Spillover Impacts of Sorghum Research

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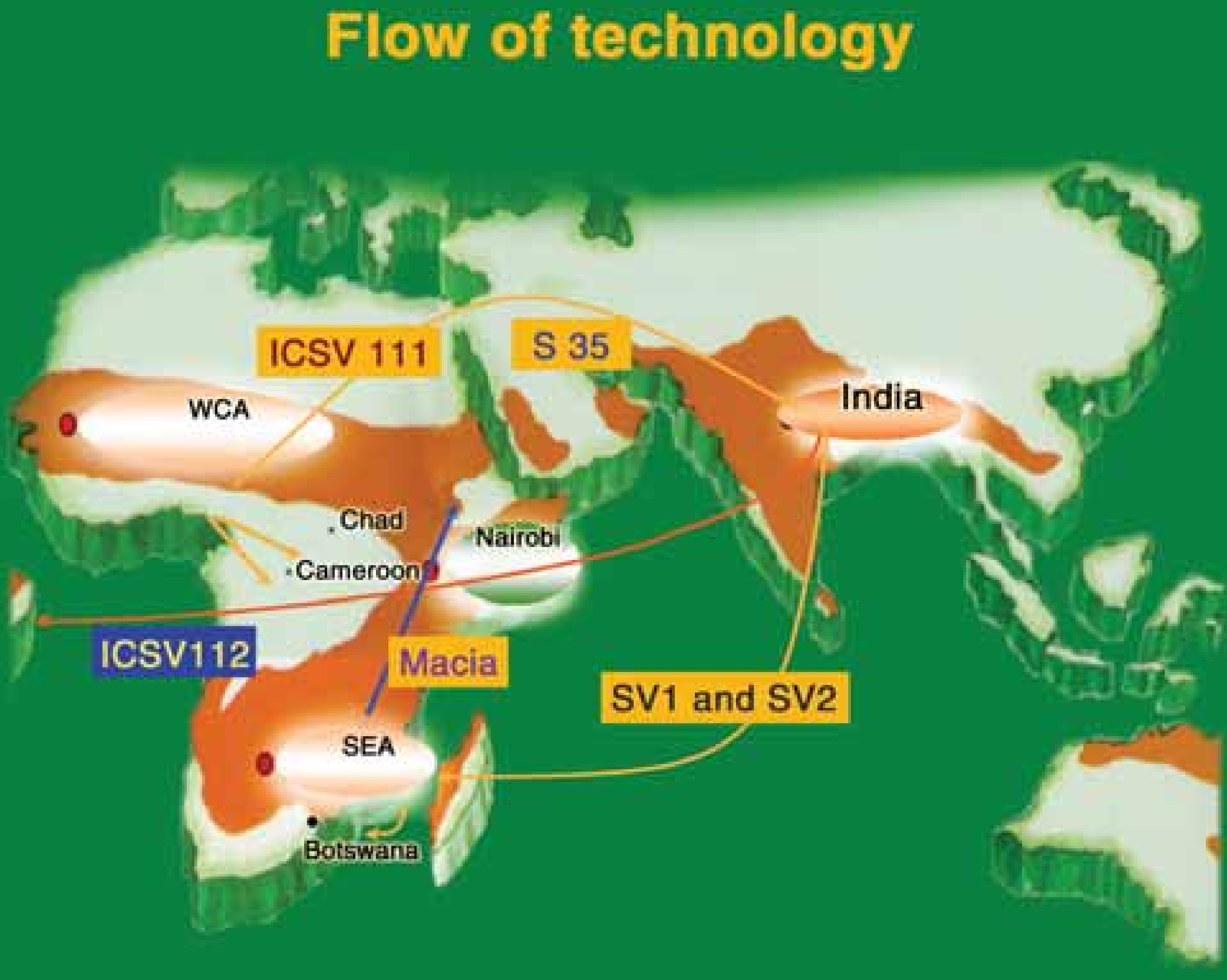

Spillover Impacts of Sorghum Research

UK Deb[1], MCS Bantilan[2], FT Bantilan[3] and CLL Gowda[2]

11.1. Introduction

A technological breakthrough in agriculture often leads to increased yields, or improves the quality of output, or enhances the efficiency of input use. If the new technology has applicability beyond the confines of the location for which it was generated, or beyond the commodity for which it was developed, such an effect is commonly referred to as spillover effects. A review (Deb and Bantilan 2001) of the spillover impacts of agricultural research has covered the evolution of the concept over time, different types of spillovers dealt in literature and techniques to quantify spillover impacts by different studies on the subject.

Bantilan and Davis (1991) identified three types of spillover effects: across-location spillover, across-commodity spillover and price spillover. The first two types are direct effects and the last indirect.

Across-location or across-environment spillover effect refers to a situation where a technology developed for a specific location can be adapted and adopted to improve the production efficiency at other locations. However, the degree of applicability may vary across locations due to agronomic, climatic, ecological and socioeconomic differences in the production environments. Also known as technology spillover, an example of across-environment research spillover is the ICRISAT-developed sorghum variety ICSV 112 (SPV 475). Primarily intended for India, it was later released in India (CSV 13), Mexico (UNAL 1-87), Nicaragua (Pinoleso) and Zimbabwe (SV 1). This variety matures in 115-120 days and yields 3.4 t ha^{-1} at Patancheru, India (ICRISAT 1990).

Evenson (1989) described across-location spillover as interlocational spillover and explained it with a generalization of the role of geoclimatic inhibitors of spillover (Figure 11.1). The horizontal axis depicts an index of a particular set of geoclimatic factors such as water stress. The vertical axis indicates the variable cost of production per unit of product. Suppose that three research programs are located, respectively, in environments 1, 2 and 3. Environment 1 is the “best” suited for production. The technology employed there has been “targeted” to location 1. When this technology is used in environments other than 1, its performance is diminished by environmental interactions. The diminution in performance is greater for the program more tightly targeted to environment 1. Research programs in locations 2 and 3 similarly target technology to their respective environments.

The real cost advantage of the technology developed for environment 1 (relative to the technology for environments 2 or 3) declines when the technology is transferred to locations dissimilar to location 1. Its absolute advantage (over type 2 or 3 technology) is shown to be limited to the range E_{21} -E_{13}. Now consider an improvement in technology produced by research in location

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Deb UK, Bantilan MCS, Bantilan FT and Gowda CLL. 2004. Spillover impacts of sorghum reseach. Pages 237-260 in Sorghum genetic enhancement: research process, dissemination and impacts (Bantilan MCS, Deb UK, Gowda CLL, Reddy BVS, Obilana AB and Evenson RE, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

