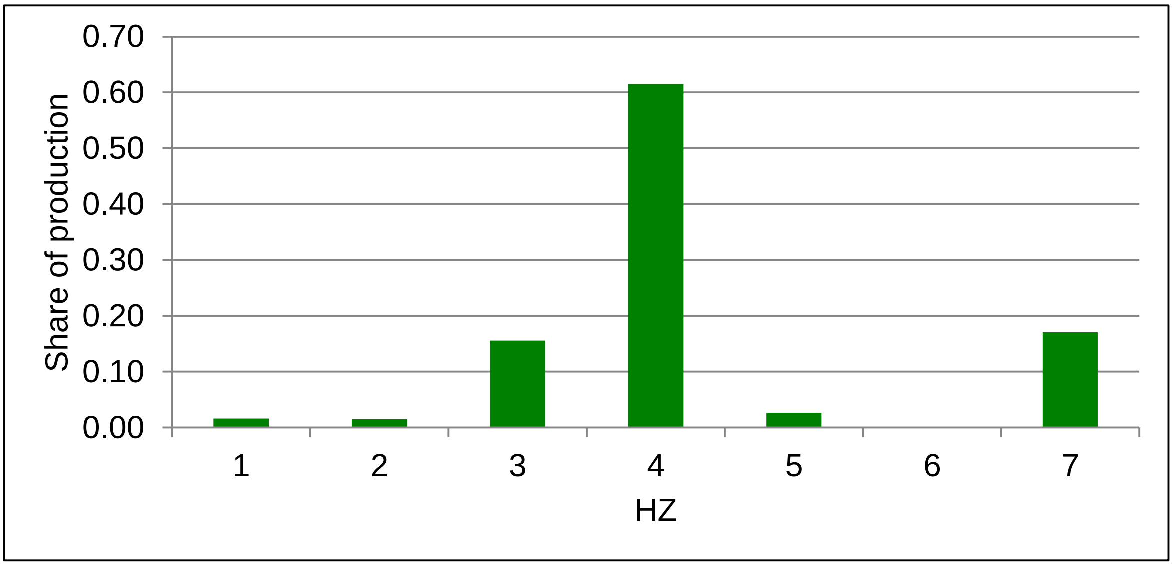

Figure 3: Production across HZs. Source: Own calculations based on Monfreda (2008).

The distribution of the total production already indicates differences in the benefit levels that potentially emerge from investments focusing on different HZs. This distribution will however be influenced by the other parameters in the model and is thus only a first indication of the most important producing zones. It clearly highlights that more than 60 % of the pigeonpea production is concentrated in one single zone, i.e. HZ number 4, the warm tropics; drylands; > 90 days LGP.

Cross homogenous zone applicability

Based on the crop-specific HZs developed, the applicability of varieties across these zones was established. The underlying question that was posed to the crop experts was 'what share of the varieties developed for one particular zone is likely to outperform the best local variety in each of the other zones?'. Ideally, this could be econometrically established using the results of a vast set of international farmer field trials (See Mareida (1996) for an example using on-station yield trial data as an approximation of performance enhancements in farmers' fields). Unfortunately, the international trials ICRISAT conducted over the past 40 years do not cover all zones and do not include enough replications of individual varieties[1] to make econometric estimation viable. Furthermore, it is only possible to attribute the target zone for a few varieties that were officially released but not for many others varieties or advanced breeding lines that were never released. Therefore, using these trials would not give a sufficient basis to fill the matrix. Nevertheless, as the most senior breeders in ICRISAT have been working in several locations and for several target zones already, their judgments are of high value for this exercise and therefore the applicability was estimated using their judgments and selectively cross checked with the data available.

For the actual discussion a large-scale printout of the HZ maps as well as the Manfreda (2008) production maps were taken to the discussion to familiarize the expert with the task at hand and to make discussions more targeted and visualize the zones in question. Starting from the location most familiar with each scientist, the matrix was filled stepwise. Based on their experiences and targets during their time in that location and their multiple cooperating agencies and scientists a baseline was established for the estimations. Due to their work in the particular location confidence levels were high and they became more comfortable with the topic. This led them to further estimate the factors for zones less familiar with them but for which they actually have a very good feeling based on their long experience with partners across the world and their generally vast background knowledge of the distribution of varieties and the conditions in each country. Based on ICRISAT's mandate and mission, the breeding focus is on the semi-arid tropics which results in some zero estimates in the matrix. The material developed by ICRISAT does not take those zones into account and thus the applicability is 0 as these particular zones are extremely different from the target zones. Admittedly, there is a chance that a certain degree of applicability exists in those zones but based on our work we are not able to predict this and it is not relevant in the framework of ICRISAT's dissemination support information. Therefore, we did accept this limitation and did not try to pursue the scientists to give us estimations for those zones or find others who would be able to do so. Based on the photoperiod and temperature sensitivity of pigeonpea, the applicability matrix does contain many zero estimates which reflects these problems in moving varieties across locations. Table 1 shows the full matrix.

