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Global homogenous groundnut zones – a tool to estimate the regional and international impact of agricultural research

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Abstract

Sustained, well-targeted, and effectively used investments in agricultural R&D improved productivity worldwide and thereby contributed to food security. In this context, research spillover effects refer to situations in which a technology that is developed for a specific target region or product is also applicable to other locations or products that are not targeted during the research process (Deb and Bantilan 2001). The focus of this paper is the definition of homogenous zones as the basis to distinguish target from non-target regions of dissemination and thereby increase efficiency of dissemination projects, as regions with the highest likelihood of applicability can be targeted first. In order to maximize impact, the thorough understanding, quantification of technology dissemination and spillover effects is an important tool that will in the end improve priority setting processes of international research institutions such as the CGIAR Centers.

This paper outlines the developments of homogenous zones along the example of groundnut growing regions and illustrates the application along the example of one ICRISAT groundnut variety. This process was based on broad and intensive interaction between scientists from various backgrounds. Results show that the similarity between African and Asian locations is much higher than former efforts in defining homogenous zones depicted. This may force scientists to rethink their efforts in dissemination and gives them a basis for choosing collaboration partners across the globe. Furthermore, the demonstrated wide potential should reinforce the global mindset of concerned scientists that tend to focus their efforts around the location they are currently based in. To improve the flow and actually make the varieties travel to all locations where they can benefit requires an in-depth analysis of past experiences and the identification of all factors affecting the movement aiming at achieving higher impact from the public funds invested. Ultimately, this will increase the returns to the investments undertaken and may convince donors to increase their investments to the levels required to feed a growing population.

***Keywords**: Homogenous Zones, Technology dissemination, Spillover effects, Africa and Asia, Agricultural research*

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Contents

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). 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 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. One part of this international dissemination could happen in the form of spillover benefits. 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 price change 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[1] (Deb and Bantilan 2001). Spillover effects from agricultural research among states or regions have received little attention in the breeding programs of ICRISAT although they can be of crucial importance for research fund allocation decisions as well as for increasing the impact of breeding.

ICRISAT, as part of the Consultative Group on 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 enables 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 of 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 2003). 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. 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

[1] An example for a spillover effect across commodities could be a drying or storage technology in regions with wet postharvest seasons aiming at the reduction of losses due to fungal infection.

background, increased efficiency in the technology development and especially its dissemination to the potential beneficiaries becomes even more crucial.

This paper is organized in four sections. The first gives a short introduction of the topic and its relevance. The second briefly outlines the theoretical framework and defines key terms used before the technical aspects of creating homogenous zones that constitute the basic tool in the analysis of ICRISAT research are given in section three along with a brief example of one ICRISAT variety against the background of the homogenous zones. In section four a brief summary is given and conclusions are drawn. Also, steps necessary to further utilize the concept and thereby increase the usefulness of the homogenous zones are outlined.

Theoretical framework

Background

To utilize the concept of spillover effects in the context of ICRISAT research and its mandate to benefit (poor) farmers all over the semi-arid tropics, several key definitions and terms have to be clarified upfront and put into perspective for this case.

The research process in ICRISAT starts from a problem-oriented research focus identification. This means the research targets all regions worldwide in which a particular problem, for example, drought, is a constraint to smallholder operations. As ICRISAT's technology development happens rather centralized, the location where research is done does not necessarily coincide with the targeted regions; therefore, in the analysis, ICRISAT is viewed as an entity that does not have a physical location. It implies that many countries all over the world have partly similar environments in which similar varieties can and are grown and therefore reflects ICRISAT's modus operandi best. The degree of this similarity of environments is quantified by a coefficient of applicability. Applicability refers to the likelihood that a particular variety grown in one location outperforms the best local variety in another location. In more similar environments this measure is increasing up to 1 for identical environments and decreasing with higher degree of heterogeneity until it reaches 0. Locations among which the applicability reaches one (or at least is close to 1) will be called homogenous zones (HZ) as they constitute similar conditions for groundnut production. The utilization of the produced groundnuts that are based on local preferences, market access, and other factors will not be considered for the HZ as these can change and in case that happens a readily available 'basket of applicable technologies' will be in place to serve the demands of the farmers and/or consumers.

The final aim and measure of success for ICRISAT is its impact in terms of welfare improvements. In the breeding context, this welfare improvement is generally realized by higher yield levels (or avoided losses) and therefore constitutes a unit cost reduction of production for the farmers using the technology. This measure will also be used here. The realized unit cost reduction can be further separated into two types of impact – first, the direct impact, which happens in the region that was targeted in the research process; second, in case the technology did move beyond the boundaries of the initially targeted zone the realized impact is based on a technology spillover and therefore referred to as spillover impact. In both cases the magnitude of the realized impact depends on the rates of adoption by farmers in various regions. Adoption refers to farmers using the developed technologies and the adoption rate reflects the share of land that is under the improved variety on a national level. The process in which the material moves from farmer to farmer and country to country is referred to as dissemination.

For ICRISAT, targeting and priority setting these two types of impacts are very important and should be looked at separately in order to accurately predict where funds are allocated most efficiently. While the ex post measurement of the total impact from breeding is served well using the traditional impact assessment methods, the ex ante measurement of the two effects is more challenging.

To measure spillover effects, Davis et al. (1987) bases his analysis on several steps where the definition of the HZs is one of the first and most important ones. This step is of crucial importance as on the basis of this classification the distinction of direct effects and spillover effects will be made and the matrix of applicability will be produced. 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 c_{ij} spillover coefficients is utilized. The coefficients c_{ij} "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) and therefore provides the measure of applicability.

Both of these concepts crucially rely on an accurate classification of HZs across the world as this determines the accuracy of the applicability measure as well as the prediction of where a variety is likely to perform. This zoning is the basic precondition for the definition of variety dissemination in target and non-target zones. Additionally, the HZs represent a useful tool to assess the applicability and thereby allow to measure spillover effects. In a situation in which two regions 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 regions are characterized as being similar but not fully equal, a variety might still perform in the other region but might not lead to the same superiority when compared to the best local variety. Then the degree of applicability is different from 1 but still there is chance of the variety performing better than any other local variety. Provided farmers adopt the variety, this scenario would then be defined as a spillover effect.

Besides being of crucial importance for the quantification of spillover effects, an improved definition of the target-region will also significantly improve 'traditional' impact assessment as the size and location of the target area might vary tremendously depending on the level of accuracy of its definition. The extrapolation of survey result to national levels will be far more accurate and therefore the impact figures generated will be more reliable. Even a reduction from an 18x18 km pixel based assessment to a 9x9 km pixel based comparison has proved to possibly lead to significant changes in the size of predefined zones in South America (Wood and Pardey 1997). These changes would then also lead to significant changes in the estimation of impact.