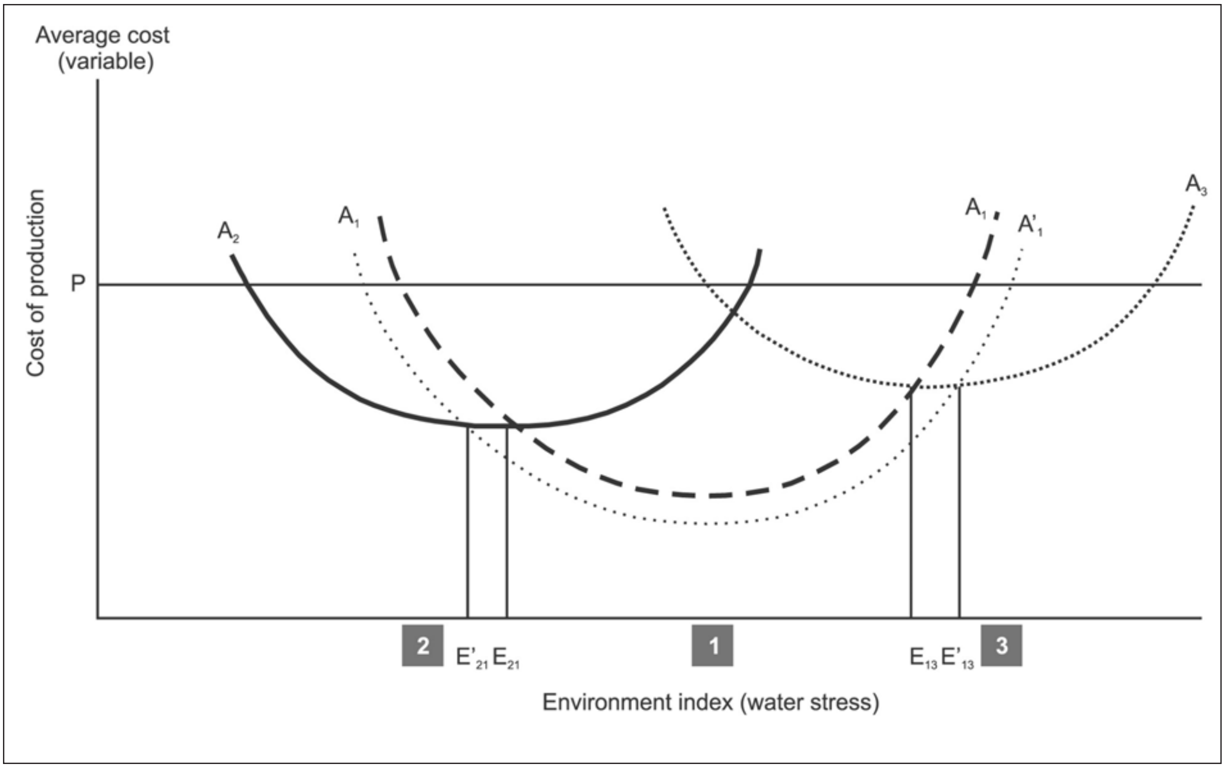

Figure 11.1. Generalization of the role of geoclimatic inhibitors of spillover effects (Evenson 1989).

1 (depicted as the A_1' curve). The direct spillover of this technology is limited to the environment range E'_{21} -E'_{13}. However, when comparable technology improvements occur in locations 2 and 3, the range of direct spillover from 1 to the other locations would be narrowed. If more locations were to build targeted research programs, the range of direct spillover would be further narrowed. Thus, the specification of direct spillover research requires consideration of the general research design of a system, including the range of locations in which the technology is applicable.

Evenson (1994) defined the potential spillover for a biological technology as $S_{ij} = Y_{ij}/Y_{jj}$, where Y_{jj} is the yield in environment j of varieties developed for that environment and Y_{ij} is the yield of the same group of varieties in environment i. Byerlee (1997) reported that the extent of the spillover, ie, the size of S_{ij} depends on various factors: agroecological similarity between the originating and receiving region, local food tastes and preferences, factor prices and institutional factors (land tenure and intellectual property rights). He also mentioned that realization of the potential spillover is influenced by other factors such as historical and cultural links between countries, geographical proximity, complexity of the problem and other institutional factors (the research networks and the level of intellectual property rights).

Across-commodity spillover effect occurs when the technology developed has applicability across commodities. For example, a cultural management technique specially developed for sorghum production may also have the potential of improving the efficiency of production of millets and other cereals. Across-commodity spillover has been termed by Evenson (1989) as intercommodity spillover. He mentioned that for some technologies the spillover mechanism would not be confined to a single commodity. Resource-or input-based technology may be relevant to several commodities. Pretechnology science findings may spill over across commodities because they enhance the invention potential of several commodity technology programs. For example, programs to control insects or correct a soil problem will spill over across commodities. A screening technology developed for sorghum may be equally useful for pearl millet screening. Research on biological control of *Helicoverpa* in chickpea and pigeonpea may be equally applicable in cotton and sorghum.

Price spillover occurs when the technological change for a particular commodity at a specific location increases supply and changes the price of that commodity in other locations through trade. It may also significantly affect the price of a related commodity in the same location. This is particularly relevant for products with low demand elasticity, and/or when the rate of product transformation among commodities is significant (Bantilan and Davis 1991).

Price spillovers can be seen as a case of intersectoral spillover as discussed by Evenson (1989). He elaborated that most private (and public) firms in an economy conduct two types of research programs. The first is directed toward process improvements in the sector itself (usually within the firm). Such research does not have spillover effects on another sector except by way of price. The second type of research is directed to product improvement. Such research can result in real and accounting spillovers because, when product quality changes, it is almost impossible to account for the quality change in terms of the price. When a manufacturer introduces a new machine and sells it at a price that is 10% higher than the price of an existing machine, accounting methods will measure the new machine as providing 10% more real services to the agricultural sector. However, there are at least two reasons why the new machine is likely to be providing 10% more real service. First, the manufacturer will have to provide a real discount to farmers to sell the new machine. Second, competition and expected competition from other manufacturers will lead him to give a real discount to farmers. Such real discounts associated with the introduction of new products from the farm-input supply sector constitute research spillovers to the agricultural sector.

Evenson (1989) also discusses another type of spillover: interfoci spillover. He defines it in the context of research system design, which is characterized by a set of hierarchical research foci. He relates this to most agricultural research programs where investment occurs in three stages: (a) pretechnology science; (b) technology invention and development; and (c) technology development and sub-invention. These stages correspond to specific specialization, which lead to locational specialization. Invention and development of new technology, ie, stage b, is the central objective of NARSs as well as IARCs. It is well-recognized that technology development rests on the twin pillars of science and technology which together define the invention potential of a national program. Almost all national and international research institutions invest in pretechnology science research programs, ie, stage a, to build invention potential. Genome mapping techniques (such as RFLP mapping and polymerase chain reaction) and genome transformation activities at ICRISAT are examples of pretechnology science research which immensely helps in technology generation and development for a group of crops rather than a single one. By enhancing invention potential, pretechnology science research has a spillover effect on programs within the given system as well as on other national and international research programs. Technology developed in one country may enhance the invention potential in another even if it is not directly transferable. Plant varieties, for example, may be valuable as germplasm in the breeding programs of another nation or state. Another example of interfoci spillover is the ongoing genome transformation activity at ICRISAT – which relates to research stage b – which is likely to make an immense contribution to prevention of fungal diseases in sorghum.

Most national research programs, especially those of small countries, concentrate on adaptive development and subinvention, ie, stage c. Typically, they are technologically dependent on international research institutes, and receive direct and indirect research spillin[4] from them. For example, Bangladesh has released six chickpea varieties; of these, four were drawn from ICRISAT crosses after screening and adaptive research trials. The other two were also from crosses provided by another international research center. Thus, Evenson's interfoci research spillover is really an indirect type of across-location spillover.

This chapter discusses the technology spillover potential from enhanced sorghum germplasm and its determinants. Actual/realized spillover from improved sorghum technologies generated by sorghum scientists are also documented.

11.2. Data and Research Methodology

11.2.1. Data

This study used data obtained from three different sources: International Sorghum Varietal and Hybrid Adaptation Trial (ISVHAT), All India Coordinated Sorghum Improvement Project (AICSIP) and NARS survey data obtained through ICRISAT's Impact Monitoring Survey.

ISVHAT Data

ICRISAT commenced international yield testing of sorghum cultivars in 1976. Several yield trials were distributed by individual breeders until 1988. From 1989 to 1993, the trial was conducted by the Cooperative Cereals Research Network. It contained 26 elite sorghum genotypes and materials from all ICRISAT centers in Asia and Africa. Materials from Egypt, India, Sudan and Syria too were incorporated. Once every two years, the trial was reconstituted with new genotypes. Each year data from 25-30 locations, ranging in latitudes from 20°S to 43°N, were obtained. Data on phonology, plant height, grain yield and response to important pests and diseases were collected. (Alagarswamy 1996).

The trial provided scientists from various disciplines an opportunity to collaborate in the systematic evaluation of sorghum cultivars, and to contribute to the identification of cultivars adapted to specific regions in the semi-arid tropics in order to facilitate sustainable sorghum production. The trial's main objectives were to:

- make available to sorghum scientists the world's elite breeding lines, varieties and hybrids either for direct use or as parents in crosses within their breeding programs
- provide sorghum scientists an opportunity to assess the performance of their advanced breeding lines and released cultivars over a wide range of climatic, soil, disease and insect conditions
- identify lines with stable resistance to major disease, insects and other stresses
- identify similarities and differences in the effects of test environments on the performance of sorghum cultivars, and to achieve more focused testing
- serve as an information dissemination center on sorghum cultivar performance over a range of environments.