Table 1: Cross HZ applicability matrix.

HZ	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	1	0	0	0	0	0	0
2	0	1	0	0.8	0	0	0.8
3	0	0	1	0	0	0	0
4	0	0.8	0	1	0	0	0.7
5	0	0	0	0	1	0	0
6	0	0	0	0	0	1	0
7	0	0.8	0	0.5	0	0	1

Source: Own elicitation from ICRISAT pigeonpea experts.

After initial estimations of the ex-ante welfare benefits, the implications of the matrix were discussed with the breeders in an effort to highlight the importance and confirm the

[1] This is due to the fact that the objectives for these trials were different and rather based on demands by several countries than on the intentional applicability trial.

assumptions made during the process. The welfare estimations with different key assumptions were made twice, once using the full applicability matrix as elaborated with the scientists and once using a matrix with all off-diagonal values set to zero assuming no applicability across HZs. These two sets of results were used to highlight the implications of the values indicated for the final estimation. During this process, the applicability levels were confirmed.

Research focus

In the original model as set up by Lubulwa et al. (2000), the research focus reflected the focus of the various national research programs in each country which could be used in efforts to facilitate collaborations across countries or donor agency support for country programs with a high likelihood of benefiting other countries with the results. In this adjusted version ICRISAT was introduced, which does research on its own and is not dependent on (although influenced by) national programs for their own priority setting. Therefore, ICRISAT's research focus is variable and reflects different scenarios that ICRISAT could pursue in priority setting.

Capacity of the national programs

The capacity of the national agricultural research programs (NARS) was assessed to determining the likelihood that any material developed or introduced would be adapted successfully. The model accounts for two different categories of capacity. First, the capacity to conduct innovative research and second, the capacity to adapt and/or adopt innovations from other sources are included separately. The innovative capacity was set to 100 % since for these estimations it was assumed that ICRISAT will conduct the innovative research and the final benefit levels were assessed based on the assumption that the research conducted will be successful. Therefore, the national programs only need the capacity to adapt the results.

Initially, ICRISAT experts were used to generate a set of estimates of the perceived strength of all national programs based on their experience and their past collaboration. After this initial round of expert judgments on the 0-1 scale, the available data was taken into account to verify and adjust the expert estimations. Multiple indicators were used as a basis for the adaptive capacity parameter estimates (see Table 4) for NARS capacity, i.e. ASTI (2012) data on NARS expenditure and personal strength as of about 2010. Pardey (1989) data on NARS expenditure and personal as of the late 1990s, number of ICRISAT trials conducted in the country, number ICRISAT releases in the country, number of NARS scientists trained by ICRISAT and finally the agricultural land as of FAO (2012) was used to standardize the aforementioned indicators.

Given the secondary data on capital and staff endowment the expert judgements were adjusted to better reflect available data. After these two rounds, estimates were critically investigated by the team to discuss whether the relativities are representative and some were adjusted. Furthermore, each indicator was used (in absolute as well as per ha terms) to create a ranking of all countries covered and thereby ensure that the final estimate represents these rankings and the relativities involved as accurately as possible.

Based on the nature of pigeonpea being a legume and mostly not the major focus in the national research agendas, the capacity levels reflect legumes in general as the crop programs are usually clubbed together under one 'legume program' in each country.

Ceiling level of adoption

The ceiling level of adoption is defined as the maximum attainable adoption rate given the current conditions facing in terms of institutional and infrastructural conditions such as market structure, road networks or trader preferences. These are the basic conditions that influence adoption to a large extent but since they also take long time to change, they are assumed to be fixed for this exercise.

In the absence of large datasets across countries expert judgments are the main tools we have to rely on to estimate the ceiling levels of adoption across all the countries studied. Similar to the stepwise procedure utilized for the capacity levels, these judgments were validated using multiple discussion rounds with experts from different regions and from different backgrounds (economists, breeders and agronomists) that was then backed with available data from various countries throughout the process. This made sure that estimates were consistent across countries and the expert estimates were validated for possible biases using available data for adjustments. Based on those adjustments the relativities were revisited and it was made sure that these are still in line with the real picture on the ground. For the final estimates see Table 5 (p. 28).

Unit cost reduction

The unit cost reduction represents the anticipated yield gain and takes possible increases in input levels into account. A range of plausible scenarios were investigated based on past experience as well as results from other projects' ex-ante estimations using expert judgments and crop models. The level used here is 10 % unit cost reduction which already sets a rather conservative estimate of the potential given household survey evidence for groundnut ranging between 9.84 % and 44 %.[2] After an in-depth cost analysis for groundnut in several countries these 10 % were then applied to the average FAO farm gate price during the years 2007 - 2009 as these are consistent with ICRISAT household survey evidence. For pigeonpea, due to the very high farm gate price recorded by FAO, the price was determined from the average ratio of groundnut and pigeonpea prices available from several surveys conducted by ICRISAT.