The measurement of spillover effects on a global level as in this research requires a more generalized definition that will lead to rather few zones that might not always fully account for the diversity within these zones. Nevertheless, it will be assured that they represent regions in which the most important features are similar with respect to groundnut production and therefore the likelihood of applicability will be close to perfect though not necessarily 100%. In this process, a close interaction with the ICRISAT scientist involved in the breeding process was maintained. This close cooperation is the key for the HZs to be meaningful in the end as the breeders know the plant and their characteristics best. Therefore, the breeders were involved in all steps of the process with an in-depth discussion before the process started, many visits during the process, confirmation and adjustments based on intermediate products and finally, the approval of the final outcome.

While it would be ideal to pursue the analysis based on the HZ level throughout the process, data availability is limiting the potential and therefore we have to switch to a country level focus at the point from which data is becoming limited. This point is depicted in Figure 1. While based on information on past releases as well as targeted environment, the dissemination can still be estimated on a level that allows attributing them to the HZs, the adoption rates are rarely

Figure 1. Research to Impact.

Source: Own presentation

reported more disaggregated than country level. Thus, all factors referred to later in this flow chart are country level data. Nevertheless, using the HZs for the spacial allocation of production and the utilization of the applicability concept significantly improves the accuracy of the model. Furthermore, connecting the country level impacts with the HZs and the sharing of these by each country leads to further insight into the distribution of the benefits and thereby implicitly generates an approximation of the disaggregated impact.

This paper will provide a methodology for the definition of these HZs as well as the spillover matrix and will therefore contribute to the improvement of the results from existing measures of research spillover effects. Furthermore, by clearly defining the zones for the direct effect and therefore the zones of the highest likelihood of applicability, efficiency of research targeted in international centers like ICRISAT will be improved.

Defining homogenous zones

As ICRISAT technologies are always designed to target certain problems or regions on a global basis with a focus on the semi-arid tropics, the applicability of a technology is generally supposed to be in the regions in which these problems are endemic or that have similar characteristics and have therefore similar problems. In an attempt to define and formalize these HZs, ICRISAT developed so called domain maps of its mandate crops in the Medium Term Plan 1994-98 (ICRISAT 1992) in order to enhance the efficiency of its breeding program and to facilitate the "international mindset" of its staff. These domains were designed to reflect the main characteristics and group regions in Africa and Asia (the main target regions of ICRISAT) according to the most important characteristics (ICRISAT 1992). Though being very useful even today, their accuracy was limited by the technology available during the early 1990s. Utilizing the progress in the area of GIS, they can be revised and improved in order to better guide scientists reflect the climatic changes that took place in the past decades. Furthermore, the zones were defined separately for India and Africa based on the expertise available in each location as well as the assessment that these regions are rather different. From recent experience and the number of varieties adopted in both regions, this might not hold nowadays and might need to be reconsidered.

In the 1990s, the first and most crucial factor during the considerations was the length of growing period across all locations. Groups were built along this most important indicator. After these basic delineations, the major cropping systems and some of the major constraints that are endemic across regions were attributed to the zones. This resulted in the zones mapped in Figure 2. From this, one can clearly see that only little overlap exists between the Asian, West African and East African locations. This would indicate that almost all dissemination from one of these ICRISAT regions to another would have to be considered spillover effect but considering the process in which these zones were designed, this mismatch between the African and Indian locations is likely only attributed to the design process rather than actual differences.

In the effort to spread these zones to further groundnut growing areas not covered in the initial attempt, consultations with leading ICRISAT groundnut scientists were held. Their assessment of the 1992 HZs indicated that they do not cover the real situations and are rather rough drawings mainly based on the LGP, which has changed by now in many locations. Therefore, it was decided to start from scratch and redefine a new set of HZs. The following outlines the main factors that went into the new zones.

As groundnut is a very specific crop and not by any means suitable for all environments, unlike,