During 1989-92, trials were conducted in 59 locations spanning 26 countries in Asia, Africa and Latin America. The test locations and their physical environments are described in Table 11.1.

4. Spillin and spillover refer to the same phenomenon of externality. The terms are used interchangeably depending on whether a research program is receiving or producing the externality.

Figure 11.2 shows the locations of the trials. The trials comprised of about 25 cultivars common to all the locations (17 varieties and 8 hybrids, including a hybrid and a variety check). The AICSIP contributed 1 hybrid and 2 varieties. ICRISAT-Patancheru's Cereals Program contributed 6 hybrids and 6 varieties while its regional programs contributed 10 varieties (2 from WASIP, 4 from EARCAL, 2 from the SADC/ICRISAT Program and 2 from LASIP. Table 11.2 summarizes the number of locations to which ISVHAT data were made available between 1989 and 1992. The pedigrees of all the cultivars used in the trials are given in Table 11.3. Besides common cultivars, cooperators were asked to include some of their choice and a local check (a variety or hybrid). The trials were conducted using randomized complete block design with three replications.

AICSIP Trial Data

The AICSIP has been conducting adaptive research trials in different states and locations in the country. The data for 1975/76 to 1995/96 were utilized to quantify spillover impacts among different sorghum domains in India. Figures 11.3 and 11.4 show the locations of the trials conducted in India. Details of the locations and year of the trials are given in Table 11.4.

NARS Survey Data

A questionnaire (Appendix III) was sent to different sorghum-producing countries in Asia, Africa and Latin America to gather information on the cultivars released, their characteristics (origin, type of cultivar, ie, variety or hybrid), pedigree, year of release, morphological traits (grain color, insect and disease resistance), ecological niches, crop domains for which they were released, commercial success (area cultivated) and reasons for release (grain, forage, dual purpose). It also provided information on the status of sorghum cultivation in the country, ie, area, production and yield in different countries by environment and cultivar. The country's research capability and infrastructure measured by the number of scientists that support crop improvement in public and private research organizations as well as information on subsequent efforts to produce and promote improved seed (number of seed companies operating in the country) was sought.

11.2.2. Research Methodology

Sorghum research in different locations was conducted under eight research domains. A research domain was delineated as a homogeneous ecoregion defined in terms of its soil and climatic conditions and spreading beyond the geographical boundary of a country. For example, the major problem in Sorghum Research Domain (SRD) 2 is grain mold and in SRD3 stem borer and *Striga*. The eight sorghum research domains were: wide adaptability (SRD1), dual purpose with specific adaptability (SRD2), dual purpose with fodder emphasis (SRD3), forage sorghum (SRD4), early sowing postrainy-season sorghum (SRD5), late sowing postrainy-season sorghum (SRD6), irrigated sorghum (SRD7) and extreme altitude sorghum (SRD8). These have already been discussed in detail in Chapter 1. Here we have estimated the potential technology spillover impact for these eight research domains.

Two types of measurement techniques—subjective and objective—have been used to assess the spillover effects in agriculture (Deb and Bantilan 2001). Subjective estimates are based on value judgments rather than experimental or farm yield/cost data. They are often arrived at through elicitation from experts. Objective estimates, on the other hand, are based on hard data

Table 11.1. The physical environment of the ISVHAT test locations, 1989-92.

Country	Location	Country code	Location code	Latitude	Longitude	1989	1990	1991	1992
Brazil	Caruaru Pe	1	1	8°.3’ S	36°.0’ W			*	
Burkina Faso	Farako-Bâ	2	2	10°.3’ N	6°.5’ W	*	*	*	*
Burkina Faso	Saria	2	3	12°.2’ N	1°.9’ W	*	*		
Cameroon	Maroua	3	4	10°.3’ N	14°.7’ E	*	*	*	*
China	Shenyang	4	5	42°.5’ N	123°.0’ E	*	*		*
Ecuador	E.E.Boliche	5	6	2°.2’ S	79°.6’ W			*	
Egypt	Assiot	6	7	30°.0’ N	30°.0’ E	*			
Egypt	Sandaweel	6	8	26°.0’ N	31°.0’ E		*	*	*
Guatemala	Cuyata	7	9	14°.7’ N	90°.5’ W	*		*	
India	Anantapur	8	10	14°.5’ N	77°.0’ E	*			
India	Bhavanisagar	8	11	11°.0’ N	77°.0’ E	*	*	*	*
India	Jalna	8	12	19°.5’ N	75°.5’ E		*		*
India	Medchal	8	13	17°.3’ N	78°.2’ E		*	*	*
India	Patancheru	8	14	17°.3’ N	78°.2’ E	*	*	*	*
India	Surat	8	15	21°.1’ N	72°.5’ E		*	*	*
India	Thimmapur	8	16	17°.3’ N	78°.2’ E				*
Indonesia	Balittan Munene	9	17	7°.6’ S	113°.2’ E	*			
Indonesia	Bontobili-Sulawesi	9	18	5°.2’ S	119°.3’ E				*
Indonesia	Citayam	9	19	7°.0’ S	107°.0’ E	*	*		
Indonesia	Maumere	9	21			*			
Indonesia	Muara Bogor	9	22	7°.0’ S	107°.0’ E				*
Indonesia	Muneng	9	23	7°.6’ S	113°.2’ E		*	*	*
Indonesia	Pati	9	24	7°.0’ S	111°.0’ E			*	
Indonesia	Sulawesi (Maros)	9	25	5°.0’ S	119°.3’ E			*	
Iran	Isfahan	10	26	32°.5’ N	51°.5’ E			*	*
Iran	Karaj	10	27	35°.5’ N	51°.0’ E				*
Kenya	Alupe	11	28	0°.3’ N	34°.1’ E		*	*	
Kenya	Katumani	11	29	1°.4’ S	37°.1’ E	*	*	*	
Kenya	Kiboko	11	30			*	*	*	
Kenya	Kiboko (long rains)	11	31	1°.3’ S	37°.1’ E			*	
Mali	Bema	12	32	14°.7’ N	9°.5’ W		*		
Mali	Cinzana	12	33	13°.2’ N	5°.6’ E	*			
Mali	Niangoloko	12	34					*	
Mali	Samanko	12	35	12°.3’ N	8°.7’ E	*	*	*	
Mali	Sikasso	12	36	11°.2’ N	5°.4’ W			*	*
Mexico	Poza Rica	13	37	18°.4’ N	99°.1’ W	*	*	*	
Myanmar	CARI Yezin	14	38	19°.5’ N	96°.7’ E	*	*	*	*
Myanmar	Mahlaing	14	39	21°.5’ N	95°.4’ E			*	*
Myanmar	Myingyan	14	40	21°.3’ N	95°.2’ E			*	*
Nepal	Khumaltar	15	41	27°.4’ N	85°.2’ E				*
Nicaragua	Managua	16	42	21°.1’ N	86°.1’ W	*	*	*	
Niger	Bengou	17	43	11°.5’ N	3°.3’ E	*	*	*	
Nigeria	Bagauda	18	44	11°.4’ N	8°.3’ E	*	*	*	
Pakistan	Islamabad	19	45	33°.4’ N	73°.7’ E	*	*	*	*
Pakistan	Yusafwala	19	46	31°.0’ N	74°.0’ E	*	*	*	*
Sudan	Sim-Sim (Khartoum)	20	47	24°.4’ N	46°.5’ E	*			
Sudan	Wad Medani	20	48	14°.4’ N	33°.3’ E				*
Tanzania	Hombolo	21	49	5°.5’ S	35°.6’ E	*			

...continued

Table 11.1 ***Continued***

Country	Location	Country code	Location code	Latitude	Longitude	1989	1990	1991	1992
Thailand	Khon Kaen	22	50	16°.0' N	103°.0' E	*		*	*
Thailand	Pakchong	22	51	14°.5' N	101°.5' E		*	*	*
Thailand	Suphanburi	22	52	14°.2' N	99°.5' E	*	*	*	*
Venezuela	Magdaleno	23	53	10°.6' N	67°.3' E		*		
Vietnam	Tu Loc	24	54	20°.6' N	105°.0' E			*	*
Vietnam	Tu Loc Hai Huing	24	55	21°.0' N	105°.1' E		*		
Zimbabwe	Lucydale	25	56	20°.5' S	28°.3' E		*	*	*
Zimbabwe	Makoholi	25	57	19°.5' S	30°.5' E	*			
Zimbabwe	Matapos	25	58	20°.2' S	28°.3' E	*	*		*
Zimbabwe	Mzarabani	25	59	16°.2' S	32°.0' E	*			
Saudi Arabia	Riyadh	26	60	24°.4' N	46°.5' E		*	*	

* = Data available.
Source: ISVHAT reports.