In the model, the level of benefits is directly linear to the unit cost reduction and will not influence the relativities across countries or zones. Furthermore, the unit cost reduction cannot be altered across countries or zones based on the model set up. It is therefore assumed that within one homogenous zone the unit cost reduction will be the same and the reductions will alter only across homogenous zones or for different technologies.

Adoption pattern

The adoption pattern illustrates adoption levels over time. It is determined by three main factors, i.e. the time lag from the start of the research until adoption starts, the annual adoption increase as well as the time until the ceiling level of adoption is reached. As this information is only available for some selected cases in some selected countries it had to remain equal for all countries. Furthermore, it is believed that this pattern will be highly

[2] Mali (9.84 %), Niger (11.31 %), Nigeria (11.06 %) (Ndjeunga et al.2008), Malawi (20.2 %) (Baseline data of Tropical legumes II project) and Uganda (44 %) (Shifferaw 2010)

correlated with the NARS strength and all judgments that could be implemented would thus be likely to lead to double discounting for countries with a weak national research system. Furthermore, sensitivity analysis showed this factor does not influence the results to a significant extent when altered within a reasonable range.

Results

Benefits across countries and HZs

Benefiting the largest possible number of people in the world to the greatest extent possible is hugely driven by the widest possible distribution of ICRISAT technologies. To achieve this, global availability of improved technologies is of crucial importance. This is best achieved by understanding the flow of technologies across countries and zone boundaries and the determining factors underlying this movement. The central question is which environment ICRISAT should emphasize in order to maximize its impact in terms the desired outcome (be it poverty reduction, nutritional improvement or others). The following section compares likely outcomes across countries or zones to ultimately utilize these to improve targeting and thus impact achievements from pigeonpea research.

Using the research focus of ICRISAT as the main targeting parameter the initial estimates build on the assumption that ICRISAT would target only one HZ at a time. The results show which HZ has the highest potential benefits and will thus provide an initial indication of which HZ would generate the maximum returns. The resulting benefits can also be utilized to simulate the outcomes when targeting multiple HZs simultaneously by setting the share of effort in each HZ and multiplying the benefit level for the maximum effort with the share of effort in this HZ. Thereby, the total benefit level is calculated from the multiplication of the vector of effort levels in each HZ by the vector of benefit levels for each HZ given full effort on the individual HZs. Results for the individual HZs are given in Table 2. While the Asia and Africa column includes all countries to give a better overview, the CRP total column only sums up all countries set as focus countries in the newly established ‘Consortium Research Program GrainLegumes’ as this is the main framework for future work in the CGIAR. These focus countries exclude some big producers like China, which is the main reason for the differences between the sum of Asia and Africa as opposed to the ICRISAT total.

Table 2: Benefits by focused HZ with and without cross-HZ applicability

HZ	With applicability CRP total US$ mill	With applicability Asia US$ mill	With applicability Africa US$ mill	Without applicability CRP total US$ mill	Without applicability Asia US$ mill	Without applicability Africa US$ mill	Production covered %
4	796	776	21	697	684	14	61.5
2	670	651	20	10	10	0	1.5
7	484	467	18	129	119	11	17.1
3	175	175	0	175	175	0	15.6
1	10	4	6	10	4	6	1.6
5	6	3	3	6	4	3	2.6
6	0	0	0	0	0	0	0.1

Source: Own calculations.

The benefit levels align much more with the production proportions. The exception is only zone 2 from which high levels of benefits arise to other zones. Zones 2 and 7 are also the only two zones where the two scenarios with and without applicability make a significant difference for the total benefit levels. This suggests that the efforts in pigeonpea should be concentrated in making the seed available within each zone and it would only rarely be economically beneficial to try and make varieties available across zones. This is with the exception of zone 2 material that could greatly benefit other zones. However, keeping in mind that each zone covers many countries and stretches across continents, it is money well spent trying to make the seed available all over each zone.

Another important point which is based on the current production is the benefit levels across the zones. At least three of the zones generate insignificant benefits which are much more focused than in other crops[3]. This calls for a much more targeted research effort as compared to groundnuts where many more zones have to be taken into account and thus different material has to be produced catering for the different needs. Pigeonpea research should therefore concentrate on those 3 - 4 zones where it can make a difference but keeping in mind the limited applicability across these need to be addressed separately.

Based on the differences in the size and relevance of each HZ across countries, the resulting benefit distribution across countries varies tremendously. This effect is highlighted in **Figure 4** where the most promising HZs (highest total benefit levels) are compared across countries. It also highlights that in most scenarios the benefits to India dominate the result as India is also the biggest producer and consumer of the crop.

[3] See Mausch et al. (2013) for the example for groundnuts.