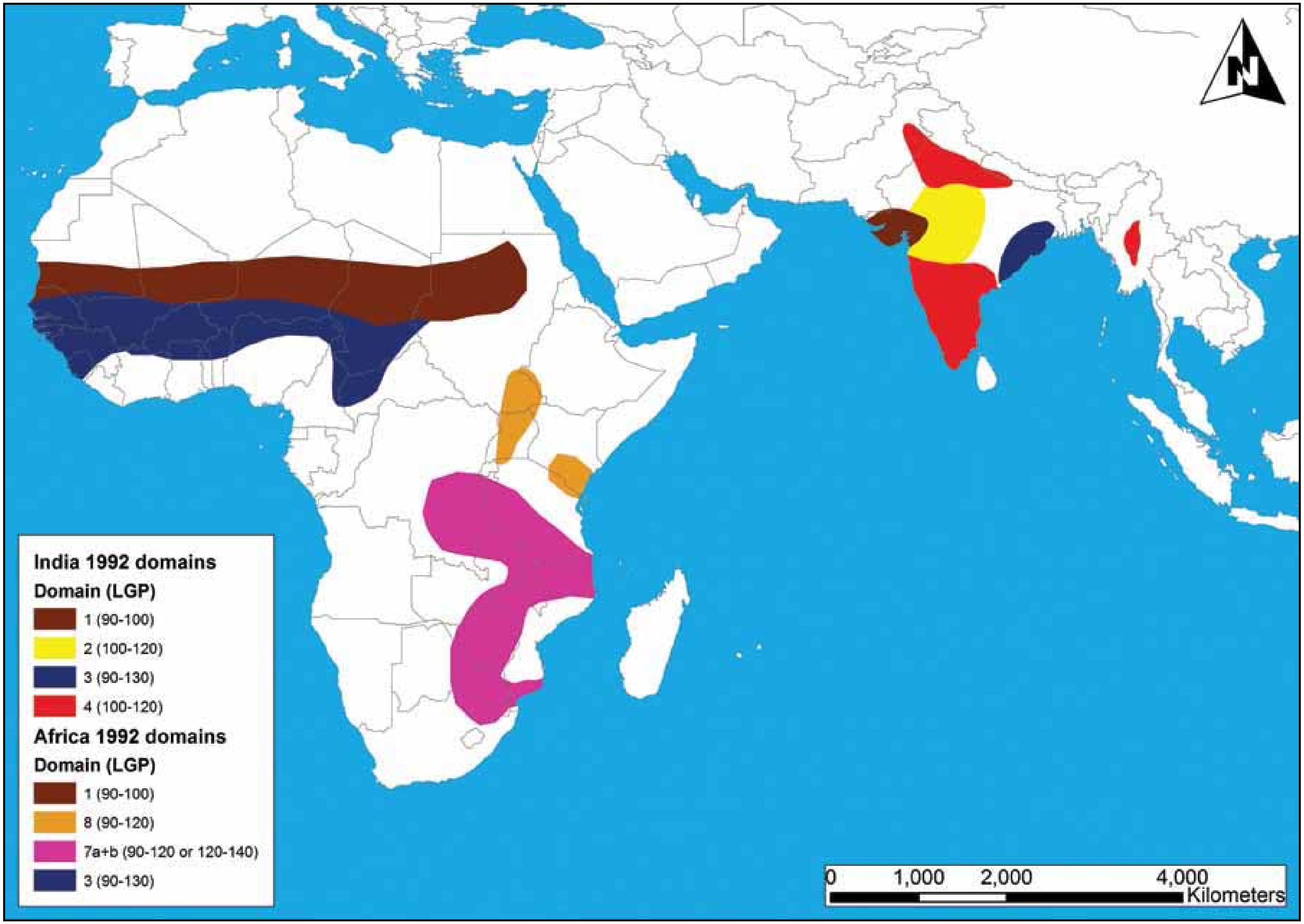

Figure 2. The ICRISAT rainy season groundnut HZs as of 1994-98.

Source: Own presentation based on ICRISAT (1992). (Data digitalized and provided by I Mohamed, ICRISAT GIS unit.)

for example, wheat that is planted in almost all environments all over the globe (although different varieties are planted in different ecoregions), the definition of HZs will firstly be based on the areas of current groundnut production. The regions where groundnuts are currently produced are incorporated as an additional layer in the formation of the base area for the delineation of the HZs.

The spatial allocation model (SPAM) by You et al. 2011 provides spatial estimates for the groundnut production (year: circa 2000) and is based on:

1. Crop production statistics on sub-national or national level for the years 1999-2001 with the reference year 2000;
2. Production systems based on several data sources available (eg, commercial production, mechanized production, fertilized use);
3. Land cover images to only attribute production to actual crop land;
4. Agroclimatic suitability based on the agroecological zones by FAO;
5. Population density as a proxy for market access; and
6. Irrigation maps to account for the mentioned extended possibilities of crop production and higher attainable yields.

As it might happen that groundnuts are currently not produced in areas that would be suitable for its production for some reasons, the current production area was combined with regions that are at least marginally suitable for rainfed groundnut production (the dominant smallholder cropping system) and therefore potential target areas for breeding efforts. For this assessment the FAO (2000) suitability maps are utilized. This already includes most of the basic requirements for groundnut production and allows reducing the area that has to be considered.

The combination of suitability and actual production (Figure 3) is used as the basis of the area considered for the generation of the groundnut HZs.

This combination does not only cover the current distribution of groundnut production but also includes potential areas in which groundnuts may be produced in the future due to environmental changes that might make groundnut production more attractive or changes in the preferences of consumers/producers. Therefore, this base area for the classification gives a very broad assessment and might overstate the potential direct effects and spillover effects that are achievable in the short run. Therefore, the divergence between the actual spillovers and direct effects realized in the past and the potential transfers and spillovers should be investigated carefully.

Based on the combination of the SPAM estimates and the suitability maps, several indicators are available that can be used and/or combined for the definition of HZs. One of the broader features are the Agro-ecological Zones (AEZ) by FAO (2000). These zones are based on climate, soil and terrain conditions that are most relevant to agricultural production. The crop specific limitations of these factors have been modeled using crop modeling and environmental matching. Therefore, they represent a broad classification of regions according to their most basic agro-ecologic features (FAO 2000; FAO 2010). These broad zones can be used to subdivide the base area into several zones as the conditions among these broad zones will be different to a certain extent. Nevertheless, similar AEZs can be found in several very different parts of the world.

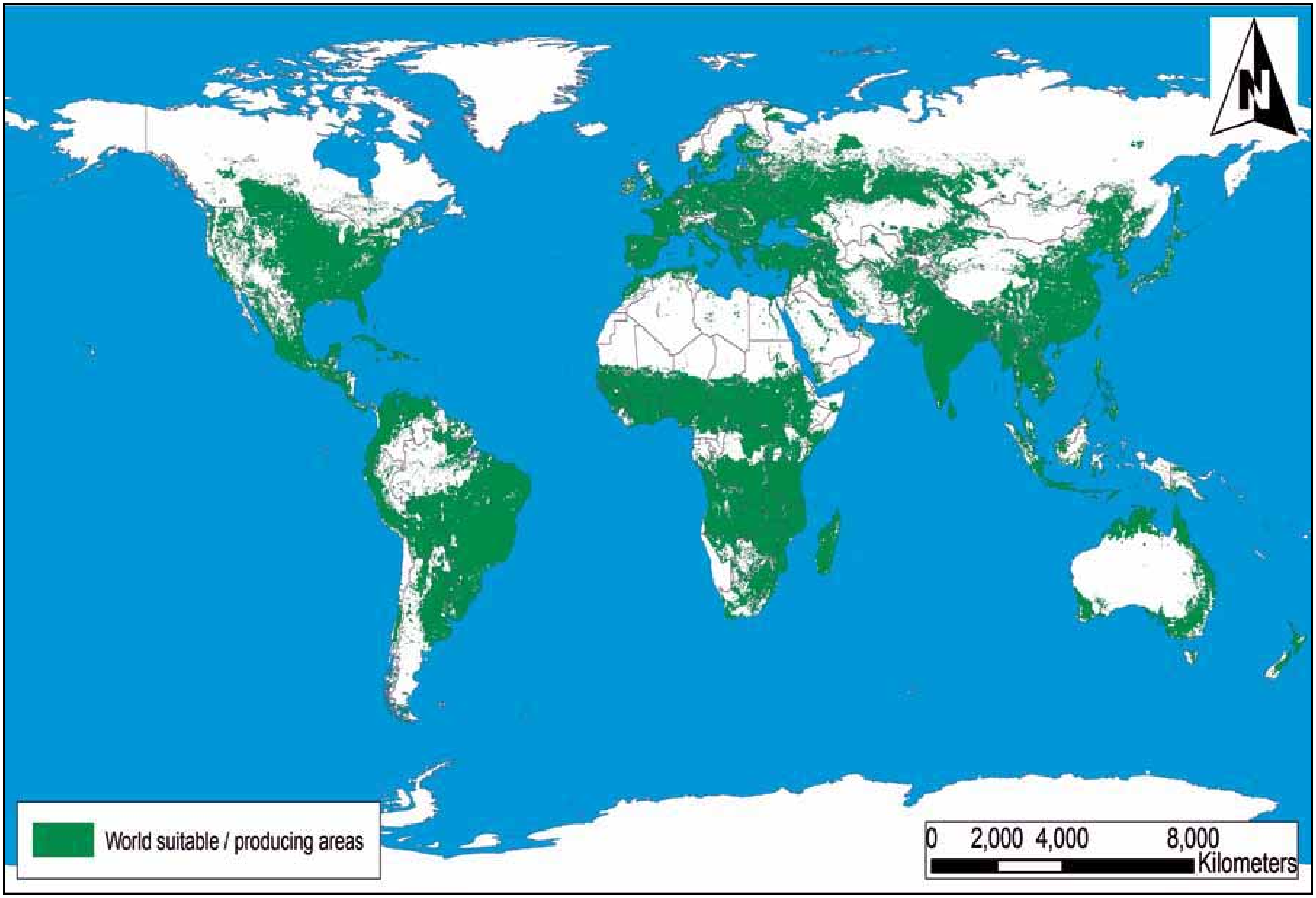

Figure 3. Intersected world suitable and producing areas.