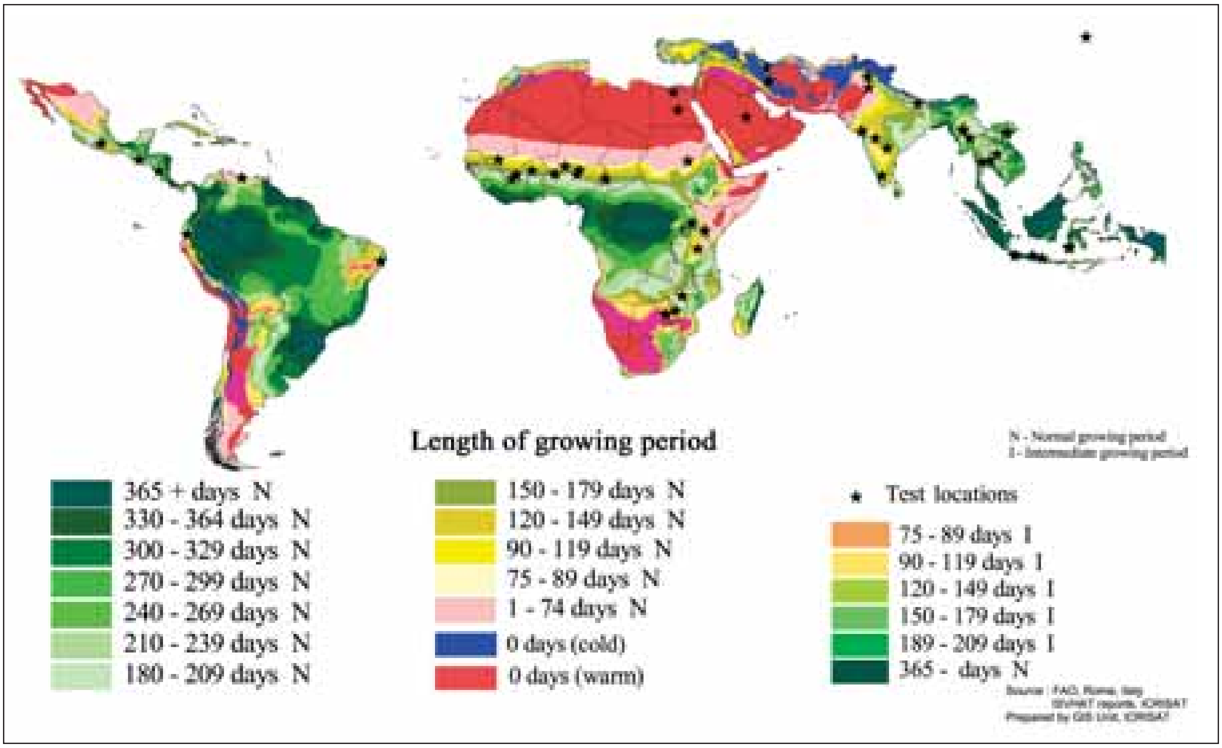

Figure 11.2. ISVHAT trial locations, 1989-1992.

and evidence reflecting the extent of applicability of a new technology across environments or commodities beyond the research target. Data requirement and methods of analysis for objective estimates vary, depending on the type of spillover to be assessed.

To quantify spillover impacts (ie, estimation of the coefficients of sorghum spillover matrix), an econometric approach based on yield trial data, similar to that of Maredia et al.(1996) was used. The first step was to identify the origin domain and trial (test) domain of sorghum cultivars tested in AICSIP and ISVHAT trials. The final step was to quantify spillover matrices.

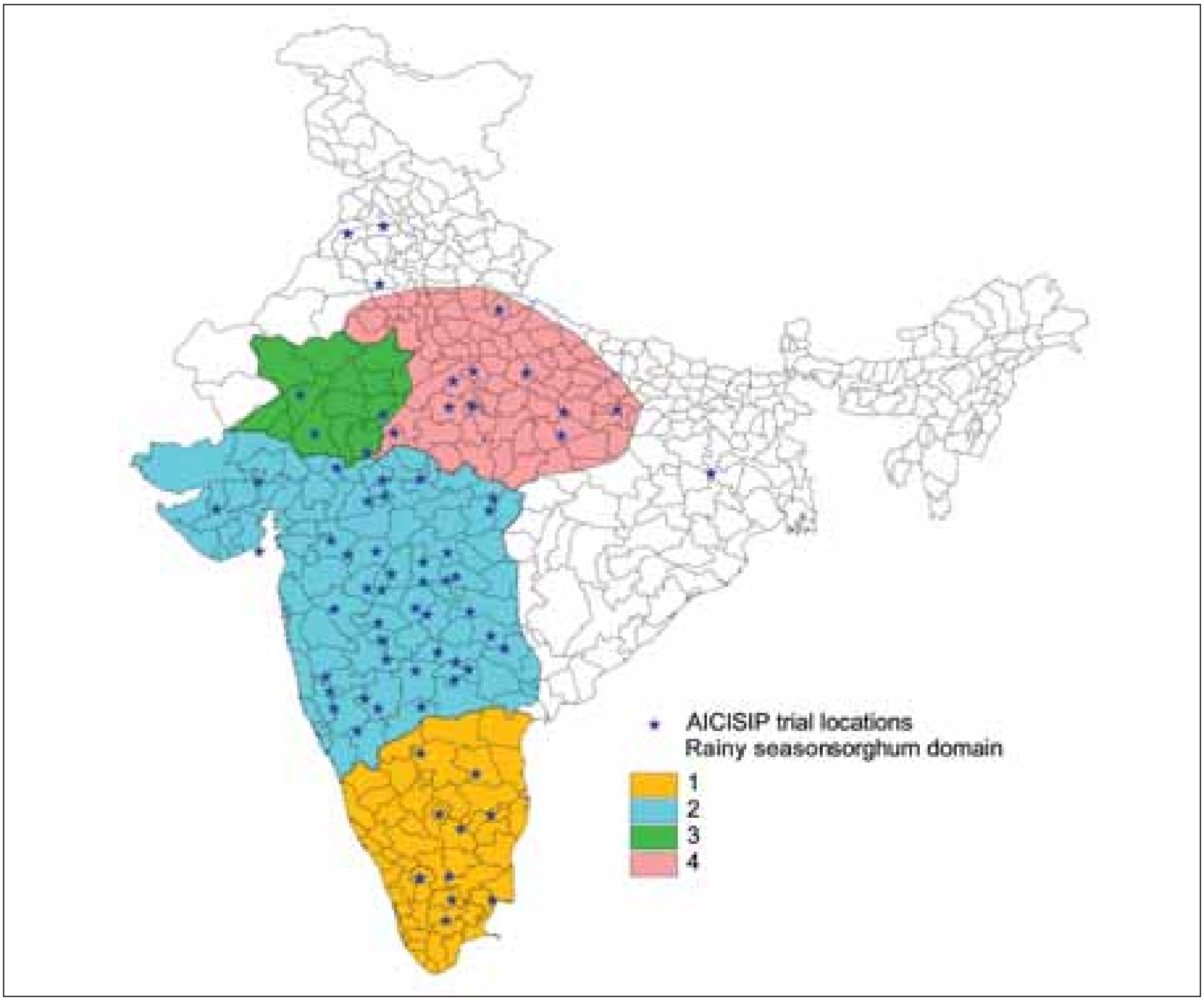

Figure 11.3. AICSIP trial locations.

