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Strategic Breeding Investments for Legume Expansion: Lessons Learned from the Comparison of Groundnut and Pigeonpea

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Contributed paper prepared for presentation at the
57th AARES Annual Conference, Sydney,
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Abstract

To examine key factors influencing global research spillovers, this study compares direct and spillover impacts of groundnut (GN) and pigeonpea (PP) research to be used for resource allocation. The estimation of global research benefits from breeding research uses an economic surplus based international trade model. GIS tools are used to analyze applicability of new technologies across a range of agro-climatically homogeneous zones.

High photoperiod sensitivity and concentrated production of PP limits global applicability of varieties and thus spillover effects are lower as compared to GN. Comparing these two crops highlights the differences across crops and their potential global benefits. Utilization of spillover measures will assist in tailoring research investments to the individual characteristics of the crop, and thus increase research efficiency and ultimately enhance diffusion of improved varieties for the benefit smallholder farmers globally.

Keywords: Strategic Agricultural Research Targeting, Spillover Effects, Legumes

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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, Dalrymple, and Ruttan 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 generates 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 fulfil its mission. One part of this 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 zone 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 zone is also applied in other zones. 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 price change will affect the world price and therefore other zones 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) Spillover effects from agricultural research among states or zones have received little attention in the breeding programs of ICRISAT although they can be of crucial importance for research fund allocation decisions as well for increasing the impact of breeding.

ICRISAT as part of the Consultative Group of International Agricultural Research (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 enable them to get out of poverty. It is important to note here the important 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 selecting and adapting crop varieties and livestock breeds for local conditions using materials developed elsewhere. Only a few developing countries in Asia and Africa were able to achieve much by themselves at the more upstream stages of the research and innovation process, even for improved crop technologies for which conventional breeding strategies are widely applied. It is widely understood that, international agricultural research aimed at improving productivity in developing countries also has spillover effects on developed countries (Brennan and Bantilan 2002). Until recently, that strategy was 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. More importantly, the ICRISAT mandate crops receive less attention in industrialized countries or at the very least the breeding targets for large scale industrialized farmers at very different from those tailored to resource poor smallholders in the semi-arid tropics. 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 six sections. The first one gives a short introduction to the topic, followed by the theoretical background on the methodology and framework used. The third section outlines the application of the model to the research problem at hand with the fourth presenting the results. Before coming to the summary and conclusions in part six, some in-depth discussion of future applications is highlighted.

Methods

In contrast to most technology spillover effects from industrial research and development, agricultural innovations are not applicable in all environments and therefore the applicability is different for these two types of innovations. While, in the context of technology spillovers, trade and FDI 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, first the movement within one ecozone and second 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 should be the norm as the same environmental factors are present and thus the same variety would have the same benefits all across. 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% while in the latter case, the spillover effect, the applicability is significantly lower than 100%.

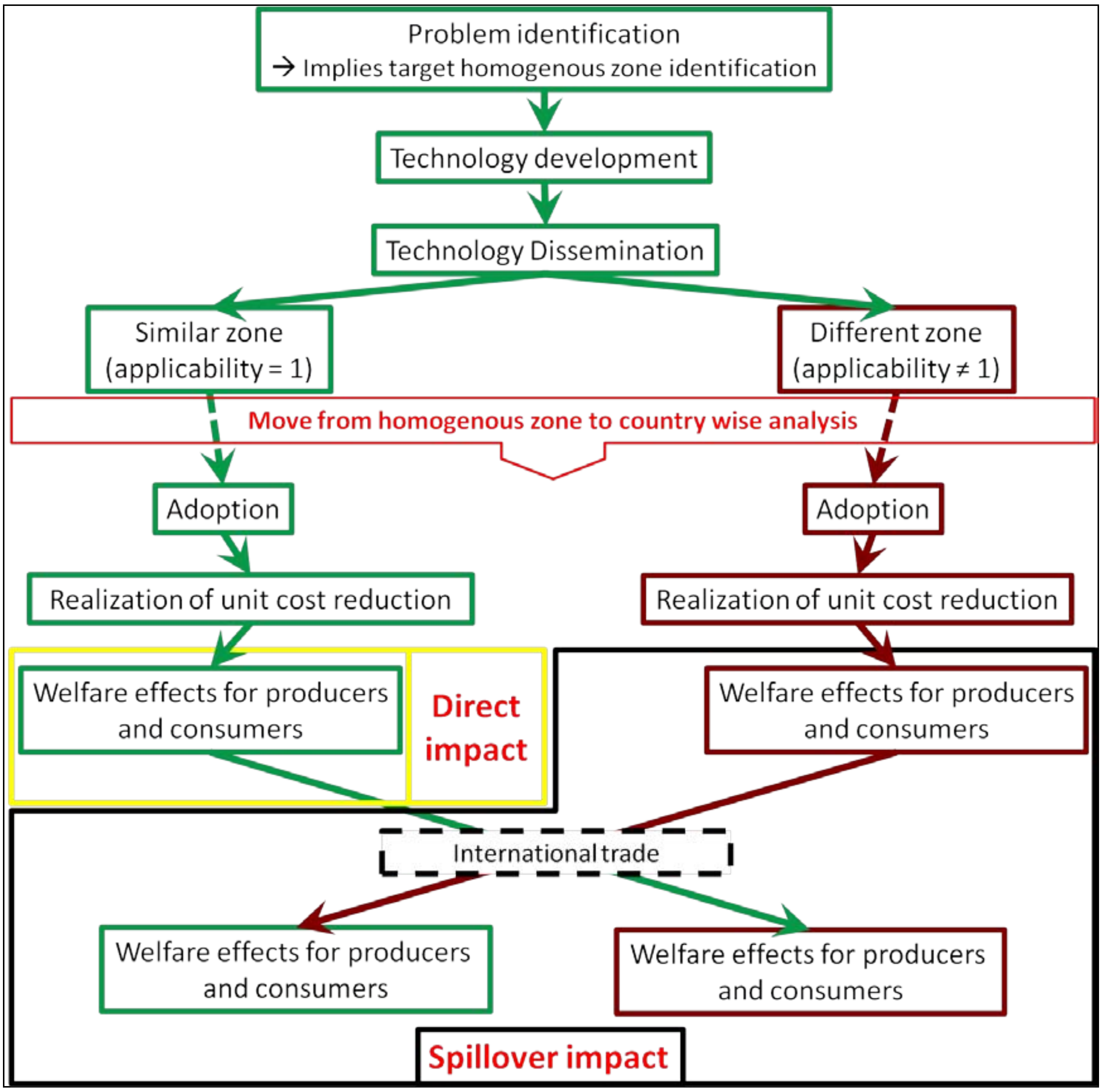


Figure 1: Spillover effects and impact. Source: Own presentation based on Davis et al (1987) and Mareida et al (1996).