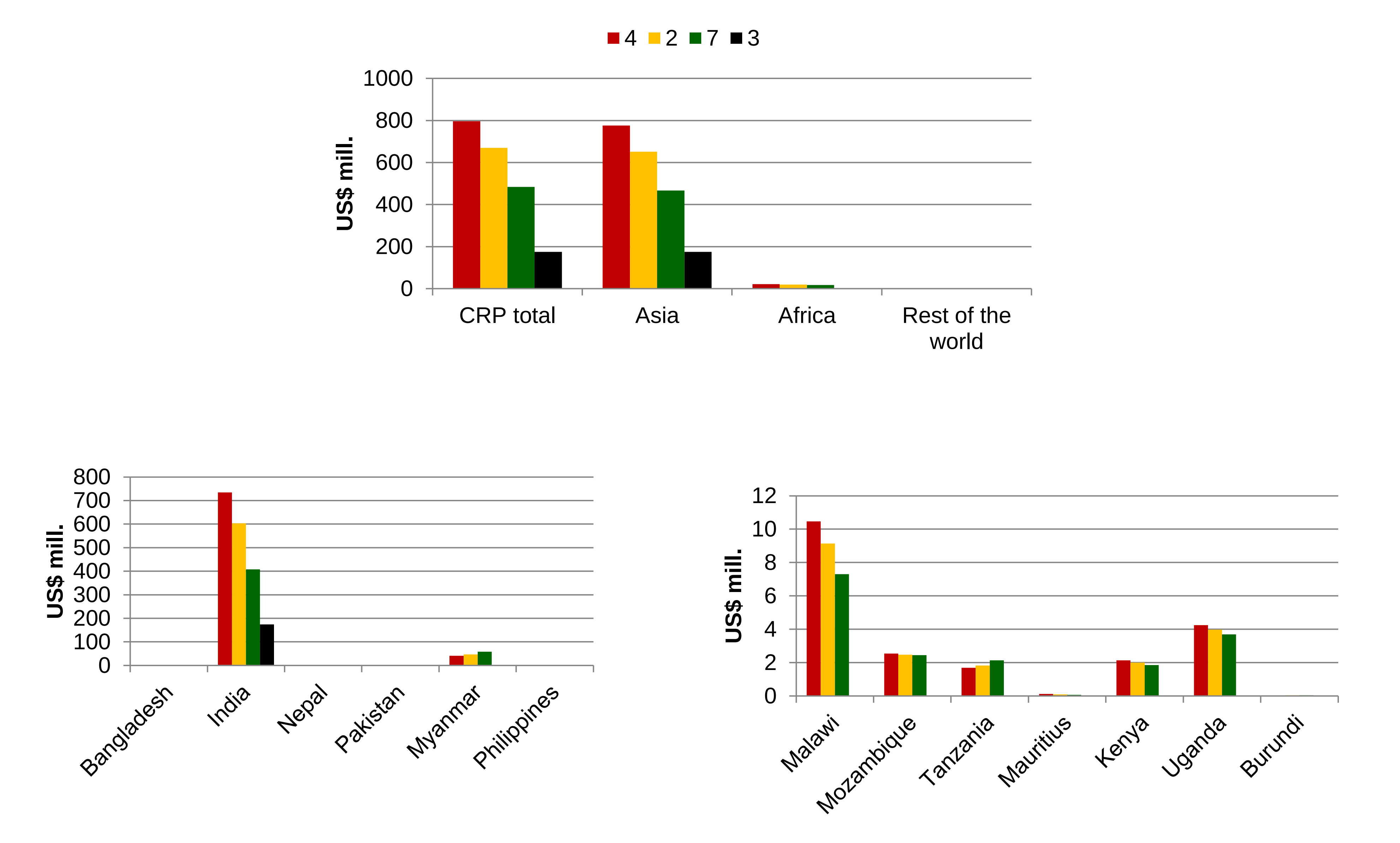

Figure 4: Realistic scenario country level pigeonpea benefits (mill. US$) for 4 main HZs. Source: Own calculations.

In pigeonpea research, the share of benefits to India is close to 100 % no matter which zone the research focuses. This however should not indicate that benefits to Africa are not significant as small countries like Malawi can still benefit hugely and the amount generated there would be more significant for the countries' GDP than the much bigger total value for a much bigger economy like India.

Overall, the results show that huge differences in the potential impacts do exist and that those do not solely depend on the share of production covered as often - implicitly or explicitly - assumed during targeting efforts when projects are set up in the “major production areas”. Nevertheless, the total benefit might not be the only important factor to consider. The potential areas that could benefit from the research are often not taken into account where research in an area that has huge applicability to other zones is not targeted as the direct benefits are lower than in other zones. However, the total benefits could be by far larger. This comparison can be highlighted by looking at the results for zone 2 where only marginal benefits accrue in the zone itself, but many other zones could benefits hugely which drives the total benefits to ten times as much.