Table 11.2. Number of locations to which ISVHAT data was made available, 1989-92.

	Data received for the year				Complete data received for the year			
Region	1989	1990	1991	1992	1989	1990	1991	1992
Asia	12	14	17	23	9	9	13	19
EARCAL[1]	2	3	4	-	2	3	4	-
WASIP[2]	7	7	7	3	5	4	4	3
Egypt	1	1	1	1	1	1	1	1
Southern Africa (SADC)[3]	4	2	1	2	4	2	-	2
Latin America (LASIP)[4]	3	2	5	-	3	-	5	-
RAB[5]	-	-	-	1	-	-	1	1
Other locations	1	3	2	-	-	2	-	-
Total	30	32	37	30	24	21	28	26

[1] EARCAL = East African Regional Cereals and Legumes Program.
[2] WASIP = West African Sorghum Improvement Program.
[3] SADC = Southern African Development Committee.
[4] LASIP = Latin American Sorghum Improvement Program.
[5] RAB = Regional Arab Bureau.
Source: ISVHAT reports.

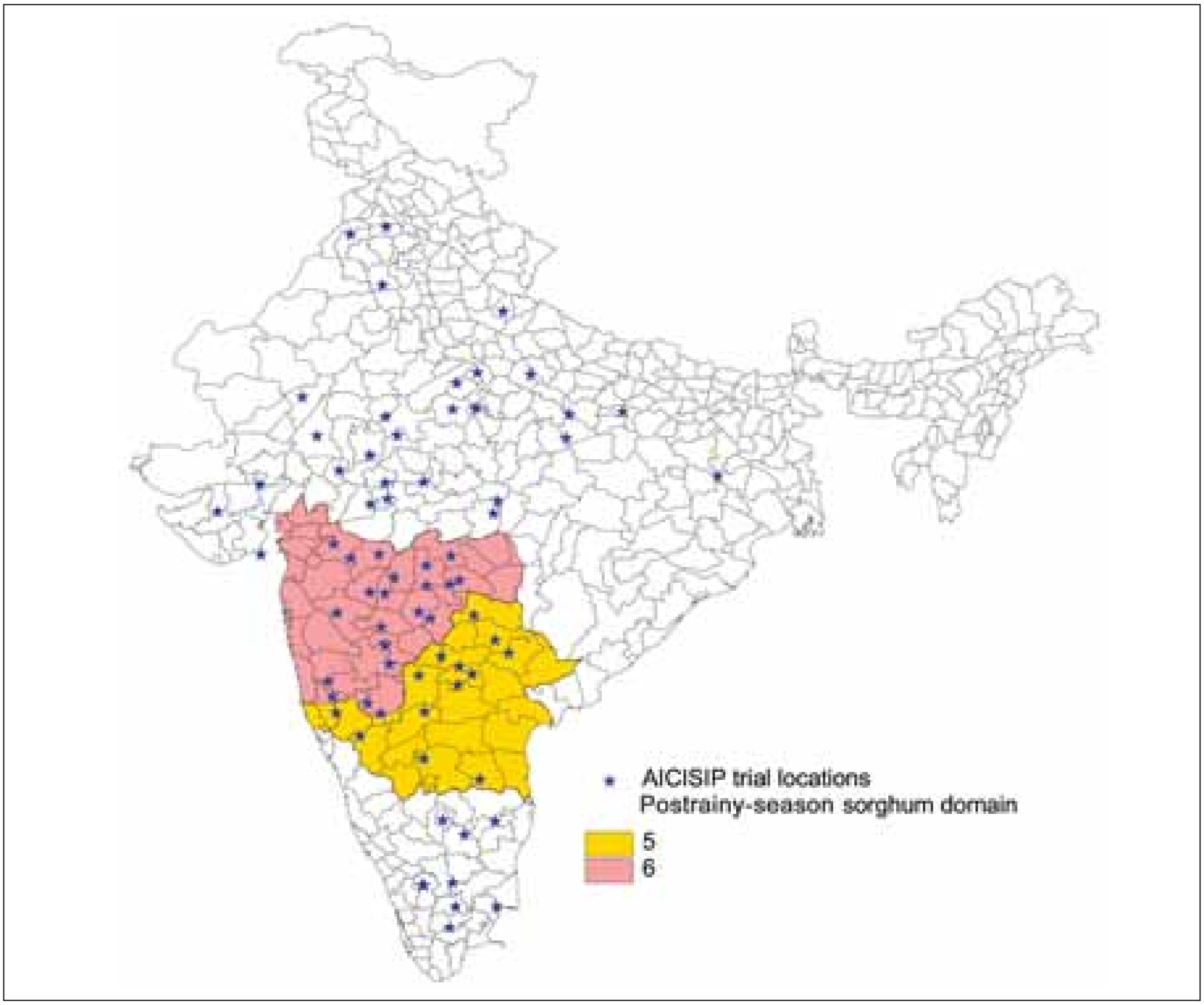

Figure 11.4. AICSIP trial locations.

Estimation of Spillover Matrix

Following Maredia et al. (1996), it was assumed that the performance of a variety is a function of environmental variables (location dummy, year dummy) and technology variables (vintage and origin of the variety). Technology variables were included to represent characteristics of varietal technology. The following regression model was used to estimate the spillover matrix.

$$Y^{j}_{hgt} = a + b_h\, DLOC_h + c_t\, DYEAR_t + v\, VINT + w_i\, DORIG_i + r\, MR + \in_{hgt}$$

for $j = 1,2,..,n$ (11.1)

where,

j is the test domain in which the yield data point is observed

Y^{j}_{hgt} is the observed yield (kg ha^{-1}) of the g^{th} entry at the h^{th} trial location in environment j in the t^{th} trial year

$DLOC_h$ is a vector of dummy variables equal to 1 if the data point belongs to location h, and 0 otherwise

$DYEAR_t$ is a vector of dummy variables equal to 1 if the data point belongs to year t, and 0 otherwise

VINT is a variable to reflect the vintage of a variety approximated by the trial year in which the g^{th} variety first appeared

Table 11.3. Name, pedigree and origin of cultivars included in ISVHAT, 1989-92.