To measure spillover effects, Davis et al (1987) base their analysis on these seven main steps: 1: Selecting commodities; 2: Definition of 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))

As for ICRISAT the commodities are clearly defined in its mandate, the selection was made from this set of five crops. In this paper, Groundnut and Pigeonpea have been chosen for the analysis as the two more widely grown legume crops. The second step - the definition of the homogenous zones/zones - is one of the most important steps. This step is of crucial importance as on the basis of this 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 on 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 the applicability on a global level and thereby allow 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 in 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 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 measure global welfare gains from agricultural research

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) when 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

For several of these indicators data is available from FAO and other sources. 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 IFPRI for the 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

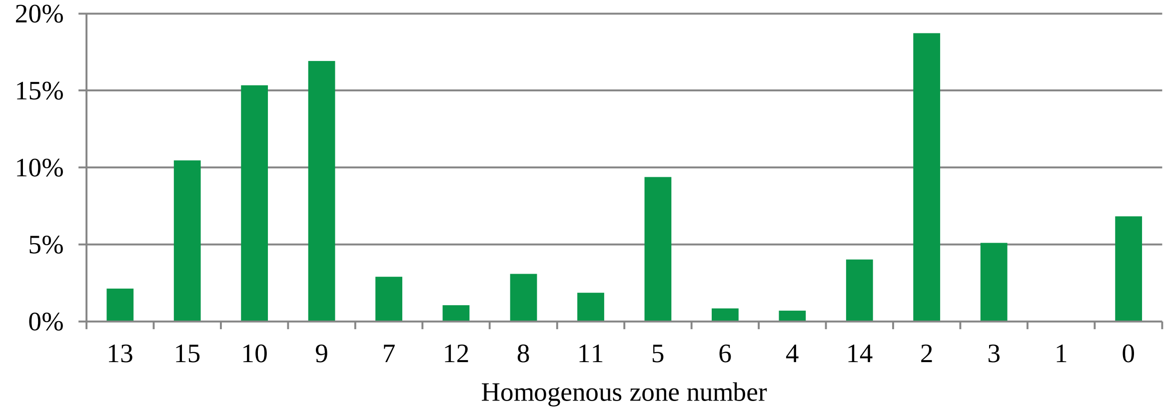
One of the crucial inputs in the model are the homogenous zones across the world for the crop in question. Therefore, the homogenous zones as developed by Mausch Bantilan (2012) were included for the groundnut estimation and using the same methodology pigeonpea zones were developed and included (See Figure 7 and Figure 8, Appendix, p.23f.). Both zones are mainly based on the agroecological zones (AEZ) developed by FAO (2000). These 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 crop expert were held to understand the specific needs of the crop and further refine the zones.

For groundnut the most important feature added was the length of growing period (LGP) and thereby the delineation between short and medium duration groundnuts and long duration groundnut growing areas. The cut-off point was set at 120 days based on international trial results conducted by ICRISAT over the last decades.

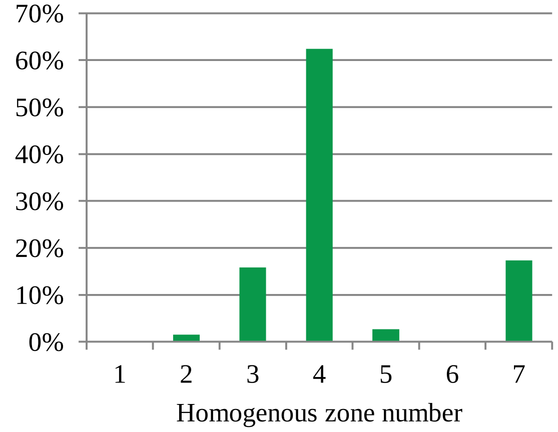
For Pigeonpea, the most important feature is the photoperiod sensitivity of the crop. This leads to a very limited applicability of one variety across latitudes. However, as the AEZ are already implicitly accounting for this factor as also the climate variable change along latitudes it was not necessary 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 is already accounting for the major temperature differences. After overlaying the elevation levels of 1500m, which was mentioned as a cutoff point, it was found that this is also already covered in the AEZ. The warm and cold tropics are delineated along just this line and therefore the AEZ was the sole base layer for Pigeonpea. 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 AEZ. Finally, all areas with less than 90 days LGP were cut out to make sure that only zones that can grow pigeonpea under rainfed conditions are included. For the final homogenous zones, see Figure 9.

Production proportions

The production proportions represent the share of the total production in each HZ. These proportion were calculated using the Harvest Choice (2009) and Monfreda (2008) for groundnut and Monfreda (2008) only for Pigeonpea as the Harvest Choice (2009) does not account for Pigeonpea individually. Therefore, we have the exact production of groundnuts and Pigeonpea in each HZ in aggregate as well as by country and HZ. The aggregate is depicted in Figure 2, for the country level see Table 5, Appendix, p.26.



a: Production across groundnut HZs.



b: Production across pigeonpea HZs.

Figure 2: Production across HZs. Source: Own calculations based on HARVEST CHOICE (2009).

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. The main difference between these two crops is the wide distribution of groundnut production across many different zones while the pigeonpea production is very concentrated in one single zone.

Cross homogenous zone applicability

Based on the crop specific HZs developed, the applicability of varieties across these zones was established for each cop. 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 this would give the actual performance (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 during the past 40 years do not cover all zones and do not include enough replications for individual varieties[2] to make econometric estimation viable. Furthermore, it is only possible to attribute the target zone for a few varieties that were officially 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 judgment is of high value for this exercise and therefore

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[2] 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.

the applicability was estimated using their judgments and selectively cross checked with the data available. This approach was consistently taken for both crops.

For the actual discussion a large scale print out of the HZ maps as well as the Harvest Choice (2009) was 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 are high and they get more comfortable with the general idea. This led them to further estimate the factors for zones less familiar with them but for which they actually have a very good feel 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 is the reason for the zero estimates for zones 0,1,2,3 and 14. As the material developed by ICRISAT is not taking those zones into account 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 between those zones but based on our work we are not able to predict this and it is not relevant in the framework of ICRISAT 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.

After a first round of estimations, some numbers were adjusted based on the discussions during the process to better reflect some ideas mentioned. Here the numbers marked in red were lowered and the green ones were increased by 0.1 each. These adjustments were reconfirmed in a second visit which led to the final matrix as given in Table 3 and Table 4(see p.25f). Additionally, after the adjustments were made a few selected trials were and inspected for consistency with the results which confirmed the confidence in the expert estimates.

After initial estimations of the ex ante welfare benefits and the implications of the matrix were discussed with the breeders in an effort to highlight the importance and confirm the 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 final (adjusted) numbers were confirmed.

Research focus

In the original model as set up and further developed by the Australian Centre for International Agricultural Research (ACIAR) the research focus reflected the focus of the various national research programs in each country. In this adjusted version we introduced ICRISAT which does research on its own and is not depended (although influenced by) on national programs for their own priority setting. Therefore the ICRISAT research focus is variable and reflects different scenarios of different possibilities ICRISAT has in distributing their efforts.

Capacity of the national programs

The capacity of the national agricultural research programs (NARS) was implemented in steps that determine the likelihood that any material developed or introduced is successfully taken up. First, the capacity to conduct innovative research successfully and second, the capacity to adopt and/or adapt innovations from other sources was assessed separately. Here, the innovative capacity was set to 100% as for the estimations it was assumed that ICRISAT will conduct the innovative research and the final benefit levels are assessed based on the assumption that the research conducted will be successful. Therefore, the national programs only need the capacity to adapt the results.

Multiple crop specific indicators were used as a basis for the parameter estimates (see Table 8, p.29) 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.