Source: Own presentation based on FAO 2000 and HarvestChoice 2009.

The less aggregate Length of Growing Period (LGP) also compiled by FAO (2000) represent the maximum available period in which crops can be grown in the region under rain-fed conditions. The LGP is the period of the year in which both moisture levels and the temperatures are suitable for crop growth. The assessment is based on rainfall, soil profiles, evapotranspiration and relies crucially on the soil moisture storage capacity.

The length of growing period has direct implications for the possibilities of farmers and on the crop portfolio from which they can choose in their specific location. Also the available LGP is important for groundnut production as different varieties have different durations. In regions with rather short LGPs, ICRISAT's efforts do focus on short or medium duration varieties as long duration varieties are not suitable for certain regions. Therefore, this is a crucial factor to differentiate regions.

The LGP areas were subdivided in LGP > 120 days and < 120 days based on the mean days to maturity for the medium and short duration varieties in the ICRISAT international trials.[2] According to the data the mean days till harvest among the medium duration groundnut varieties is 120 days, which was therefore chosen as the threshold. A further subdivision between short- and medium duration was not implemented as the required LGP was overlapping to a great extent depending on the region in which they were planted. The close relationship between the HZs and the LGP and the huge importance of this factor that was already visible in the ICRISAT HZs was confirmed by several groundnut breeders who were involved in the HZ mapping during the early 1990s.

Further important factors to be considered here are rainfall patterns that have a big impact on crop production as well as the pest and disease distribution. First, the rainfall pattern, ie, the differentiation between unimodal and bimodal rainfall determines to a huge extent how much of the days are actually useable for cropping as well as which types of crops are suitable. On the one hand, if a region with unimodal rainfall has a LGP of 120 days, it is no problem to grow a crop that takes up to 120 days till maturity. But if, on the other hand, a region with bimodal rainfall (eg, summer and winter rains) has a total LGP of 120 days, it is highly unlikely that the same crop can grow there as the continuous LGP is not long enough for the crop to mature. Therefore, this factor is included to further subdivide the homogenous regions.

Second, the spread of pests and diseases is another very important factor that influences the applicability of technologies and especially varieties. Accurate maps are, however, not available on a global level and this factor was therefore not possible to incorporate. Nevertheless, we believe that the factors included are already covering the differences to a great extent as many pests and diseases rely on specific environmental conditions that are covered, which was confirmed in initial discussions with groundnut pathologists and entomologists. Therefore, the zones as they are should to a great extent cover this factor already. The pest and disease incidences in the domains will be incorporated at a later stage based on the assessment of groundnut breeders.

[2] The international trials conducted by ICRISAT are a set of trials that are regularly conducted since shortly after ICRISAT was founded. Here, the 6321 trial datasets for more than 800 varieties conducted in 95 cities of 43 countries between 1985 and 2008 are utilized.

The new homogenous zones and some implications

The updated groundnut homogenous zones

The approach outlined in the previous chapter lead to 62 possible HZs. After excluding deserts, “no data” regions, water and HZs that consist of less than 1% of the data fields, there are 15 HZs with the remaining areas grouped into the 16th category ‘others’. The details are shown in Table 1 and Figure 4.

Table 1. Classification system for the narrow homogenous regions.

GN relevance	LGP	LGP pattern	AEZ	Zone #
Producing and/or at least marginally suitable areas	Above 120 days	Bimodal rains	Subtropical drylands	11
			Warm tropics sub-humid	12
			Warm tropics drylands	13
		Unimodal rains	Boreal drylands	1
			Temperate humid	2
			Temperate drylands	3
			Subtropical humid	4
			Subtropical drylands	5
			Cool tropics mixed	6
			Warm tropics perhumid	7
			Warm tropics humid	8
			Warm tropics sub-humid	9
			Warm tropics dryland	10
	Below 120 days		Temperate drylands	14
			Warm tropics drylands	15
	Other combinations			000

The highest share of about 26% of all data fields falls into the warm sub-humid region with unimodal rains and more than 120 days LGP. The tropical drylands with more than 120 days LGP and unimodal rainfall are also covering a wide region with about 16% of all data fields. Almost 13% of the fields were attributed to regions that are too small to constitute individual zones and are therefore clubbed into ‘others’. Though this leads to the third biggest category being not an actual HZ, the limit was set rather low and the possible number of HZs of 62 would not be meaningful for further analysis. Furthermore, this category spreads over areas that are generally less relevant for groundnut production.

The final step in the process of establishing HZs/groundnut HZs was the verification from experts within ICRISAT. During earlier discussions of the efforts to measure applicability, dissemination possibilities and spillover effects it was mentioned that varieties are more likely to disseminate horizontal (along similar latitudes) or vertical (mirrored at the equator with similar latitudes north and south of the equator). This assessment is confirmed by the new HZ maps as the main HZs stretch along those regions. Zone #9, for example, spreads around the 8th degree North and South in Africa, South/Middle America and in Asia/Australia. After finalizing the update of the HZs, the newly established zones were briefly presented after the general background was introduced.[3]

[3] Due to time limitations and practical reasons, this was initially done via email and a telephone conference but in subsequent interaction verified during personal discussions.