Cultivar	Pedigree	Origin	Trial years
5D ´ 160		EARCAL (Burundi)	1990, 1991, 1992
CSH 9	296A × CS 3541	AICSIP	1989,1990
CSV 10	SB 1066 × CS 3541	AICSIP	1989, 1990
ICSH 110	296A × MR 836	IC	1989, 1990, 1991, 1992
ICSH 205	SPL 117 A × SPL 16 R	IC	1989, 1990
ICSH 310	ICSA 32 × MR 841	IC	1989
ICSH 401	ICSA 11 × MR 913	IC	1989
ICSH 566	ICSA 42 × SPL 13 R	IC	1989, 1990
ICSH 798	ICSA 17 × MR 926	IC	1989, 1990
ICSH 807	ICSA 17 × SPL 6 R	IC	1989, 1990
ICSH 871001	ICSA 84 × ICSR 172	IC	1991
ICSH 88051	ICSA 22 × MR 841	IC	1989, 1990
ICSH 88056	ICSA 32 × MR 924	IC	1989
ICSH 88058	ICSA 52 × MR 846	IC	1989, 1990
ICSH 88065	ICSA 67 × ICSR 154	IC	1991, 1992
ICSH 88071	ICSA 37 × MR 908	IC	1989
ICSH 88074	ICSA 39 × MR 844	IC	1989
ICSH 89020	ICSA 31 × ICSR 89022	IC	1991, 1992
ICSH 89034	ICSA 88005 × ICSR 89032	IC	1991, 1992
ICSH 89034	ICSA 88005 × ICSR 89032	IC	
ICSH 89051	ICSA 11 × ICSR 89018	IC	1991, 1992
ICSH 89123	ICSA 56 × ICSR 89028	IC	1991, 1992
ICSH 90002	ICSA 88005 × ICSR 112	IC	1991, 1992
ICSV-LM 86513		LASIP	1990, 1991, 1992
ICSV 202	(SPV 350 × SPV 475)-2-2-7	IC	1989
ICSV 1	(SC 108-3 × CS 3541)-19-1	IC	1989, 1990
ICSV 111		WASIP	1990, 1991, 1992
ICSV 112	[((IC 12622C × 555) × ((IS 3612C × 2219B)-5-1)) × E 35-1]-5-2	IC	1991, 1992
ICSV 210	(SPV 350 × SPV 475)-2-2-5	IC	1989, 1990
ICSV 233	[IS 9562 (IS 12611 × SC-108-3)]-3-2-2-5-1	IC	1989, 1990
ICSV 298	[(M-35-1 × M-1009)-3-2-1 × 6 F5 s]-5-1-4-2	IC	1989
ICSV 401		WASIP	1990, 1991, 1992
ICSV 421	(148 × 555)-Bulk-1-1-1	IC	1989
ICSV 689	(PS 21314 × A 6180)-8-9-1-1-2	IC	1989
ICSV 725	(M 60048 B × PS 19230) -17-2-2-1-1	IC	1989
ICSV 745	(PM 11344 × A 6250)-4-1-1-1	IC	1989
ICSV 747	(PM 11344 × A 6250)-8-2-1-4-3	IC	1989
ICSV 88002	[(ICSB 3 × SPV 615) × (BT × 678)B.bulk))]-1-9-2-1	IC	1991, 1992
ICSV 88013	(PM 11344 × SPV 351) -27-1-1-2	IC	1990, 1991, 1992
ICSV 88032	(PM 11344 × SPV 351) -27-1-1-2	IC	1990, 1991, 1992
ICSV 89102	[(IS 23528 × SPV 475) × PS 29159]-4-2-1	IC	1991, 1992
ICSV 89106	[(IC 149 × SPV 475) × ICSB 1]-6-1-1	IC	1991, 1992
IS 23496		SADC	1990
IS 23509		SADC	1990, 1991, 1992
IS 8193		EARCAL (Kenya)	1990, 1991, 1992
IS 9302		EARCAL (Ethiopia)	1990, 1991, 1992
ISIAP DORADO		LASIP	1990, 1991, 1992
KAT/83369		EARCAL (Kenya)	1990, 1991, 1992
Local check			1989
Local check			1990
Local check			1991
Local check			1992
SPH 468	AKMS 14 A × R 150	AICSIP	1991, 1992
SPV 462	MS 8271 × IS 3691	AICSIP	1989, 1990
SPV 669	[353 (604 × 512) × (Vidisha 60-1 × CS 1151)]	AICSIP	1991, 1992

Source: ISVHAT reports.

Table 11.4. Multilocational trials conducted by AICSIP, 1975-95.

	Trails conducted (year)																				
Location	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Maharashtra																					
Parbhani	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Akola	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Nagpur		*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Gadhinglaj			*								*	*	*	*		*		*	*		*
Jalgaon	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*		*
Karad	*		*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Jalna									*												
Digraj	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*		*
Somanathpur		*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Amaravati	*	*	*	*	*	*	*	*	*	*	*	*	*	*					*	*	*
Nanded		*	*	*	*	*	*	*	*	*	*	*	*						*		*
Dhulia	*	*	*	*	*	*		*	*	*	*	*	*	*		*		*			*
Ekarjuna									*											*	
Mohol									*											*	
Badnapur									*											*	
Solapur									*											*	
Rahuri		*		*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	
Buldana	*	*	*	*	*	*	*	*	*	*	*		*	*		*		*	*	*	*
Yeotmal	*	*	*	*	*	*	*	*	*	*		*	*	*		*		*	*	*	*
Kolhapur			*											*							
Ambejogai		*											*								
Akola (Dryland Project)	*		*																*		
Aurangabad														*		*				*	*
Karnataka																					
Dharwar	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Gulbarga								*											*		
Arbhavi	*	*	*	*	*	*	*														

...continued

Table 11.4 ***Continued***

Location	Trails conducted (year)																				
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Bijapur		*														*			*		
Raichur	*		*																		
Bagalkot	*	*	*	*	*	*	*		*				*								
Bidar									*									*	*	*	*
Gangavati	*	*		*																	
Baihongal	*							*	*	*	*	*	*	*		*		*	*	*	
Dharwar ADC			*			*															
Konnur			*			*															
Jhamkhandi			*																		
Tyavangi		*				*															
Andhra Pradesh																					
Palem	*	*	*	*	*	*	*	*	*	*		*				*		*	*	*	*
Hayatnagar																					
Rajendranagar		*		*	*	*	*														
Anantapur		*	*	*		*	*		*	*	*		*								
Dindi									*												
Madhole	*		*	*	*					*	*										
Adilabad	*	*	*	*		*	*	*	*		*	*	*			*		*	*	*	*
ICRISAT							*	*	*	*	*	*	*			*					
Karimnagar		*	*		*				*	*		*	*								
Dryland Project, Hyderabad				*																	
Warangal	*		*	*																	
Sadhasivpet													*								
Madhira																		*			
Madhya Pradesh																					
Indore	*	*	*	*	*	*	*	*	*	*	*	*	*			*		*	*	*	*
Sehore												*									
Gwalior	*		*							*	*					*			*		
Mandsaur	*	*	*	*	*	*	*		*	*						*					
Khargaon			*	*		*			*									*			

...continued

Table 11.4. ***Continued***

Location	Trails conducted (year)																				
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Chindwara	*	*	*					*	*	*	*										
Poewerkheda		*	*		*																
Tikamgarh									*												
Rewa		*																			*
Burhanpur	*			*																	
Ujjain																*		*			
Tamil Nadu																					
Coimbatore	*	*	*	*	*	*	*	*	*	*	*	*	*			*		*	*	*	*
Bhavanisagar	*	*	*		*	*	*	*	*	*	*	*									
Kudumlai		*	*	*																	
Paiyur			*	*	*	*	*	*	*	*	*							*	*	*	*
Krishnagiri	*	*																			
Vellore											*	*									
Kaveripattinam		*																			
Kovilpati																*					
Rajasthan																					
Vallabhnagar	*																				
Udaipur		*	*	*	*	*	*	*	*	*	*	*		*		*		*	*	*	*
Sumerpur			*		*	*	*														
Aklera		*	*								*		*					*			*
Pali			*	*	*			*	*	*											
Kota	*					*	*	*	*	*	*										
Diggi						*										*		*			
Banswara	*	*	*							*		*		*							
Jhalwar	*																				
Gujarat																					
Navsari	*	*	*	*	*	*		*	*	*		*	*	*		*		*	*	*	*
Surat	*	*	*	*	*	*	*	*				*	*	*		*		*	*	*	*
Targhadia									*	*				*				*			
Dharia									*		*										
Talaja		*	*	*																	

...continued

Table 11.4. ***Continued***

Location	Trails conducted (year)																				
	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Deesa			*		*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Manavadar		*	*																		
Veerangam						*	*	*	*	*	*										
Rajkot			*	*			*	*								*					
Chharodi												*	*	*		*		*			*
Uttar Pradesh																					
Jhansi (RAS)		*																			
RATDC Jhansi					*																
Jhansi		*	*					*		*		*	*			*		*			
Jhansi (IGFRI)	*																				
Varanasi			*																		
Pantnagar		*	*	*	*	*	*	*	*	*			*	*				*	*		
Kanpur	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*
Mauranipur									*	*	*	*	*	*					*	*	*
Bareilly											*										
Bulandshahar			*																		
Bihar																					
Ranchi	*	*	*																		
Mungir											*								*		
Kanki				*																	
Dholi								*													
Sabour								*	*	*											
Orissa																					
Bhavani Patna											*										
Punjab																					
Ludhiana								*	*	*	*	*	*								
Faridkot									*												
Haryana																					
Hissar		*	*	*	*	*		*		*											
Jammu & Kashmir																					
RK Pura (Jammu)	*	*																			

* = Data available.
Source: AICSIP reports (various years).