Initially, ICRISAT experts were used to generate a set of estimates of the perceived strength of all national programs based on their experience and interactions with them 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. Given the secondary data on capital and staff endowment the expert judgements were adjusted to better reflect data available. After these two rounds, estimates were critically investigated by the team to discuss if the relativities are representative and some were adjusted to better reflect these. Furthermore, each indicator listed in Table 8 was used (in absolute as well as per ha terms) to create a ranking of all countries (see Table 9) covered and thereby ensure that the final estimate represents these ranking and the relativities involved as accurate as possible for each crop. In the end it turned out that, based on the nature of both crop being legumes and mostly not the major focus in the national research agendas, the capacity levels are equal for groundnut and Pigeonpea as the crop programs are mostly clubbed into 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 the most important institutional and infrastructure conditions like market structure, road network or trader preferences. These are the basic conditions that influence adoption to a large extend but also take long time to be changed and therefore can be assumed 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 countries considered. Similar to the procedure utilized for the capacity levels, in a stepwise procedure, these judgments were validated using multiple discussion rounds with experts from different zones and from different backgrounds (economists, breeders and agronomists) which were along the process backed with available data from various countries. This process made sure that estimates are consistent across countries as starting from pure expert estimates the rates given were cross-checked against 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 10 (p.33).

Unit cost reduction

The unit cost reduction represents the anticipated yield gain and takes possible increases in input levels into account that result from the research conducted. 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 ranging between 9.84 and 44%[3]. After an in-depth cost analysis for several countries, in the case of groundnut, 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 the very high farm gate price in 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 only across homogenous zones or for different technologies the reductions will alter.

Adoption pattern

The adoption pattern is illustrating the adoption 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 was decided to leave it equal for all countries. Furthermore, it is believed that this pattern will be highly correlated with the NARS strength and all judgments that could be implemented would thus be likely to lead to double discounting for

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[3] 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)

countries with a weak national research system. Furthermore, sensitivity analysis showed this factor does not influence the results to a significant extends when altered within a reasonable range.

Results

Benefits across zones and countries

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 it is of crucial importance to understand the flow of technologies across countries and zone boundaries and the determining factors underlying this movement. The central question is on 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 main target of this paper is providing evidence to compare likely outcomes across countries or zones and utilizing these to improve targeting and thus impact achievements with respect to the desired outcome(s) from groundnut and 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 which HZ focus 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 1 for groundnut and in Table 2 for pigeonpea. While the Asia and Africa column includes all countries to give a better overview, the ICRISAT total column only sums up all countries set as focus countries in the newly established Consortium Research program 3.5 (CRP) 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 1: Benefits by focused HZ with and without cross-HZ applicability – Groundnut.

	Applicability			**NO applicability**			**production covered**
HZ	**CRP total**	**Asia**	**Africa**	**CRP total**	**Asia**	**Africa**	
	US$ mill	US$ mill	US$ mill	US$ mill	US$ mill	US$ mill	%
10	1363	1313	233	818	699	121	15.3%
9	1336	1444	239	462	380	112	16.9%
7	1254	1378	217	35	35	0	2.9%
15	1015	1156	176	400	310	90	10.5%
13	961	1119	158	128	127	1	2.1%
12	843	1031	146	86	84	2	1.1%
5	802	1438	136	13	759	0	9.4%
8	642	859	121	41	42	13	3.1%
4	631	776	108	36	36	2	0.7%
11	557	1004	93	1	12	0	1.9%
6	449	540	86	12	14	12	0.8%
0	69	365	21	69	365	21	6.8%
2	1	1924	1	1	1924	1	18.7%
3	0	543	0	0	543	0	5.1%
14	0	426	0	0	426	0	4.0%
1	0	0	0	0	0	0	0.0%

Note: Results sorted according to Total in focus countries under applicability assumption.
Source: Own calculations based on the assumptions in Table 5, Table 6, Table 7 and Table 10.

The most obvious point from the comparison above is the huge difference between the benefit levels from the two scenarios with and without applicability across HZs. This not only highlights the importance of spillover effects across HZs but also highlights that effort put into promoting the movement of varieties across countries and continents are well spend as they do generate huge benefits. All in all, comparing the different benefits levels across the HZs, there is not one or a couple of HZs that dominate the benefit levels but there are several that generate high and comparable benefit levels with a rather equal distribution thereafter.

For Pigeonpea the distribution is very different based on several factors. First of all, the high degree of photoperiod sensitivity hugely reduces the potential for cross zones applicability as seen in the applicability matrix and thus the benefits levels align much more with the production proportions. The exception is only zone 2 from which high levels of benefits arise to other zones. Zone 2 and 7 are also the only two zones where the two scenarios with and without applicability to make a significant difference for the total benefit levels. Which suggest that the efforts in pigeonpea should be concentrated in making the seed available within each zone but it would almost never be economically beneficial to try and make varieties available across zones – this is with the exception of zone 2 material that could benefit other zones hugely.

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

	With applicability			**Without applicability**			**Production covered**
HZ	**CRP total**	**Asia**	**Africa**	**CRP total**	**Asia**	**Africa**	
	US$ mill	US$ mill	US$ mill	US$ mill	US$ mill	US$ mill	%
4	702	687	16	610	601	10	62.4
2	592	577	15	9	9	0	1.5
7	429	416	13	119	111	8	17.3
3	153	153	0	153	153	0	15.8
5	8	3	5	5	3	2	2.7
1	5	3	2	8	3	5	0.2
6	0	0	0	0	0	0	0.1

Source: Own calculations.

Another big difference between the two crops is that the pigeonpea production and also the benefits are, in the 'with applicability' and thus the reality case, very concentrated in 2-3 zones. 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.

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 3 (for groundnut) and Figure 4 (for Pigeonpea) where the four 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 for both crops.