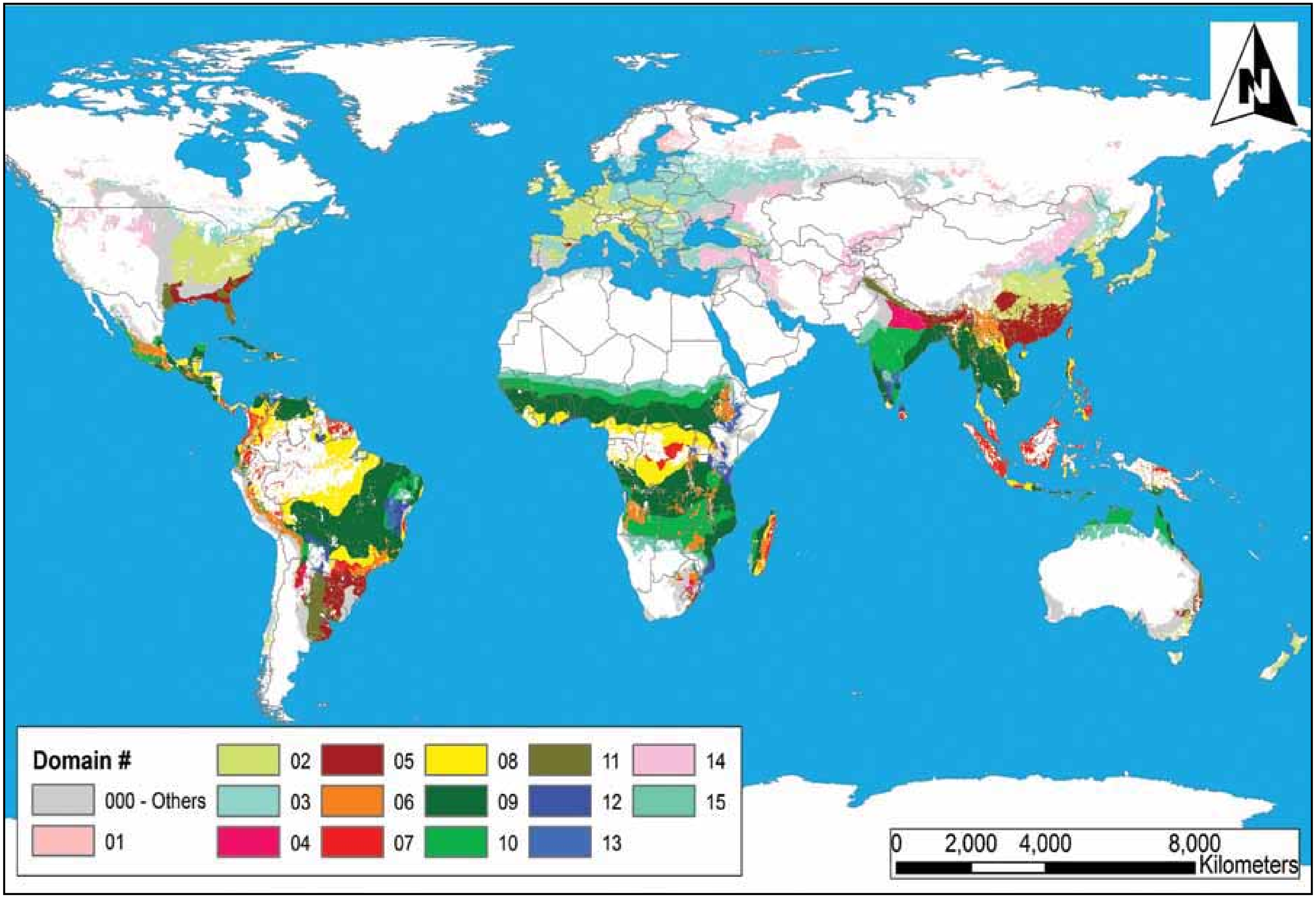

Figure 4. Groundnut homogenous zones.

Source: Own presentation.

This led to a general agreement that the new HZs do in fact represent the nature and potential of the groundnut crop and does represent the possible distribution of individual varieties.

Finally, based on the SPAM estimates of area and production as well as the GIS calculations of the total area covered, it is now possible to compare the relevance of the resulting HZs (Table 2).

Table 2. Homogenous zone characteristics.

	Total area		Estimated GN area[1]		Estimated production[1]	
Zone #	‘000 km^2	% of total	‘000 ha	% of total	‘000 tons	% of total
1	913	1.7%	0.4	0.0%	0.4	0.0%
2	5,487	10.0%	2,550	9.1%	8,271	20.4%
3	4,083	7.4%	792	2.8%	2,440	6.0%
4	487	0.9%	183	0.7%	209	0.5%
5	2,502	4.5%	1,738	6.2%	3,683	9.1%
6	2,216	4.0%	467	1.7%	450	1.1%
7	1,740	3.2%	217	0.8%	267	0.7%
8	4,908	8.9%	1,396	5.0%	1,550	3.8%
9	11,484	20.8%	5,771	20.6%	5,888	14.5%
10	5,140	9.3%	6,019	21.5%	6,039	14.9%
11	1,057	1.9%	510	1.8%	1,096	2.7%
12	722	1.3%	649	2.3%	640	1.6%
13	505	0.9%	626	2.2%	629	1.6%
14	2,570	4.7%	435	1.6%	1,172	2.9%
15	2,364	4.3%	4,606	16.4%	4,112	10.2%
000	8,957	16.2%	2,095	7.5%	4,045	10.0%

[1]Source: Based on overlay of the HZs and You (2011) estimates.

Note: These estimates are not yet final as the SPAM model is currently under review and especially in western India the figures included are vastly underestimated due to some initial data problems. Therefore, the area as well as the production in HZ #9 and #10 will be even higher but for now these are the best estimates available on a global level.

Based on the area estimates, the difference in the size of the zones is also obvious. The largest in terms of size are now #9, #000 and #2 in that order. When it comes to production and actual groundnut area, the ranking changes, for example, HZ 10 with less than 10% of the total area produces almost 15% of the world’s groundnuts and constitutes more than 21% of the total area under groundnut production.

When comparing the new HZs to the former ICRISAT HZs, some changes occur. Besides the minor movements of some HZs that otherwise align very closely with the former ones, the most obvious difference is the coverage. The new HZs go far beyond the ‘old’ HZs and now cover the whole groundnut production while earlier, large areas were left out and would therefore be unaccounted for when using the previous ‘domains’. These additionally covered production areas are not necessarily within ICRISAT’s mandate region (the Semi-Arid Tropics), but as the review of the variety distribution showed, are important for the measurement of international dissemination and spillover effects and are therefore very relevant for the impact of ICRISAT research.

The updated HZs have the potential of guiding ICRISAT breeders in targeting their efforts to regions with high likelihood of success and thereby contribute to further dissemination of developed varieties and collaborate with scientists in the national systems. Furthermore, the Learning Systems Unit of ICRISAT could improve the targeting of their exchanges by linking visiting scientists and students to the breeding program that is most likely to benefit their country of origin best. Thus, resource allocation can be more efficient and benefits could spread wider and faster.

The applicability matrix

Based on the HZ developed, the next step was to establish an estimation of the applicability across these zones. The basic question is what share of the varieties developed for one particular zone is likely to outperform the best local variety in each of the other zones. In an ideal world, this could be econometrically established using the results of a vast set of international trials as this would give the actual performance (see Mareida 1996 for an example). Unfortunately, the international trials ICRISAT conducted during the past 40 years do not cover all zones and it is only possible to attribute the target zone for a few varieties[4]. 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.