Benefits under different scenarios

The next step in the strategic positioning of projects would be the question of the intervention planning. Therefore the following section will present results that can help answer the question of how else can we use this model to reflect other project objectives such as capacity building efforts to thus get a comparative picture on where research managers should put their money to get the often referred to ‘biggest bang for the buck’? To make a final decision on this, it will be of crucial importance to gather information on the cost associated with projects targeting other parameters aside from yield increase or unit cost reduction. Several factors will be influencing these costs and an in-depth study of various past projects would have to be evaluated to compare timeframes as well as the likelihoods to achieve the results within the given timeframe as well as the costs associated. Against this background however, the following section provides food for thought and a first insight in the potential these further options will have for research management decisions and project design and shed light on the benefit side of the equation.

Strategic consideration such as the above-posed questions within the international agricultural research community and in the framework of setting up research projects becomes increasingly important with pressure mounting to improve ex-ante targeting efforts and thereby increase measurable outcomes and impacts. When comparing the total benefit levels in an ideal world with perfect capacity and full adoption across the world to the realistic scenario with at times very low adoption and/or capacity levels across countries, the total outcome goes up by more than 50 % (see **Figure 5**). This effect is even more pronounced for many African countries as current levels for both of these factors are often low and thus the result of improving these by using e.g. increased training efforts for either scientific staff in the national programs or farmers directly will have a big effect on total country-level benefits.

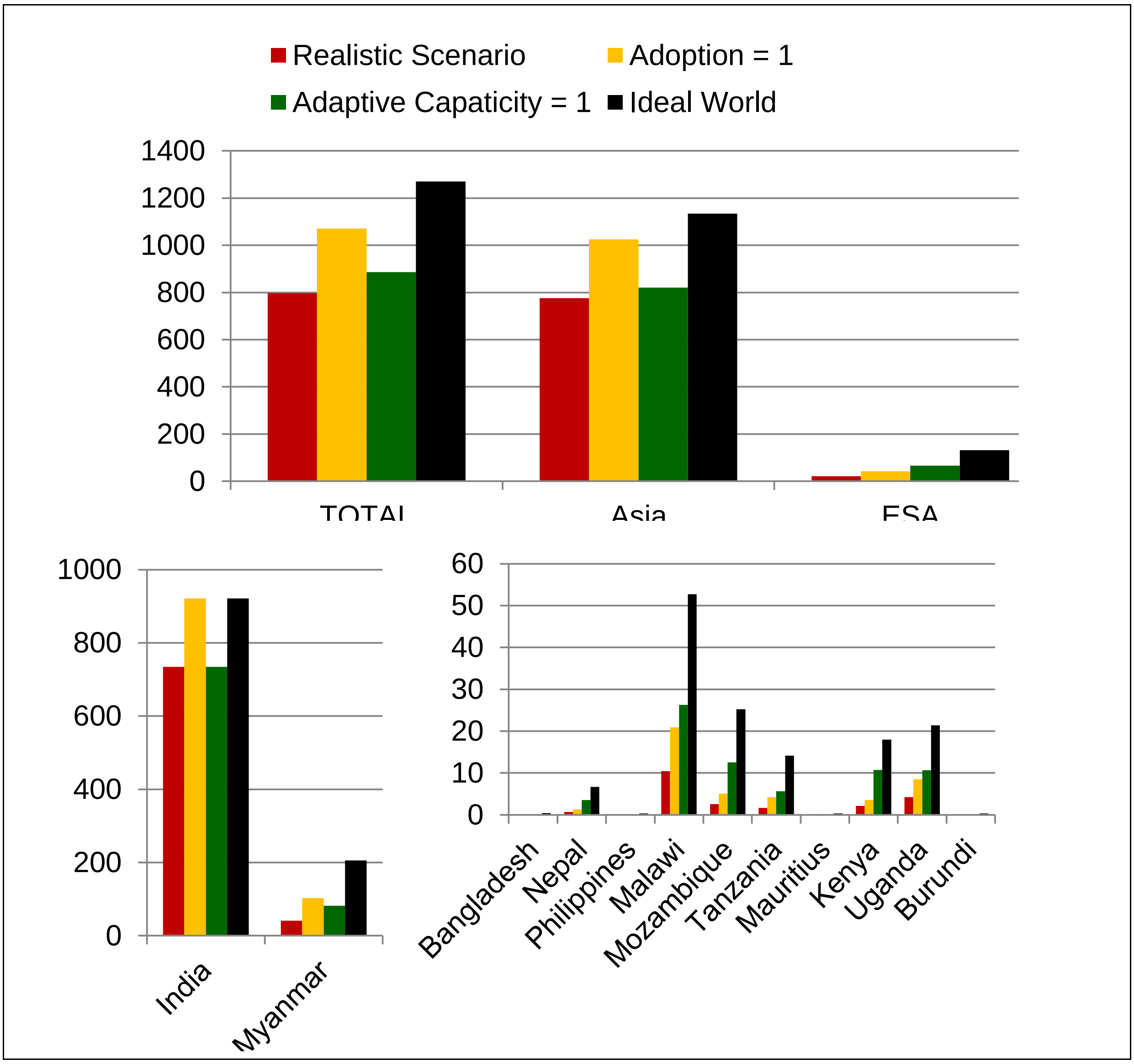

Figure 5: Benefit levels (all in US$ mill.) across continents and selected countries under different scenarios (targeting the highest total benefit - HZ 4). Source: Own calculations.