$DORIG_i$ is a vector of dummy variables equal to 1 if the g^{th} variety belongs to the origin group i, and 0 otherwise
MR is the inverse Mill's ratio
$\in$ is the error term

ISVHAT panel data was used to estimate the model. Location and year dummies (DLOC and DYEAR) were included to factor out the site and time effects (such as different levels of management) on the observed trial. To correct probable selection bias related to the correlation between varietal attrition and experimental response (ie, yield) of nonrandomly missing varieties in the trials conducted over a number of years, the variable MR (inverse Mill's ratio) was included. The model was estimated separately for each sorghum domain; therefore the coefficients for DORIG represent the performance of varieties of different environmental origins in a given sorghum domain relative to the 'home varieties'[5]. The varietal group originating from the test domain was considered the benchmark variable (ie, the dummy variable $DORIG_j$ was dropped from the equation for each domain). Therefore, the coefficients of $DORIG_i$ are the differential yields defined as ($w^j_i = Y_{ij} - Y_{jj}$). These coefficients were used to estimate Y_{ij}/Y_{jj} to give the elements of the spillover matrix, C_{ij}, based on the constant Y_{jj} (approximated by the arithmetic mean) for each domain.

11.3. Technology Spillover Potential

11.3.1. Across Sorghum Research Domain Spillover Matrix for the World

Model parameters in Equation (11.1) were estimated using the ordinary least square method from ISVHAT data. Results from the regression analyses (Table 11.5.) indicate that the inclusion of the location dummy variables had a significant positive effect on the R^2 of all the seven regression models. Similarly, the year dummy variables for the trial years significantly increased the R^2 of the estimated models. The coefficient of the MR variable indicates the relationship between observed yields and the probability of retention in the trials.

The coefficient of origin variables (w_i) estimate the yield advantage or disadvantage (kg ha^{-1}) of varieties originating in different sorghum domains relative to the test sorghum domain. The zeros on the diagonal indicate that the coefficient of variety group of the same domain origin as the test domain is defined as the 'benchmark' and all the other coefficients in that column represent deviations from that value.

The negative values of NARS technology in most of the sorghum research domains (Table 11.5) confirm the hypothesis that varieties developed in a test domain perform better than those developed in other domains. For example, NARS varieties of SRD2 origin on an average yielded 96 kg less in SRD1 (after adjusting for other variables). However, it needs to be mentioned that the values (related to DORIG) in most of the cases were not statistically significant. Negative values in a given column result from either both genetic differences among cultivars and a difference in the selective domain at the test versus origin domain, or only from a difference in the genetic properties of the cultivars tested. The latter circumstances could reflect different levels of breeding success and would result in a symmetrical relationship such that $w_i^j = - w_j^i$. The abundance of negative values both above and below the diagonal shows that ICRISAT's sorghum domains reflect true differences in selective environmental properties.

[5] Home varieties are the best performing varieties presently cultivated in the area. In other words, the 'checks' used in the yield trails.

Table 11.5. Regression results of potential spillover at the sorghum research domain level using ISVHAT data, 1989-92.

Independent variables	SRD1	SRD2	SRD3	SRD4	SRD7	SRD8.1	SRD8.2
Constant[1]	4779***	4506***	4199***	4341***	8331***	15968***	5936***
Dummies for year							
R^2 change[2]	0.07	0.02	0.04	0.09	0.06		0.06
F change[3]	-15	-32	-6	-2	-6		-17
Dummies for location							
R^2 change[2]	0.07	0.39	0.22		0.22		0.18
F change[3]	-27	0	3		7		-12
Mill's ratio (MR)[1]	-4101902***	-2071749***	-1496520***	-3054522***	-6644808***	-9772124***	-7674958***
Origin, DORIG[1,4]							
DORIG1		-139	24	-126	-797	-5221**	440
DORIG2	-96		-134	53	-316	-5989**	734*
DORIG3	148	-97		-2323	-76	-4443*	732*
DORIG4	-642						
DORIG7		74	-764	810	-26		93
DIDC	277*	175	354	-56			
Number of observations	457	1549	601	249	307	194	371
R^2	0.53	0.26	0.32	0.61	0.32	0.65	0.54
F value	102***	109***	57***	65***	30***	31***	87***

1. Estimated coefficient (kg ha^{-1}).
2. Change in R^2 when a given set of dummy variables is included in the equation that includes all the other variables.
3. Change in the F-ratio when a given set of dummy variables is included in the equation that includes all the other variables.
4. Origin groups DORIG1 to DORIG7 represent cultivars developed by national programs for the respective domains. DIDC indicates cultivars developed at ICRISAT-Patancheru.

* = P<0.05, ** = P<0.01, *** = P<0.001.

The last row shows that ICRISAT cultivars performed well in most sorghum research domains, especially SRD1, SRD2, SRD3 and SRD8.2. For example, ICRISAT cultivars bred at Patancheru enjoyed a yield advantage of 277 kg ha^{-1} in SRD1, 354 kg ha^{-1} in SRD3 and 175 kg ha^{-1} in SRD2. This positive yield advantage indicates their potential to spill over to these test domains. It also indicates the success of ICRISAT's breeding for wide adaptability. This interpretation is strengthened by data in Table 11.6.

Table 11.6 presents the average yield (kg ha^{-1}) of sorghum cultivated in ISVHAT trials. The grain yield of ICRISAT-bred cultivars was higher in all the sorghum domains compared to those bred exclusively for those domains, except in the case of SRD7 and SRD8.1. In SRD1, it was 472 kg ha^{-1} while in SRD2 it was 446 kg ha^{-1}. In SRD3, ICRISAT-bred cultivars had a yield advantage of 256 kg ha^{-1} while in SRD4 and SRD 8.2 the corresponding figures were 1645 kg ha^{-1} and 995 kg ha^{-1}. SRD4 is the sorghum domain for forage-type sorghum. Therefore, comparing grain yield is not appropriate. One of the major limitations in ISVHAT is the lack of data on fodder yield. ICRISAT's programs were not breeding and testing for forage. However, the lower grain yield of NARS-bred cultivars for forage in SRD4 compared to those developed in other sorghum domains suggests that research on forage sorghum was probably successful in developing more stalk-producing cultivars (but with low grain yield). Sorghum cultivars developed for SRD7 (irrigated environment) and SRD3 (dual purpose, late maturing) also performed better in SRD2 (dual purpose, early maturing) than the local NARS-bred cultivars. This indicates the potential of sorghum cultivars developed for irrigated domain to spill over into rainy season, late maturing and dual-purpose sorghum areas. However, it may be noted here that irrigated-type sorghums may not have an advantage in terms of fodder yield since this was not available in ISVHAT data. The higher grain yield of SRD3 cultivars compared to SRD2 cultivars indicates the high spillover potential between two different maturity groups of dual-purpose sorghum. Again, firm conclusions cannot be drawn without analyzing fodder yield data which is one of the two major objectives—high grain yield and high fodder yield—of sorghum breeding for dual purposes.

The spillover coefficients are presented in Table 11.7 in terms of percentage coefficients based on average yields of the benchmark variables (i.e., $c_{ij} = Y_{ij}/Y_{jj}$). Off-diagonal values of less than one indicate that sorghum cultivars directly introduced from other sorghum domains yielded less than those developed by local breeding programs in the test domain. Similarly, values greater

Table 11.6. Average yield (kg ha^{-1}) of sorghum obtained in ISVHAT trials, 1989-92.