Consequently, an approach was taken starting from the location most familiar with the scientist currently in the discussion. 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 a particular location, confidence levels are high and they get more comfortable with the idea, which makes them more willing and able to make statements for regions less familiar with them. Moreover, the zones were sorted according to a sequence that reflects a logical order based on more or less favorable conditions.

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 the work, we are not able to predict this and also, 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 issues 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.

After initial estimations, 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 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 reduced 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.

[4] An example for a spillover effect across commodities could be a drying or storage technology in regions with wet post-harvest seasons aiming at the reduction of losses due to fungal infection.

Table 3. Adjusted applicability matrix.

	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.

The new HZs and the example of ICGV 87123 (ICGS 11)[4]

ICGV 87123, also known as ICGS 11, originates from a single plant selection in a natural hybrid of Robut 33-1 conducted in ICRISAT India during the 1977/78 planting season. The research process that led to the release of ICGV 87123 was started in 1980 in an effort to improve yield levels. ICGV 87123 is a Spanish type, medium height, high yielding variety that matures in India within 109-120 days. It was first released for several states of India in 1986 after broad testing during the postrainy seasons between 1980 and 1983. During these trials, it outyielded the then popular local cultivar SB XI by 25.5% and 33.3% respectively, depending on the region (ICRISAT 1989). ICGV 87123 was expected to be suitable for release in Benin, Sri Lanka and the Indian states of Andhra Pradesh, Karnataka and Maharashtra. These countries/states are mainly located in HZ 9 and 10 depending on the exact location within these countries/states (see Figure 6).

Based on this assessment, this variety should be applicable to many more countries/regions within these HZs. Thus, the potential area for ICGV 87123 covers more than 40% of the global groundnut area as well as more than 30% of the world groundnut production. Officially however, it was then only released in nine Indian states (1986 as ICGS 11) and Sri Lanka (1994 as Indi). Besides, it is planted by farmers in Gambia and was sent for pre-release testing in Guinea-Conakry (see Figure 5 and Figure 6).

[4] For a complete list of international ICRISAT varieties, see Appendix.

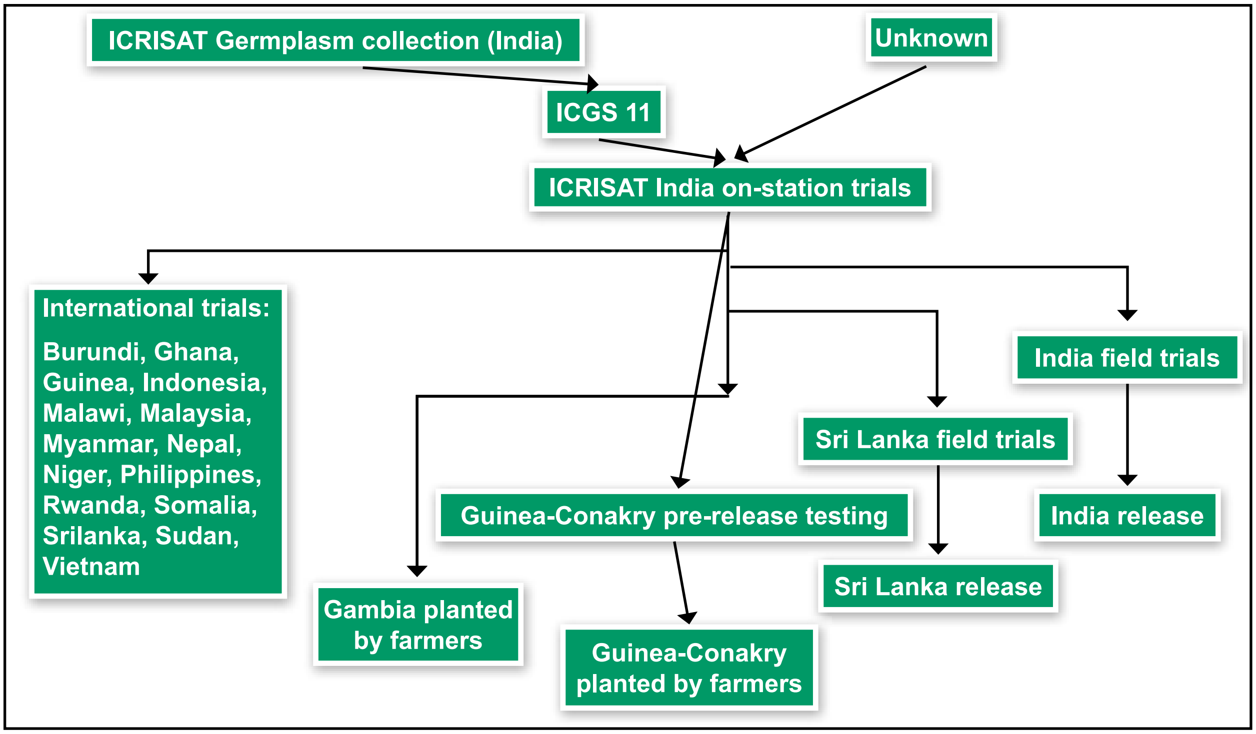

Figure 5. The dissemination of ICGV 87123.

Source: Own presentation based on ICRISAT (1989) and international trial data.

While it is found in Sri Lanka already, ICGV 87123 has not yet been released in Benin although the similarities in the environmental characteristics suggest very good applicability to Benin, and during the international trial it outperformed the local control by 15%. This suggests that further factors besides the pure applicability might have prevented ICGV 87123 from being released in Benin. Besides possible repeat tests that have not been recorded or are not available to ICRISAT and might have shown different results, the factors hindering the release could be political or socioeconomic factors like a missing strong connection to the Benin national groundnut program or consumer/producer preferences that might have been unfavorable for the introduction.

Since its development, the results of 29 trials in 17 countries[5] have been reported and documented. These trials cover zones 5-10, 15 and 000. Across the HZs, trial results range from 10% to 130% yield as compared to the local control (see Figure 6). These figures, however, have to be looked at with caution as the number of cases is low and therefore many other factors may have influenced the results. This highlights that more data on the performance of the variety is essential for further analysis. This could be done by aggregating several varieties entered in the international trials. However, this will come at the cost of combining very different varieties targeting different problems and therefore they are not really comparable. The data available so far outlines the purpose of each trial and therefore the data can at least be separated by medium, short duration and long duration trials. Nevertheless, many varieties enter the international trials for several reasons and are not necessarily very promising and therefore more detailed information is mostly not available. The aggregation, therefore, has other problems with respect to interpretation but at least it leads to more meaningful number of cases across the HZs (see Table 4).