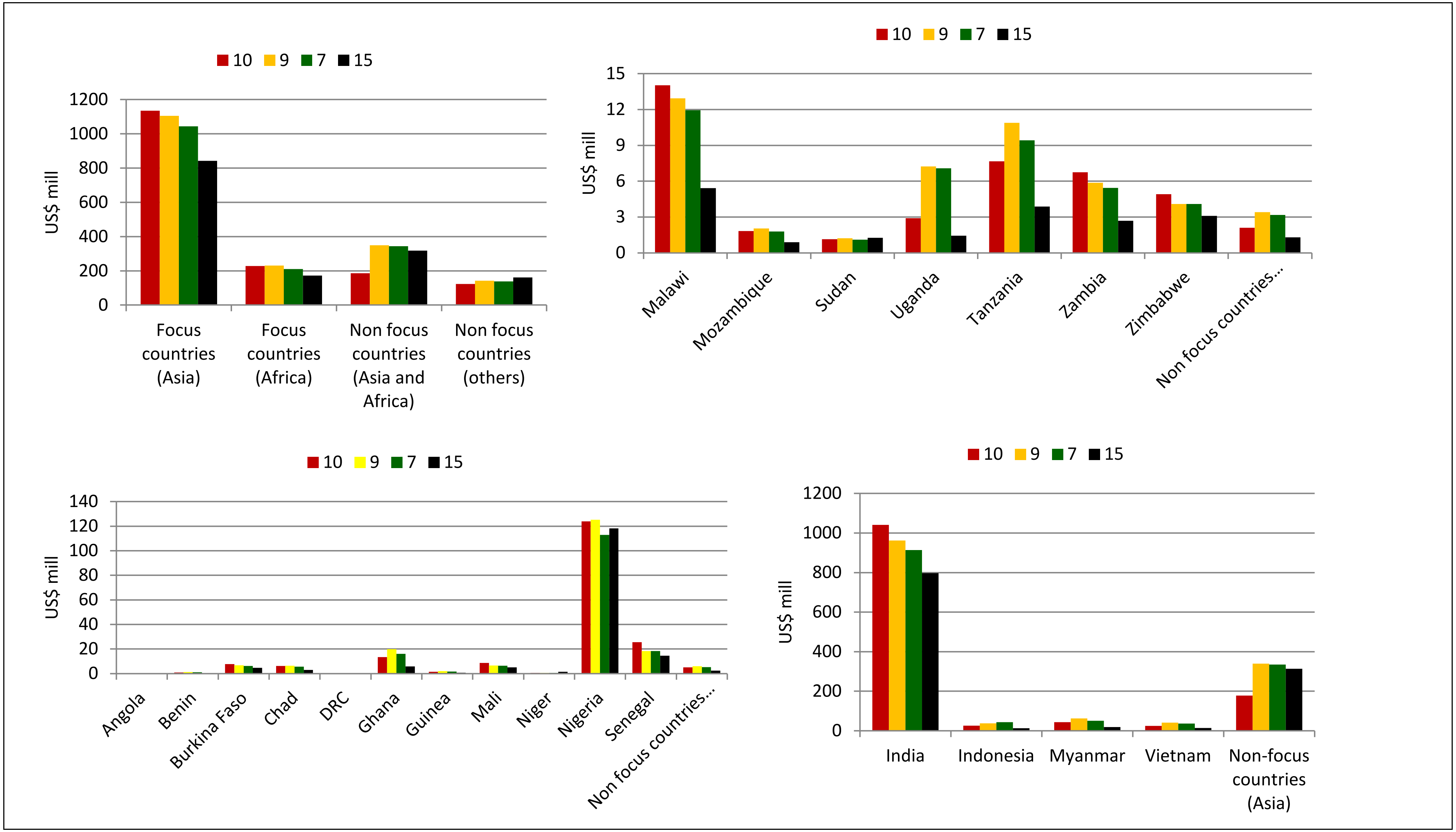

Figure 3: Realistic scenario country level groundnut benefits (mill. US$) for 4 main HZs. Source: Own calculations.

While for some countries like Nigeria the results are fairly constant based on their size and the diverse environments that incorporate many different zones, others fluctuate much more. Taking the case of Malawi and Tanzania as one of the most prominent East African groundnut producers, the move from HZs 7, 9 or 10 to number 15 significantly reduces the benefits while for some of the non focus countries like China it wouldn't make a difference in benefit levels and in Niger it would even more than double the resulting benefits – although these are still minimal due to their very limited production level. However, it is also obvious that most of the benefits will be generated in India and therefore the overall aggregate ranking is hugely influenced by the presence and size of each zone in India itself.

One of the major differences between groundnut and pigeonpea is the cross country distribution of the benefits. While India is the major beneficiary of groundnut research for most scenarios, many countries do benefit to an often large extend. In pigeonpea however, the share of benefits to India is close to 100% no matter on which zone the research focuses. Furthermore, the difference in the total benefit levels between the main zones research benefits are much higher than in groundnut. The targeting of zones and the funding allocation between those is thus even more important in efforts to maximize the benefits.

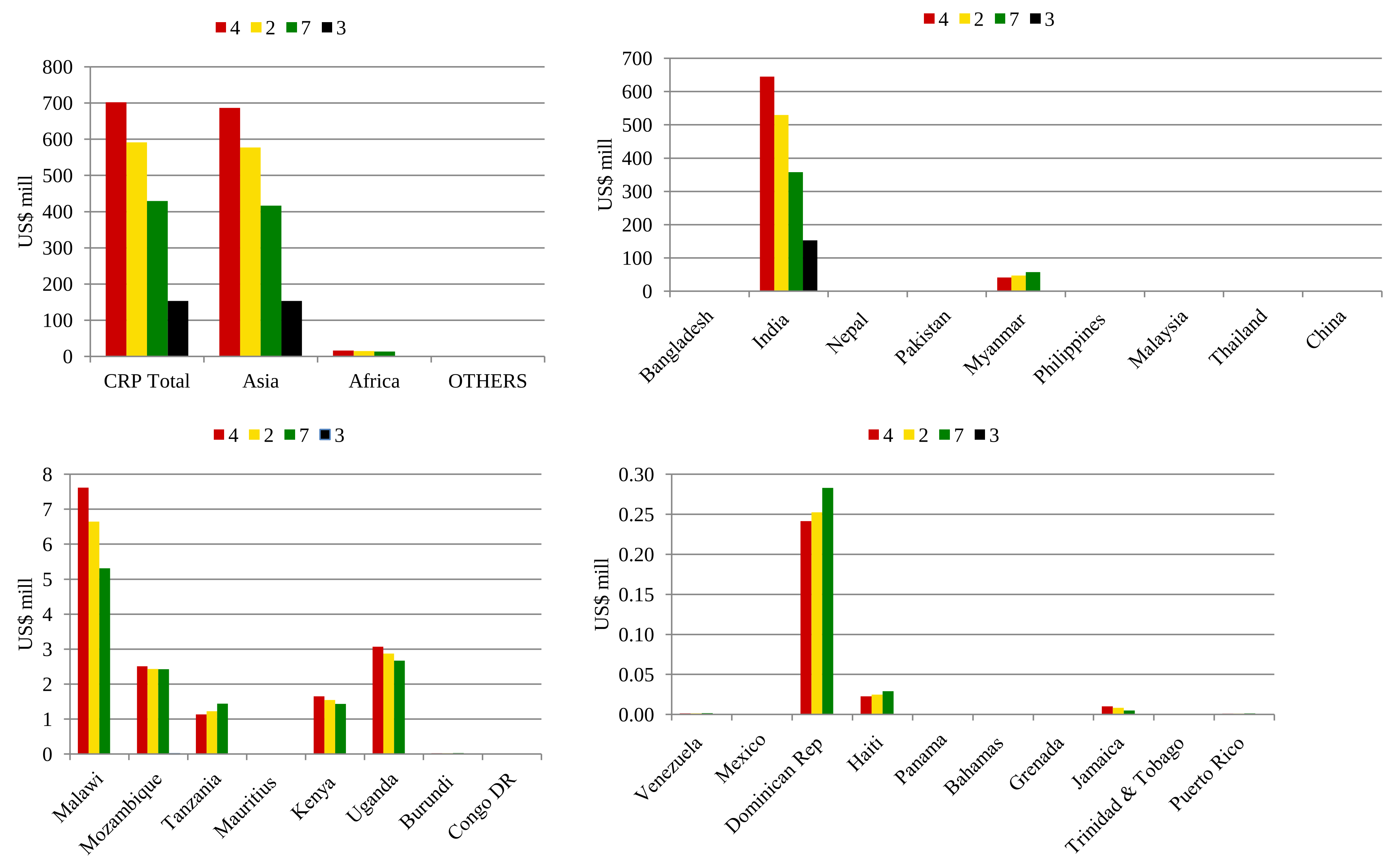

Figure 4: Realistic scenario country level pigeonpea benefits (mill. US$) for 4 main HZs. Source: Own calculations.

Results for both crops 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 most 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 7 in groundnut where only marginal benefits accrue in the zone itself but many other zones could benefits hugely.

Discussion and first steps for future research directions – Reaching the outcomes we aspire to and benefits under different scenarios

Following these results, the intuitive next step is asking two central questions. First, how do these aggregate welfare gains affect the target population? In case of the CGIAR and ICRISAT these groups could be the rural poor, the undernourished, women or any other group targeted with the various outcome statements. Second, how else can we use this model to reflect other projects like capacity building efforts and thus get a comparative picture on where research managers should put their money to get the often referred to ‘biggest bang for the buck’?