Comparing these effects across countries reveals clear implications for targeting different problems across different countries and the potential benefits that result. Figure 5 shows the potential for piegonpea that exists in e.g. Malawi, Mozambique or Tanzania with benefit levels multiplying when the adoption constraint along with the capacity constraint is lifted. This comparison also highlights the different needs of countries. Whereas in India the adoption constraint is more binding, the adoption is already at higher levels. In many African countries due to low levels of capacity and adoption, the effects of pure focus on breeding are negligible when these other factors are not addressed alongside. Investing in improving these conditions by e.g. training of research staff has the potential to increase benefits and it will have to be looked at carefully when thinking of new projects. However, these factors can be time consuming and expensive to address and thus an ex-ante cost benefit evaluation has to be incorporated to make sure targeting these factors is economically beneficial.

This example highlights the need for different approaches for different countries as improved varieties alone can have fairly low effects in some zones or countries. The adoption and capacity levels are often so poor that the technology does not reach the farmers which will result in low impact and thereby inefficient allocation of resources although those zones should be the main target based on mostly high poverty and malnutrition levels as well as their potential for the crop. Benefit levels in other countries such as India with its very high capacity and adoption levels are entirely or mostly driven by improved variety development (either by ICRISAT or others) alone and the resulting unit cost reduction.

Conclusions

All in all, utilizing the concept of spillovers and the multi country model led to several entry points being identified that can be utilized in research management and project targeting. These are the homogenous zones, the applicability matrix and the ex-ante benefit levels.

First, the homogenous zones and the analysis highlights the huge potential that efforts like zone-wise releases could have which would make the movement of improved varieties across country borders much easier and quicker. The global applicability within one zone could be fully captured if the mostly long and expensive release procedures would be made easier. The benefit levels that would result from the wider spread and accessibility would be huge and thus efforts such as the Association for strengthening Agricultural Research in Eastern and Central Africa (ASARECA) policy to ease the release procedure for varieties that are already released in at least three countries in the zone should be fully supported and the replication of this policy in other zones promoted. This effort to ensure intra-zone spread of varieties could be enhanced using a more focused set of international trials to include not only new promising varieties but also several released varieties that have already proved to be successful. The trials could be aligned with the zones developed in Mausch and Bantilan (2012) and an effort should be made in trying out the varieties in the countries they can benefit. However, adaptation trials and agronomic research will always be needed locally to make sure the varieties can be fully utilized by local farmers, are well adapted to the local farming systems, and that the agronomic practices associated with the varieties are tailored to that particular location.

Secondly, the applicability matrix highlights the potential for cross-zone spillovers. Though limited due to pigeonpea's sensitivity to changes in climatic conditions like photoperiod, altitude and temperature there are some zones that have applicability potential. The movement of pigeonpea is much more difficult as compared to other crops, but using the applicability matrix along with the homogenous zones offers a good tool to make predictions on promising trials across zones.

Finally, the comparison of different scenarios with reference to the national research system strength as well as country level adoption rates led to useful results in terms of more detailed project planning. It offers insight in which types of interventions are likely to be more efficient in which country. Targeting yield increase in some regions or countries and trying to improve capacity and adoption in other regions will lead to a more balanced and better targeted project set up and thereby to improved impact achievement.

To further enhance this analysis and increase the possible applications of this research the further disaggregation of benefits across target groups like men and women or poor and non-poor would be ideal. Additionally, the incorporation of research costs would enable to further judge on the cost-benefit aspects of interventions at planning stages. While some attempts have been made to approach these, there is no final solution and options have to be assessed further.

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Appendixes

Table 3: Indicators on capacity used.

CAPACITY	Agricultural land FAO (1000ha)	Bantilan estimates	Mausch adjusted	# trials	# releases	LSU training	ASTI		Pardey (1989)	
		adaptive	adaptive	ICRISAT	ICRISAT		spending	personal	Personal	Expenditure (mio)
Bangladesh	9,133	0.50	0.50	128	3	17			1152	65
China	523,144	1.00	1.00	102	1	61			33454	1101
India	179,793	1.00	1.00	1626	*26*	253			8389	471
Indonesia	52,200	0.50	0.50	288	5	26			1372	139
Myanmar	12,234	0.50	0.50	401	5	76				
Pakistan	26,480	0.50	0.50	63	3	13			3431	49
Thailand	19,726	0.70	0.70	16	1	53			1429	85
Viet Nam	10,192	0.70	0.70	302	4	58				
Benin	3,345	0.30	0.30	126	2	9	22	115	56	2
Burkina Faso	11,862	0.50	0.50	235	1	10	19	240	110	140
Cameroon	9,246	0.40	0.40	75	0	3			245	24
Central African Republic	5,218	0.10	0.10	0	0	1			27	3
Chad	49,231	0.40	0.40	23	0	3			28	15
DRC	22,450	0.00	0.00	0	2	0				
Gambia	652	0.20	0.20	0	2	9	3	38	62	
Ghana	15,500	0.60	0.60	156	3	12	95	537	151	3