[5] These trials were conducted in Benin, Burundi, Ethiopia, Ghana, Guinea, Indonesia, Malawi, Malaysia, Myanmar, Nepal, Niger, Philippines, Rwanda, Somalia, Sri Lanka, Sudan and Vietnam.

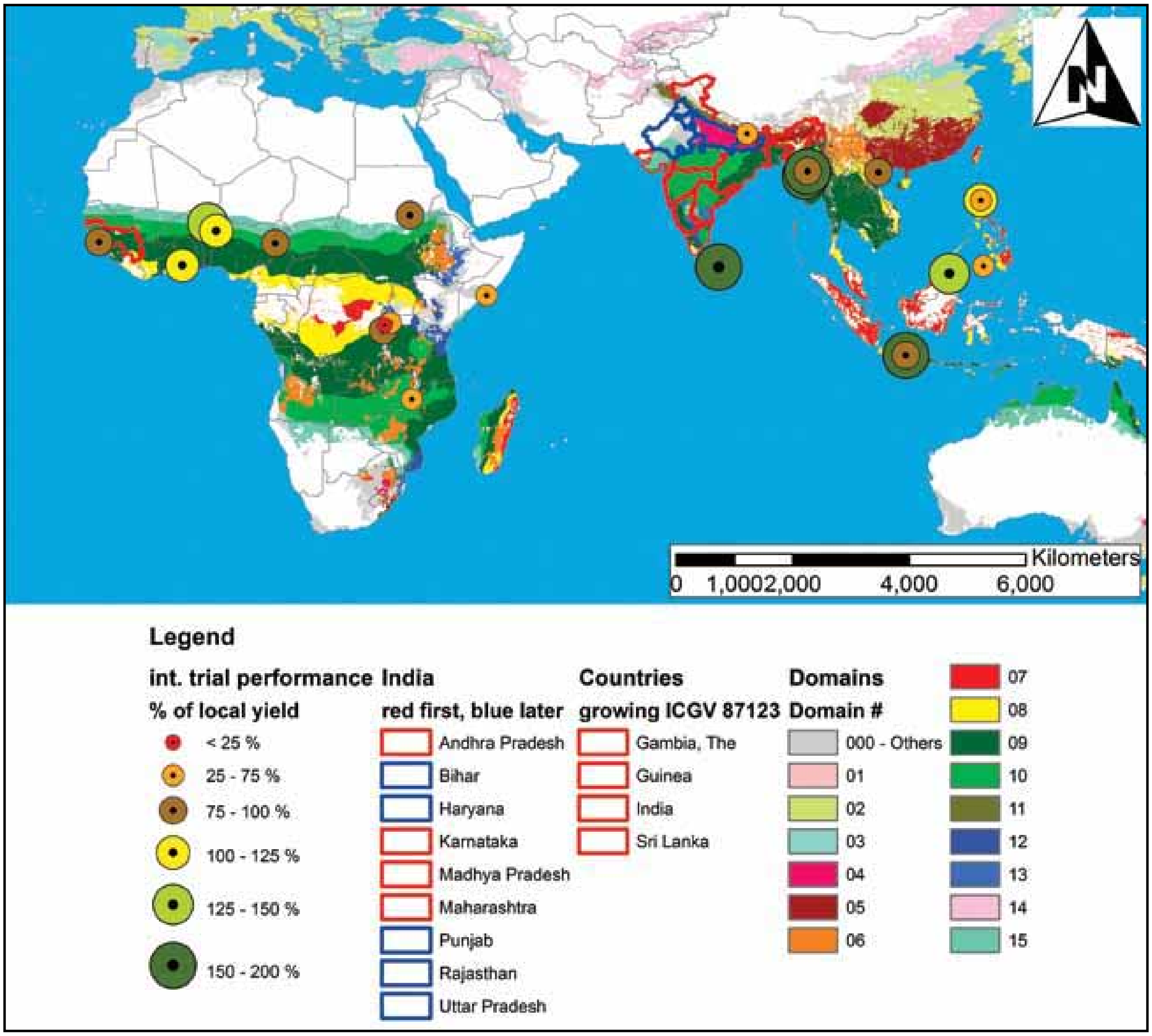

Figure 6. The distribution and international trials of ICGV 87123 against the background of the narrow HZs.

Source: Own presentation, partly based on ICRISAT (1990) and international trial results.

The aggregated performance of varieties developed in India shows some changes as compared to the performance of ICGV 87123 only. When comparing the share of trials in which the ICRISAT variety out yielded the local control, these are much higher for ICGV 87123. This is likely to result from the fact that ICRISAT is testing a huge number of varieties in the international trials that are not necessarily superior but might have some advantages over the local control other than yield. These can be resistance to pests and diseases, duration or other marketing related feature like pod size or oil content. This shows once more that extensive consultations with breeders and other groundnut specialists is the only possible option in the development of the domains and the verification in the absence of extensive trial results across a huge number of locations.

The distinction between spillover effects and direct effects is not yet possible as only the countries where the varieties were released is known and therefore these cannot be assigned to a specific

Table 4. Medium and short duration trial results for varieties developed in ICRISAT headquarters, Patancheru, India.

	Yield advantage over local control (% of local)		Outyielding local control	
HZ	Mean	Median	%	N
1	-	-	-	0
2	89	85	21	14
3	-	-	-	0
4	84	82	31	51
5	90	91	36	171
6	-	-	-	0
7	22	20	0	14
8	105	94	43	123
9	86	88	32	298
10	105	92	41	536
11	91	89	36	56
12, 13	-	-		0
14	60	52	0	14
15	104	98	43	126
000	109	108	67	15
Total	97	91	37	1418

Note: Some of the medium duration trials have been combined with late maturing. Therefore, some HZs in which ICGV 87123 was tested are not included here as the medium duration trials could not be separated from the late maturing.
Source: ICRISAT international trial data.

HZ with certainty. However, as indicated earlier, since HZ 10 is by far dominant in all the regions and countries of release, it seems very likely that these releases are direct effects rather than spillover effects.

Summary and conclusions

The HZs developed for groundnuts are able to fulfill multiple purposes along the agricultural research for development continuum. In a first step, they will assist breeders in targeting their efforts more precisely by providing clearly defined zones of applicability and will therefore improve the efficiency of the breeding program and thereby increase impact. Additionally, they will serve as a reference point for dissemination efforts as the HZs clearly outline the “best bet” regions for successful adoption. Finally, the HZs will improve the impact assessment as they allow for clear distinction between target and non target regions and thus lay the basis for the more accurate measurement of impacts of agricultural research and provide a useful tool for sampling of households.

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 the initial breeding is finalized. A crucial precondition for the successful implementation is the collaboration among scientists from all fields affected as only this will ensure the acceptance of the final output as well as make sure all relevant factors are considered and the zones 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.