The following section presents some first attempts to get closer to answer those two major questions. However, there are several further research questions to be investigated before these results should be used in decision making. One of the major constraints so far remains that the distribution across several subgroups of the population cannot be incorporate based on data limitations. Thus, for we have to rely on the assumption that in whichever zone the benefits occur, the group in question will inevitably benefit in one way or the other and do not yet attempt to quantify those benefits. Furthermore, for the ICRISAT mandate crops presented here we can comfortably say that the majority of the area under production is farmed by small and poor farmers which is one of the target groups.

To reliably make decisions on the second question, it is of crucial importance go 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 time frames 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 option will have for research management decisions and project design once the further background work is done.

Strategic consideration like the above posed questions within the international agricultural research community and in the framework of setting up research projects become increasingly important with pressure mounting to increase measurable impact in improve ex ante targeting efforts. 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 almost doubles. (see Figure 5 for a country level comparison) Especially for many African countries, this effect is even more pronounced 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 the total country level benefits.

Comparing these effects across countries[4] reveals clear implications for targeting different problems across different countries and the potential benefits that result. Figure 5 shows the potential that exists in e.g. Chad or DRC in case of groundnut or Malawi and Mozambique for Pigeonpea with benefits levels multiplying when the adoption constraint along with the capacity constraint is lifted. This comparison also highlights the different needs of countries. While for groundnut in Myanmar the capacity constraint is more binding, the adoption is already at higher levels, Indonesia already

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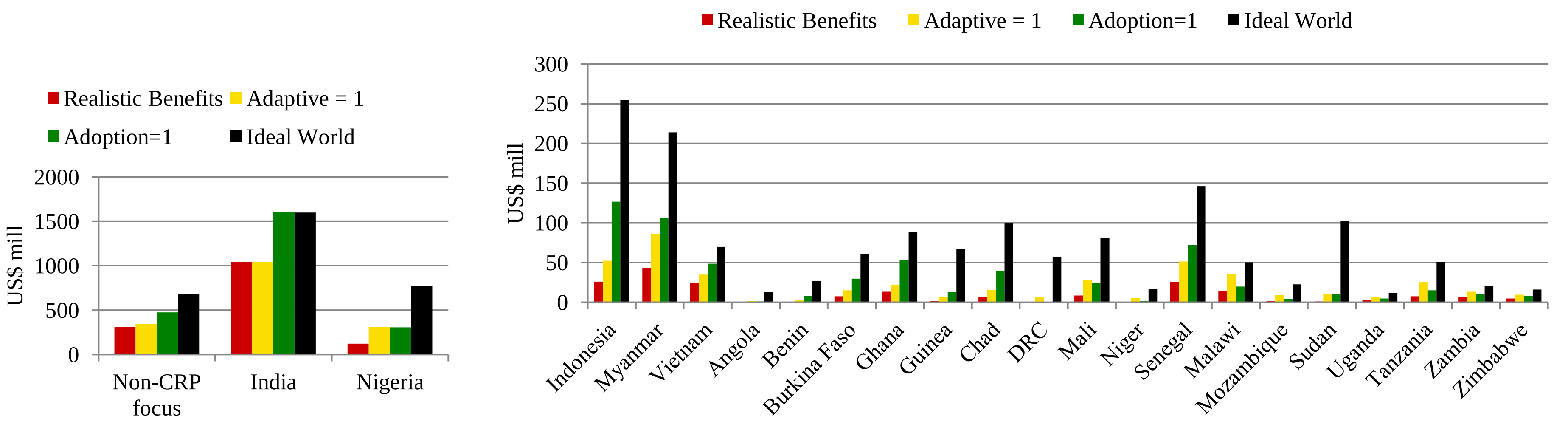
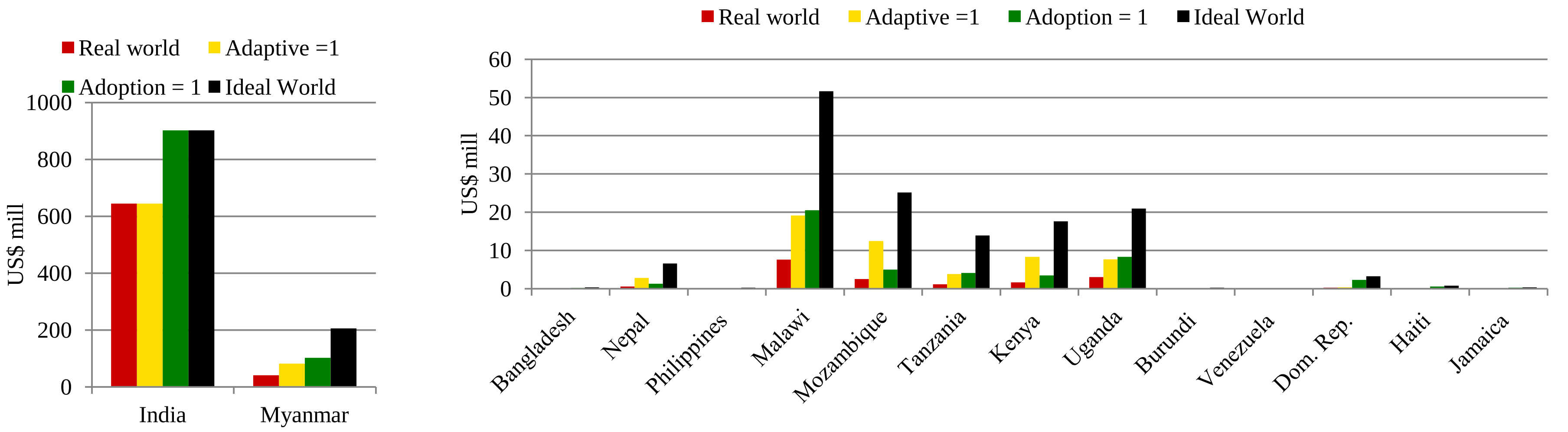
[4] India and Nigeria were separated based on the huge difference in total benefit levels.

has good capacity levels and therefore lifting the adoption levels to its full potential would result in a bigger jump in benefit levels. In many African countries with often very low levels of capacity and adoption which lower their benefit levels, the effects the effects of pure focus on breeding are negligible when these factors are not addressed alongside. Investing in improving these conditions by e.g. training of research staff in these countries has the potential 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.



(a) Groundnut



(b) Pigeonpea

Figure 5: Groundnut and Pigeonpea benefits (mill. US $) by country under different scenarios (targeting the highest total benefit HZ). Source: Own calculations.

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 like DRC. The adoption and capacity levels are so poor that the technology will not reach the farmers which will results 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 like India with its very high capacity and adoption levels are entirely or mostly driven by improved variety development alone and the resulting unit cost reduction.

Turning to the question about the distribution of benefits with a country, the outcome desired might not always be best served by targeting the highest total benefit zones. There could be cases in which other zones where e.g. malnutrition or poverty levels are higher and although total benefit levels are lower a project could have a bigger impact on these outcomes. One first attempt to visualize this concern is utilizing GIS tools and publicly available global maps on the subnational distribution of indicators like poverty or malnutrition. One example is outlined in Figure 6 where the average calorie consumption per capita is mapped alongside the country level benefits.