Guinea	14,220	0.20	0.20	216	3	18	4	229	177	5
Ivory Coast	20,300	0.40	0.40	0	0	1	43	123		
Mali	40,716	0.60	0.30	258	6	11	25	313	275	13
Niger	43,782	0.20	0.10	55	5	6	6	93	77	2
Nigeria	76,667	0.60	0.40	257	1	13	404	2062	986	74
Senegal	9,149	0.50	0.50	136	0	16	25	141	183	15
Sierra Leone	3,390	0.40	0.40	0	3	0	6	67	46	1
Ethiopia	34,858	0.80	0.50	36	2	13	69	1318	240	14
Malawi	5,339	0.90	0.40	177	5	65	21	127	92	5
Mozambique	49,133	0.80	0.20	0	3	24	18	263	77	7
South Africa	99,328	1.00	1.00	96	4	0	272	784	1647	126
Sudan	135,887	0.20	0.10	123	0	33	51	1020	248	11
Uganda	13,745	0.90	0.40	0	4	12		299	185	
Tanzania	35,100	0.90	0.30	0	9	15	77	674		
Zambia	23,152	0.80	0.50	46	8	37	8	209	153	2
Zimbabwe	16,367	0.50	0.50	18	4	9		139	193	19
WANA		0.10	0.10	-	-					
Other ESA		0.20	0.20	-	-					
Other WCA		0.20	0.20	-	-					
Other Asia		0.20	0.20	-	-					
Latin America		0.70	0.70	-	-					
Other developing		0.20	0.20	-	-					
Australia	417,255	1.00	1.00	-	-	4				
Other developed		1.00	1.00	-	-					

Table 4: Ranking of capacity

Country	Mausch final adjusted	Bantilan initial estimates	# trials rank	releases rank	LSU training rank	ASTI spending rank	ASTI persons rank	Pardey (1989) Persons rank	Pardey (1989) spending rank	trials per ha rank	releases per ha rank	LSU train per ha rank	ASTI per ha sepnding rank	ASTI per ha persons rank	Pardey (1989) per ha persons rank	Pardey (1989) per ha spending rank
China	1.00	1.00	15	9	4	-	-	1	1	24	24	26	-	-	5	7
India	1.00	1.00	1	1	1	-	-	2	2	10	15	10	-	-	6	5
South Africa	1.00	1.00	16	6	23	2	4	4	5	20	22	29	6	15	12	10
Thailand	0.70	0.70	24	9	6	-	-	5	6	22	21	6	-	-	4	3
Viet Nam	0.70	0.70	3	6	5	-	-	-	-	4	6	4	-	-	-	-
Ghana	0.60	0.60	10	7	16	3	6	18	20	9	13	14	2	3	18	21
Pakistan	0.50	0.50	18	7	15	-	-	3	9	15	16	17	-	-	1	8
Indonesia	0.50	0.50	4	5	9	-	-	6	4	13	17	16	-	-	8	4
Bangladesh	0.50	0.50	12	7	12	-	-	7	8	8	8	7	-	-	2	2
Ethiopia	0.50	0.80	21	8	15	5	2	12	14	19	20	19	10	2	20	16
Zimbabwe	0.50	0.50	23	6	19	-	14	13	11	18	11	15	-	14	17	11
Senegal	0.50	0.50	11	10	13	8	13	15	12	7	25	8	7	12	9	9
Zambia	0.50	0.80	20	3	7	14	12	17	22	16	7	9	16	13	22	23
Burkina Faso	0.50	0.50	7	9	18	12	10	19	3	5	19	13	12	8	19	1
Myanmar	0.50	0.50	2	5	2	-	-	-	-	3	5	3	-	-	-	-
Nigeria	0.40	0.60	6	9	15	1	1	8	7	14	23	24	3	5	15	12
Cameroon	0.40	0.40	17	10	21	-	-	11	10	11	25	20	-	-	7	6
Uganda	0.40	0.90	25	6	16	-	8	14	-	25	9	12	-	7	14	-