As useful as the HZs are, the short example of the application to an actual ICRISAT variety and its dissemination showed the need for this more qualitative approach based on the huge data needs for efforts to utilize econometric approaches. Furthermore, the need of more disaggregated data on dissemination has been shown as the HZs do not stick to administrative boundaries, which are the usual delineations for available adoption data. Further research will require a detailed analysis of the dissemination of varieties in countries of release in order to attribute those to the HZs and then measure the impact of transfers and spillovers.

All in all, the usefulness of the HZs for the thorough analysis of applicability and spillovers has been shown. Only a brief outline of the application could be given here as the main focus was the development of the HZs that will serve as the basis for the further assessment of ICRISAT research. Analyzing past dissemination against the background of these zones will further strengthen the message and highlight which factors can be tackled to further increase impact and reach more farmers with technology that will benefit them in their efforts to improve their livelihoods.

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Appendixes

Description of the ICRISAT HZs as in Figure 2.

HZ	Production system characteristics	Major constraint	Locations
GN I	Rainy season 90–100 days duration Rainfed Oil and confectionary use	Drought Late leaf spot Rust Rosette Aflatoxin	Mid tier of Sahel (Senegal, Mali, Burkina Faso, Niger) India (Gujarat)
GN II	Rainy season 100–120 days duration Rainfed Mostly oil use	Late leaf spot Rust Drought Aflatoxin Rosette	East Africa (Sudan) India (N Maharashtra, Madhya Pradesh)
GN III	Rainy season 90–130 days duration Rainfed Oil and confectionary use	Late leaf spot Rust Rosette Millipedes Pod rots	Southern tier of Sahel (Nigeria, Gambia, Cameroon, Ghana) India (N coastal Andhra Pradesh, Orissa, West Bengal) Bangladesh North Vietnam Indonesia
GN IV	Rainy season 100-120 days duration Rainfed Mostly oil use	Late leaf spot Rust Drought Leaf minor Spodoptera	India (S Maharashtra, Andhra Pradesh, Tamil Nadu, Karnataka) Myanmar Thailand Southern Vietnam
GN V	Summer season 110-120 days duration Full irrigation Mostly oil use	No major constraint	India (Gujarat, N Maharashtra, Madhya Pradesh)
GN VI	Postrainy season 100-120 days duration Full irrigation Mostly oil use	Late leaf spot Bud necrosis Leaf minor Spodoptera White grubs	India (W & S Maharashtra, Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, Kerala) N India Pakistan Nepal
GN VIIa	Rainy season 120–140 days duration Mostly monocropping Confectionary use Large seeded varieties preferred	Early leaf spot Rust Rosette Aphids Jassids	Southern Africa (N Mozambique, N Zimbabwe, C Malawi, E Zambia, S Tanzania, DR Congo)
GN VIIb	Rainy season 90–110 days duration Mono- and intercropping Rainfed Mostly oil use	Late leaf spot Rust Rosette Drought Alflatoxin	Southern Africa (S Mozambique, S Zimbabwe)

HZ	Production system characteristics	Major constraint	Locations
GN VIII	Rainy season Rainfed (bi-modal) Mono- and intercropping 90-120 days Oil and confectionary use Three seeded varieties preferred	Early leaf spot Late leaf spot Rust Rosette Pod rots	Central Africa (N Tanzania, N Zaire, Uganda, Rwanda, Burundi, W Kenya)

Source: ICRISAT (1992).

ICRISAT international groundnut varieties.

	ICRISAT name	Where found	Also known as	Special feature	Where developed
1	ICGV-SM 83708 (ICGMS 42; ICGV 89322)	Malawi (90) Uganda (99) Zambia (90) *Testing*: Swaziland (94)	CG 7, MGV 4, Serenut 1R, ICGMS 42	High yielding, large seeds, confectionary trait	Parental line from Patancheru, India; further developed in Lilongwe, Malawi
2	Robut 33-1	Myanmar (84) Tanzania (85) *Testing*: Gambia	Sinpadetha-3, Johari		ICRISAT network
3	JL-24 (ICG 7827)	Malawi (00) Mali (00) Myanmar (84) Philippines (92) Congo (90) Zambia (99) South Africa (02) *Testing*: Sierra Leone (92)	Kakoma, Sameke, Sinpadetha-2, UPL Pn 10, Luena	Early, high yield	ICRISAT network (India); Collected in farmers' fields
4	CGS 11 (ICGV 87123)	India (86) Sri Lanka (94) *Testing*: Guinea *Grown in:* Gambia	India	High yielding, tolerant to bud necrosis and end season drought	Patancheru, India
5	ICGV 87160 ICG(FDRS)	India (90) Myanmar (93)	Sinpadetha - 5	Foliar disease resistant	Patancheru, India
6	ICGV 86015 (ICGS(E)56)	Nepal (96) Pakistan (94) Vietnam (92) Sri Lanka (04)	Jayanti, BARD 92, HL 25, Tikiri	Short duration	Patancheru, India
7	ICGV 86143	India (94) Vietnam (00) Zambia (99)	BSR-1, LO 5, MGS 2	High yielding, tolerant to bud necrosis & PMV	Patancheru, India
8	ICGV-SM 90704	Malawi (00) Uganda (99) Mozambique (02) Zambia (04)	Nsinjiro, Serenut 2R, Mamane, Chishango	Need for rosette resistant variety	Lilongwe, Malawi
9	ICGV 86065	Mali (00) Benin (00)		Short duration	Patancheru, India
10	ICGV 93437	Zimbabwe (99) Zambia (04) Mozambique (04) South Africa (04)	Nyanda		Patancheru, India

	ICRISAT name	Where found	Also known as	Special feature	Where developed
11	ICGV 86124	Senegal (05) Mali (n.a.)			Patancheru, India
12	ICGV 86061	Congo (90) Philippines (04)	ICGS (E) 27, NSIC Pn 12		Patancheru, India
13	ICGV 86564	Philippines (06) Sri Lanka ((94)	Walawe		Patancheru, India
14	ICGV 87003	Niger ((06) Sierra Leone (93)			Patancheru, India
15	ICGV 88438	Cyprus (95) Timor Leste (07)	Nikolia, Utamua		Patancheru, India
16	ICGV 93437	Mozambique (04) South Africa (05) Zambia (04) Zimbabwe (99)	Nyanda		Patancheru, India
17	ICG 12991	Malawi (01) Mozambique (02) Uganda (01) Zambia (04)	Baka, Mametil, Serenut 4R, Msandile	Rosette resistant, early leaf spot resistant	ICRISAT network (India) Collected in farmer fields

Source: CLL Gowda: ICRISAT germplasm database (update of 2009) supplemented and extended by Deom et al. (2006) and SN Nigam: various documents from the Groundnut unit.

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 and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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