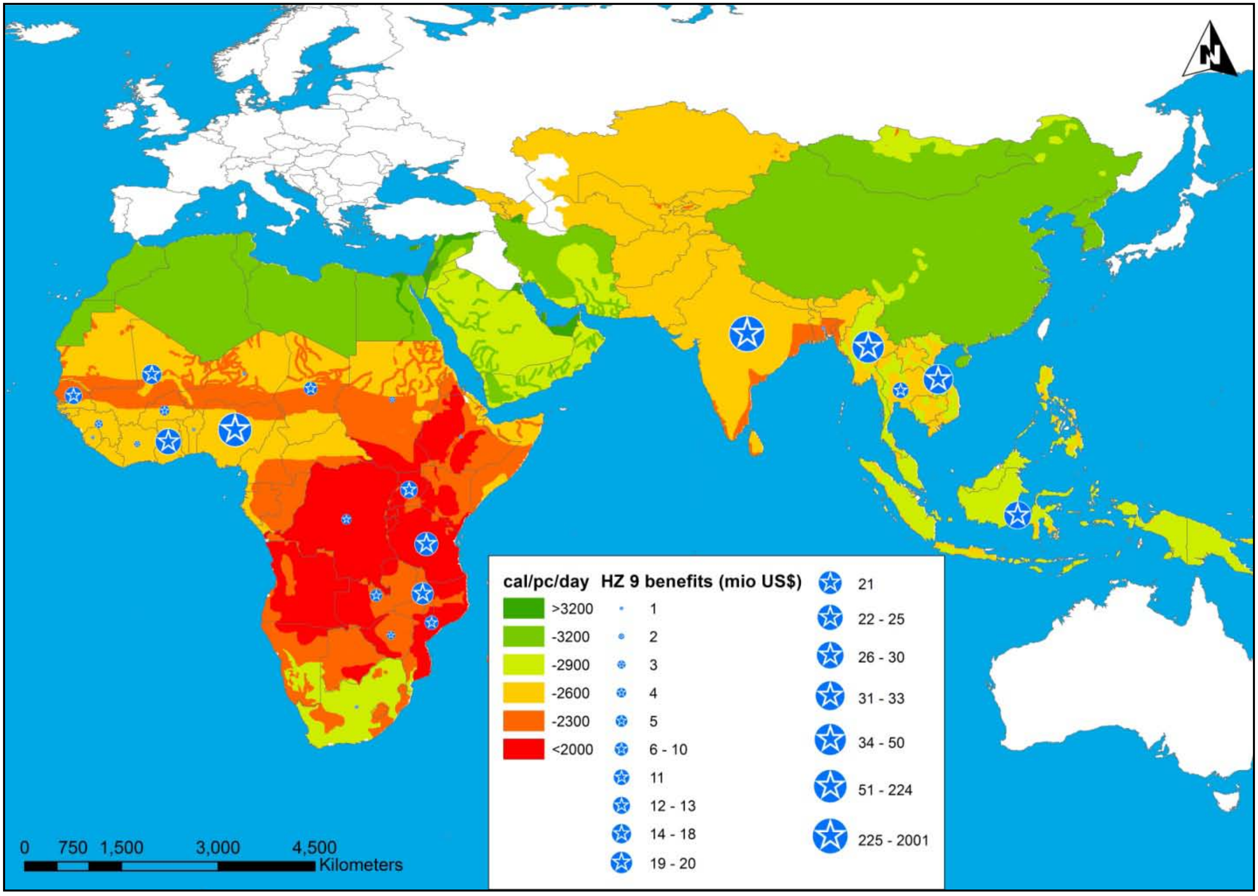


Figure 6: Groundnut research benefit levels of HZ 9 targeting and calorie consumption per capita. Source: Own calculations. The calorie data used is based on ifpri (2011).

When the outcome is supposed to be reduced food insecurity the zones with lower levels of consumption should be the primary focus and thus the HZ should be targeted that provides a distribution of benefits that favors those food insecure areas. Figure 6 gives an example for groundnut research in HZ 9.

To further improve upon this analysis, it would be ideal to get subnational benefits. This could be attempted by disaggregating the country level benefits along the HZs. However, this disaggregation is not trivial and has to be carefully examined.

Summary and Discussion

The comparison of Pigeonpea and Groundnut breeding efforts and their resulting benefit levels across the world in this paper led to interesting insights that can assist in targeting future research and has the potential to increase efficiency in fund allocation. Especially with both crops being legumes the comparison is not distorted by very different target groups and zones which could lead to problems when comparing e.g. groundnut and millets. Furthermore, avenues for further enhancement of the analysis have been highlighted and will be explored in the future.

First, 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 also quicker. The wide applicability of groundnut varieties could be fully utilized if the mostly long and expensive release procedures would be easier. The benefit levels that would result from a wider spread and accessibility would be huge and thus efforts like the ASARECA policy to ease the release procedure for varieties that are already released in at least 3 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 (e.g. under ICRISAT leadership) to include not only new promising varieties but also several released varieties that already proofed to be successful. The trials could be aligned with the zones developed in Mausch / 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 and are well adapted to the local farming systems.

Secondly, the comparison highlights the difference in these two legume crops in terms of their potential for cross border and cross-zone spillovers. While groundnut is generally widely applicable, pigeonpea is much more sensitive to changes in climatic conditions like photoperiod, altitude and temperature. This makes the movement of pigeonpea much more difficult and therefore the spillover effects are much lower as compared to groundnut. Thus, one could call groundnut a truly global crop that accrues benefits all over the world while pigeonpea is a rather regional / niche crop with production focused in South Asia and some (export) production in East Africa. Therefore, while doing research in a centralized system one could still harness benefits all over the world in the case of groundnut, in pigeonpea research with its limited applicability across zones the benefits will only accrue in those two zones where pipeonpea is currently grown and / or consumed.