Malawi	0.40	0.90	9	5	3	11	15	20	19	2	2	2	5	6	10	13
Sierra Leone	0.40	0.40	25	7	23	16	19	25	25	25	3	29	11	9	13	20
Chad	0.40	0.40	22	10	21	-	-	26	13	23	25	27	-	-	27	19
Ivory Coast	0.40	0.40	25	10	22	7	16	-	-	25	25	28	9	18	-	-
Mali	0.30	0.60	5	4	17	9	7	9	15	12	14	21	13	16	21	18
Benin	0.30	0.30	13	8	19	10	17	24	24	1	4	5	1	4	11	14
Tanzania	0.30	0.90	25	2	14	4	5	-	-	25	10	18	8	10	-	-
Guinea	0.20	0.20	8	7	11	17	11	16	18	6	12	11	17	11	16	17
Mozambique	0.20	0.80	25	7	10	13	9	21	17	25	20	17	15	19	26	22
Gambia	0.20	0.20	25	8	19	18	20	23	-	25	1	1	4	1	3	-
Sudan	0.10	0.20	14	10	8	6	3	10	16	21	25	22	14	17	24	24
Niger	0.10	0.20	19	5	20	15	18	22	23	17	16	25	18	20	25	25
Central African Republic	0.10	0.10	25	10	22	-	-	27	21	25	25	23	-	-	23	15
DRC	0.00	0.00	25	8	23	-	-	-	-	25	18	29	-	-	-	-

Table 5: Adoption rates and indicators used.

ADOPTION	FINAL Adjust ments	GN area (05-07 mean)	Expert estimat es	Group adjust ments	DIVA based adjust-ments	ICRISAT releases	Release s per ha (10000)	Ndjeunga CRP estimates	1998 "DIVA"	2010 DIVA	Others
Bangladesh	0.20	32,430	0.20	0.20	0.20	3	0.93				
China	0.90	4,211,574	0.90	0.80	0.90	1	0.00		0.9		
India	0.65	5,974,000	0.70	0.60	0.65	26	0.04		0.56		
Indonesia	0.20	639,775	0.20	0.20	0.20	5	0.08				
Myanmar	0.40	803,500	0.40	0.40	0.40	5	0.06				
Pakistan	0.40	91,700	0.40	0.40	0.40	3	0.33				
Thailand	0.50	31,319	0.50	0.50	0.50	1	0.32				
Viet Nam	0.50	253,000	0.50	0.50	0.50	4	0.16		0.17		
Benin	0.10	124,783	0.10	0.10	0.10	2	0.16	0.10			
Burkina Faso	0.25	414,173	0.20	0.20	0.20	1	0.02	0.25			
Cameroon	0.13	325,519	0.30	0.30	0.15	0	0.00	0.13			
Angola	0.10	159,522	0.00	0.00	0.00	0	0.00	0.10			
Chad	0.15	485,168	0.30	0.30	0.15	0	0.00				
DR Congo	0.10	475,578	0.00	0.00	0.00	2	0.04	0.10			
Gambia	0.10	133,208	0.10	0.10	0.10	2	0.15	0.10			
Ghana	0.25	342,933	0.40	0.40	0.40	3	0.09	0.25			
Guinea	0.10	212,280	0.20	0.20	0.20	3	0.14	0.10			
Ivory Coast	0.10	71,049	0.30	0.30	0.15	0	0.00	0.10			
Mali	0.35	353,799	0.60	0.40	0.40	6	0.17	0.35			0.44
Niger	0.30	546,482	0.30	0.30	0.30	5	0.09	0.30			0.14

Nigeria	0.40	2,391,783	0.60	0.40	0.40	1	0.00	0.40			0.32
Senegal	0.35	834,376	0.30	0.30	0.15	0	0.00	0.35			
Sierra Leone	0.10	90,823	0.10	0.10	0.10	3	0.33	0.10			
Ethiopia	0.40	39,695	0.40	0.40	0.40	2	0.50				
Malawi	0.70	263,724	0.60	0.60	0.70	5	0.19		0.10	0.58	
Mozambique	0.40	295,000	0.60	0.30	0.40	3	0.10		0.75		
South Africa	0.85	49,840	0.90	0.60	0.85	4	0.80		0.75		
Sudan	0.10	832,372	0.10	0.10	0.10	0	0.00				
Uganda	0.60	244,000	0.60	0.40	0.60	4	0.16		0.10	0.55	0.59
Tanzania	0.50	548,333	0.40	0.40	0.50	9	0.16			0.35	
Zambia	0.65	150,009	0.40	0.40	0.65	8	0.53		0.20	0.57	
Zimbabwe	0.60	208,367	0.60	0.50	0.60	4	0.19		0.52		
WANA	0.15		0.15	0.15	0.15						
Other ESA	0.10		0.10	0.10	0.10						
Other WCA	0.10		0.10	0.10	0.10						
Other Asia	0.10		0.10	0.10	0.10						
Latin America	0.35		0.35	0.35	0.35						
Other developing	0.10		0.10	0.10	0.10						
Australia	0.75	10,717	0.75	0.75	0.75						
Other developed	0.75		0.75	0.75	0.75						