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Appendices

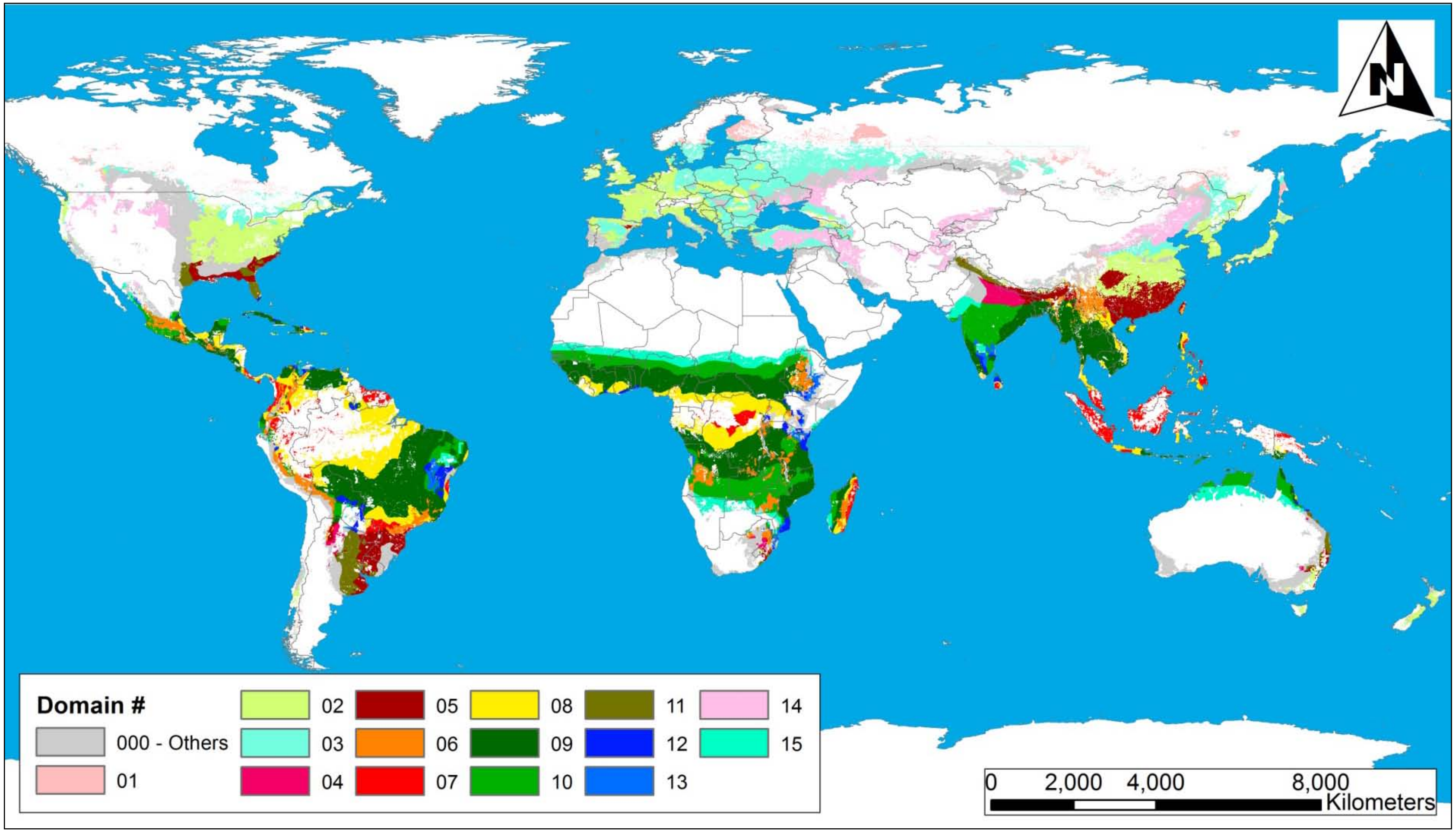

Figure 7: Groundnut homogenous zones. Source: Own presentation.

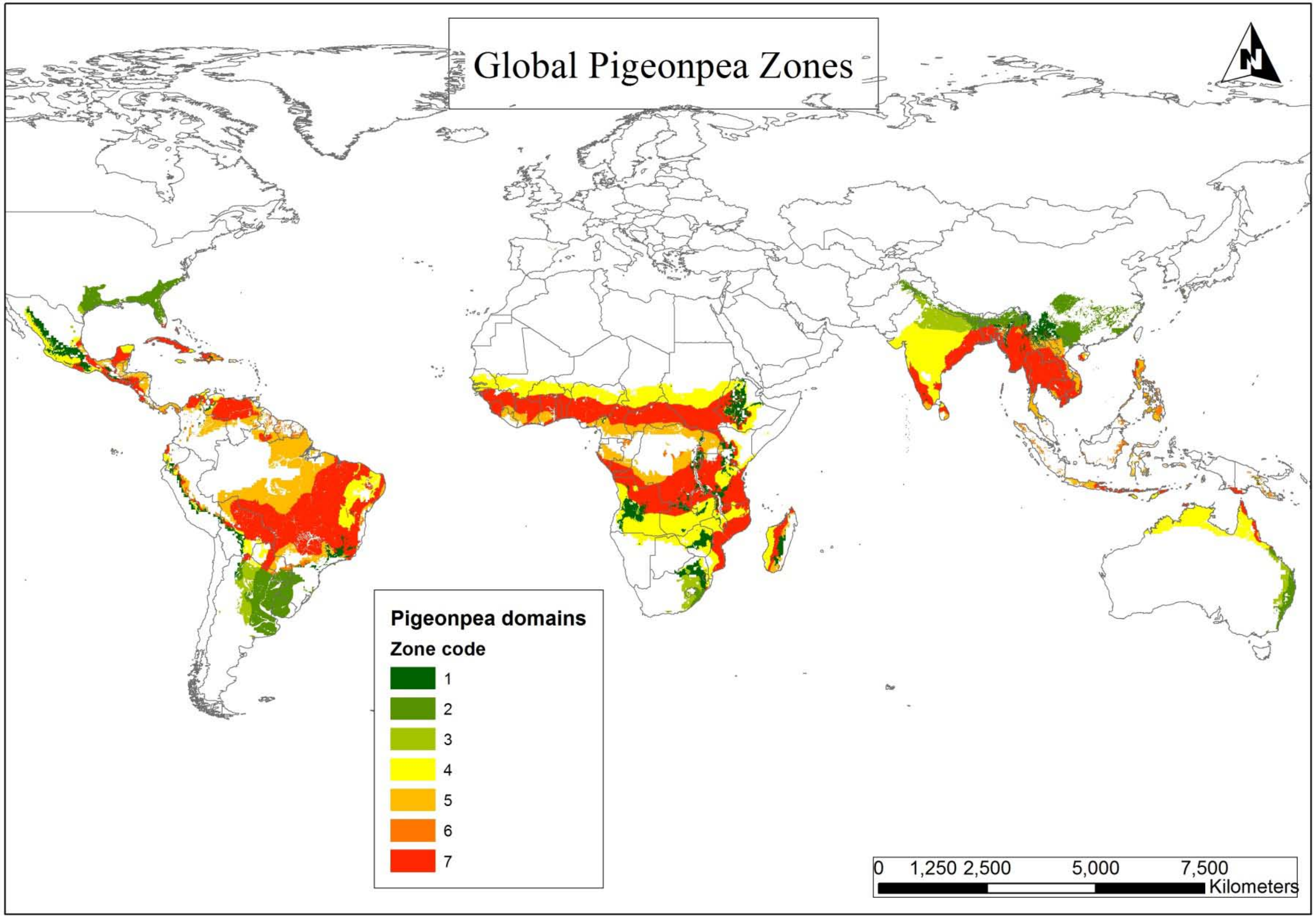

Figure 8: Global pigeon pea homogenous zones

Table 3: Adjusted applicability matrix for groundnut

	13	**15**	**10**	**9**	**7**	**12**	**8**	**11**	**5**	**6**	**4**	**14**	**2**	**3**	**1**	**0**
13	1	0.8	0.4	0.3	0.3	0.3	0.1	0.5	0.4	0	0	0	0	0	0	0
15	0.8	1	0.4	0.3	0.3	0.3	0.1	0.5	0.4	0	0	0	0	0	0	0
10	0.3	0.3	1	0.7	0.6	0.3	0.2	0.4	0.2	0.2	0	0	0	0	0	0
9	0.4	0.3	0.7	1	0.8	0.6	0.6	0.2	0.4	0.3	0.4	0	0	0	0	0
7	0.3	0.3	0.7	0.8	1	0.8	0.6	0.2	0.4	0.3	0.4	0	0	0	0	0
12	0.3	0.3	0.3	0.6	0.8	1	0.6	0.2	0.4	0.3	0.4	0	0	0	0	0
8	0	0	0.2	0.7	0.7	0.7	1	0	0.4	0.2	0.6	0	0	0	0	0
11	0.5	0.5	0.2	0.2	0.2	0.2	0	1	0.7	0	0.1	0	0	0	0	0
5	0.4	0.4	0.4	0.4	0.4	0.4	0.1	0.7	1	0.2	0.3	0	0	0	0	0
6	0	0	0.3	0.3	0.3	0.3	0.2	0	0.2	1	0.2	0	0	0	0	0
4	0	0	0.4	0.4	0.4	0.4	0.7	0.1	0.3	0.2	1	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Source: Own presentation based on elicitation with several ICRISAT scientists.

Table 4: Applicability matrix for pigeon peas

	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 presentation based on elicitation with several ICRISAT scientists.

Table 5: Production proportions and research focus by country.

	13	**15**	**10**	**9**	**7**	**12**	**8**	**11**	**5**	**6**	**4**	**14**	**2**	**3**	**1**	**0**
Bangladesh				0.88			0.00		0.10							0.01
China				0.003			0.003	0.002	0.187	0.003		0.107	0.482	0.136		0.075
India	0.081	0.196	0.441	0.166		0.052	0.001		0.001		0.023					0.039
Indonesia			0.014	0.087	0.705		0.180			0.005						0.009
Myanmar				0.917			0.030		0.020	0.030						0.003
Pakistan								0.457	0.022			0.002	0.009			0.510
Thailand				0.960			0.038									0.002
Viet Nam				0.476	0.001	0.021	0.304		0.169	0.001						0.029
Benin			0.098	0.814		0.086										0.002
Burkina Faso		0.181	0.566	0.252												0.002
Cameroon		0.077	0.407	0.232			0.248			0.031						0.005
Angola			0.008	0.795			0.198									
Chad		0.071	0.436	0.489												0.003
DR Congo			0.002	0.542	0.010	0.001	0.379			0.053						0.013
Gambia			0.943													0.057
Ghana	0.002			0.891		0.014	0.080									0.014
Guinea			0.028	0.930			0.042									0.001
Ivory Coast			0.001	0.804		0.008	0.179									0.008
Mali		0.184	0.739	0.073												0.005
Niger		0.926	0.069													0.005
Nigeria		0.388	0.291	0.312			0.002			0.002						0.007
Senegal		0.171	0.828													0.001
Sierra Leone				0.995			0.005									
Ethiopia	0.080	0.111	0.067	0.079		0.012	0.002			0.392						0.256
Malawi			0.525	0.268						0.187						0.019
Mozambique	0.041	0.021	0.311	0.549		0.031				0.032						0.015
South Africa	0.003	0.007	0.005							0.071	0.103					0.811
Sudan		0.459	0.206	0.314		0.007	0.003									0.012
Uganda				0.093		0.030	0.761			0.014						0.102
Tanzania	0.042	0.006	0.042	0.579		0.101	0.029			0.120						0.079
Zambia			0.660	0.268						0.065						0.007
Zimbabwe		0.177	0.430	0.008						0.346						0.038
WANA												0.007	0.001	0.004		0.319
other ESA	0.016	0.038	0.089	0.497	0.012	0.012	0.048			0.215						0.046
Other WCA		0.007	0.127	0.542	0.016	0.049	0.254									0.005
other Asia	0.001		0.013	0.639	0.103	0.027	0.176			0.004						0.024
Latin America	0.018	0.011	0.046	0.268	0.017	0.007	0.150	0.009	0.026	0.014	0.002					0.429
Other developing												0.403	0.001	0.267	0.001	0.043
australia	0.001	0.015	0.196	0.088		0.002		0.086			0.002					0.611
other developed								0.299	0.373			0.006	0.169	0.007		0.145

Source: Own calculation based on HARVEST CHOICE (2009) maps provided by ifpri. Note: empty cell represent no production in the country in that HZ.

Table 6: Average Production and consumption over latest available 3 years (2005-2007).

Country	**Average Production** ('000 mt)	**Average Consumption** ('000 mt)	**Country**	**Average Production** ('000 mt)	**Average Consumption** ('000 mt)
Bangladesh	40.92	41.22	Nigeria	3712.87	3723.27
China	13428.13	12458.60	Senegal	498.35	603.35
India	7346.43	6662.63	Sierra Leone	111.64	111.65
Indonesia	1440.47	1651.77	Ethiopia	39.92	39.69
Myanmar	984.67	982.74	Malawi	201.99	200.56
Pakistan	75.48	82.04	Mozambique	93.97	91.15
Thailand	115.00	155.61	South Africa	65.33	80.98
Viet Nam	487.27	361.76	Sudan	546.33	546.53
Benin	118.06	125.15	Uganda	159.33	159.65
Burkina Faso	226.96	226.25	Tanzania	294.62	299.68
Cameroon	192.65	187.73	Zambia	72.74	72.70
Angola	63.22	62.54	Zimbabwe	88.64	123.70
Chad	374.09	385.60	WANA	304.67	454.95
DR Congo	368.74	368.80	other ESA	259.40	259.39
Gambia	98.02	84.54	Other WCA	105.86	107.46
Ghana	413.92	454.27	other Asia	100.84	243.37
Guinea	291.51	291.42	Latin America	1109.82	698.03
Ivory Coast	68.58	68.48	Other developing	24.93	80.25
Mali	289.75	286.04	australia	24.70	44.83
Niger	146.46	160.08	other developed	1965.24	3040.81

Source:Own calculations based on FAOstat 2010 data.

Table 7: Elasticities used in the model

Country	Supply Elasticity	Demand Elasticity	Country	Supply Elasticity	Demand Elasticity
Bangladesh	0.41	0.51	Nigeria	0.65	0.68
China	0.43	0.26	Senegal	0.74	0.68
India	0.53	0.46	Sierra Leone	0.74	0.68
Indonesia	0.53	0.58	Ethiopia	0.53	0.50
Myanmar	0.46	0.51	Malawi	0.70	0.63
Pakistan	0.43	0.33	Mozambique	0.70	0.63
Thailand	0.44	0.35	South Africa	0.67	0.47
Viet Nam	0.46	0.54	Sudan	0.53	0.50
Benin	0.74	0.68	Uganda	0.77	0.67
Burkina Faso	0.53	0.50	Tanzania	0.77	0.67
Cameroon	0.74	0.68	Zambia	0.70	0.63
Angola	0.70	0.63	Zimbabwe	0.60	0.40
Chad	0.53	0.50	WANA	0.25	0.60
DR Congo	0.74	0.68	other ESA	0.66	0.57
Gambia	0.74	0.68	Other WCA	0.68	0.63
Ghana	0.74	0.68	other Asia	0.46	0.44
Guinea	0.74	0.68	Latin America	0.70	0.35
Ivory Coast	0.74	0.68	Other developing	0.62	0.56
Mali	0.53	0.50	australia	0.70	0.44
Niger	0.53	0.50	other developed	0.70	0.40

Source: IFPRI(2012)

Table 8: Indicators on capacity used.

CAPACITY	**Agricultural land FAO (1000ha)**	**Bantilan**	**Kai adjusted**	**# trials**	**# releases**	**LSU training**	**ASTI**		**Pardey (1989)**	
		adaptive	**adaptive**	**ICRISAT**	**ICRISAT**		**spending**	**personal**	**Personel**	**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 9: Ranking of capacity

Country	Kai final adjusted	Bantilan	# 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 10: Adoption rates and indicators used.

ADOPTION	FINAL Adjust menst	GN area (05-07 mean)	Expert estimat es	Group adjust ments	DIVA based adjust-ments	ICRISAT releases	releases per ha (10000)	JN 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					