Origin of cultivar	Sorghum Research Domains where cultivars were tested						
	SRD1	SRD2	SRD3	SRD4	SRD7	SRD8.1	SRD8.2
SRD1	3123	3288	2946	2103	5418	5390	4266
SRD2	2991	3463	3042	2633	5733	3498	4705
SRD3	2758	3622	3500	2362	6267	6275	4457
SRD4	No cultivar	No cultivar	No cultivar	1404 16	No cultivar	No cultivar	No cultivar
SRD7	2490	3913	2788	1793	7381	No cultivar	No cultivar
SRD8.1	No cultivar	No cultivar	No cultivar	No cultivar	No cultivar	15089 (11)	No cultivar
SRD8.2	No cultivar	No cultivar	No cultivar	No cultivar	No cultivar	No cultivar	3677 (23)
ICRISAT-Patancheru	3595	3909	3756	3049	6142	4973	4672

Source: Authors' estimate.

Table 11.7. Estimated spillover matrix for sorghum improvement research at the global Sorghum Research Domain level (computed from ISVHAT trial data, 1989-92).

Origin of cultivar	Sorghum Research Domains where cultivars were tested						
	SRD1	SRD2	SRD3	SRD4	SRD7	SRD8.1	SRD8.2
SRD1	1.00	0.95	0.84	1.50	0.73	0.36	1.16
SRD2	0.96	1.00	0.87	1.88	0.78	0.23	1.28
SRD3	0.88	1.05	1.00	1.68	0.85	0.42	1.21
SRD4				1.00			
SRD7	0.80	1.13	0.80	1.28	1.00		
SRD8.1						1.00	
SRD8.2							1.00
ICRISAT-Patancheru	1.15	1.13	1.07	2.17	0.83	0.33	1.27

Source: Authors' estimate.

than one (as in the case of ICRISAT-Patancheru-bred cultivars) indicate that sorghum cultivars directly introduced from these sources tended to yield more than those developed by local breeding programs in the test domain.

The significant yield advantages shown by varieties developed and evaluated in SRD7 and SRD 8.1 (implying less direct spillins of cultivars developed for other sorghum domains) can be explained by the fact that sorghum cultivars bred for rainfed environments cannot perform better in irrigated environments. 'Environmental distance' plays a role in explaining the significant yield advantage enjoyed by locally-bred cultivars in SRD7 (irrigated) and SRD8.1 (high altitude). The poor performance of all the cultivars developed for other sorghum research domains or bred for wide adaptability by ICRISAT-Patancheru in SRD8.1 (high altitude, ie, China) can be explained by the fact that the climate adaptation patterns are entirely different compared to other domains. Therefore, the best way ICRISAT can assist China's national program is by providing intermediate products (enhanced germplasm materials) rather than finished ones (varieties/hybrids). This argument is strengthened by the fact that of the 10 hybrids developed in China after 1987, 7 are derived from ICRISAT materials, but after incorporating genes for local adaptation. The implications for ICRISAT are that the focus should be on upstream (strategic) research to develop basic materials and provide NARS with strong research programs. ICRISAT moved in this direction in 1995.

Sorghum cultivars developed for irrigated environments (SRD7) showed 13% grain yield advantage in SRD2 (late maturing, dual purpose) but not vice versa. The asymmetry of these two domains explains the asymmetry in the spillover matrix (i.e. $c_{ij} \neq c_{ji}$). However, without comparing fodder yield it cannot be said that sorghums bred for irrigated environments (SRD7) were really performing better in SRD2. The major objective of dual-purpose sorghum (SRD2) is to provide high grain and fodder yield, while breeding of irrigated sorghum concentrates on increasing grain yield. Therefore, SRD7 cultivars may provide higher grain yield but not higher fodder (stalk) yield.

An analysis of the performance of ICRISAT-Patancheru-bred cultivars across sorghum domains using the regression analyses reveals wide adaptability and transferability to different sorghum growing domains. This points to the success of research in reducing G × E interactions and developing widely adaptive cultivars, especially in all types of rainfed cultivation and in low altitude areas, which account for a significant share of the sorghum growing area in developing countries.

These results are based on a spillover analysis at the global sorghum domain level using data from ISVHAT coordinated by ICRISAT and with considerable representation of ICRISAT-bred-cultivars. In order to check if the evidence of high transferability of ICRISAT-bred cultivars is sustained, the model in Equation (11.1) was estimated for India in the country-level environments using AICSIP trial data.

11.3.2. Across Sorghum Research Domain Spillover Matrix for India

The AICSIP trial data for 1975-96 was used to estimate the spillover coefficient matrix for sorghum in India. It was computed for each of the eight sorghum domains for ICRISAT-derived-cultivars (IDCs) and NARS-derived cultivars. IDCs are those varieties/hybrids developed through research partnership between ICRISAT and NARS using ICRISAT-derived germplasm or breeding material, while NARS-developed cultivars are cultivars developed solely by NARS.

The results of the regression analyses (Table 11.8) indicate that the inclusion of dummy variables for the year had a significant positive effect on the R^2 of all the seven regression models.

As mentioned earlier, the coefficient of the MR variable indicates the relationship between observed yields and the probability of retention in the trials.

It may be recalled that the coefficient of origin variables (w_i) estimate the yield advantage or disadvantage (kg ha^{-1}) of varieties originating in different environments relative to the test environment. The zeros on the diagonal indicate that the coefficient of variety group with the same origin and test domains is defined as the 'benchmark'; and all the other coefficients in that column represent deviations from that value.

The dominance of the positive values of Indian NARS-developed varieties for wide adaptability (SRD1) and dual purpose with specific adaptability (SRD2) to other test domains except irrigated sorghum domain (SRD7) confirms the hypothesis that varieties developed by the Indian NARS in SRD1 and SRD2 perform better than varieties developed in other domains. For example, Table 11.8 shows that NARS varieties of SRD1 origin yielded 320 kg more on an average in SRD2 (after adjusting for other variables). Similarly, NARS varieties of SRD1 have a yield advantage of 305 kg ha^{-1} in SRD3 and 423 kg ha^{-1} in SRD6. The implication of this finding is that the Indian NARS was successful in its efforts to generate widely adaptable cultivars.

A few negative values can also be found in the coefficients. For example, the field of cultivars originating from SRD2 and SRD5 is less than the cultivars that originated in SRD1 (the wide adaptability domain). Negative values in a given column result from either both genetic differences among cultivars and/or a difference in the adaptation pattern at the test versus origin domain. The genetic difference could reflect different levels of breeding successes and would result in a symmetrical relationship such that $w_i^j = - w_j^i$. The presence of negative values both above and below the diagonal show that the sorghum domains used for the analysis reflect the true differences in selective environmental properties in India.

The last row in Table 11.8 shows that ICRISAT-derived cultivars perform well in most sorghum domains, especially in SRD1, SRD2, SRD3 and SRD4. For example, the dummy for IDCs indicate that they enjoy a yield advantage of 354 kg ha^{-1} in SRD1, 418 kg ha^{-1} in SRD2 and 576 kg ha^{-1} in SRD3. The positive yield advantage of IDCs is an indication of their potential to spill over to these test domains. It also indicates the success of ICRISAT-Patancheru's breeding program in developing enhanced materials for wide adaptability. This interpretation is strengthened by Table 11.9.

Table 11.9 presents the average yield $(kg\ ha)^{-1}$ of sorghum obtained in AICSIP trials during 1975-96. The per hectare grain yield of IDCs was higher in all the sorghum domains compared to the cultivars bred for those domains, except in SRD7. In SRD1, yield increase was 166 kg ha^{-1} while in SRD2 it was 328 kg ha^{-1}. The corresponding figures for SRD5 and SRD6 were 492 kg ha^{-1} and 252 kg ha^{-1}.

The spillover coefficients are presented in Table 11.10 in terms of percentage coefficients based on average yields of the benchmark variables (ie, $c_{ij} = Y_{ij}/Y_{jj}$). Off-diagonal values of less than one indicate that sorghum cultivars directly introduced from other sorghum domains yield less than those developed in the test domain. Similarly, values greater than one (as in the case of IDCs) indicate that sorghum cultivars directly introduced from these sources yield more than those developed in the test domain.

A regression analyses of the performance of IDCs across sorghum domains shows their wide adaptability and transferability to different domains. The environmental specificity and associated selective environmental heterogeneity evident in the comparison of NARS-developed cultivars are minimized when IDCs are compared across different sorghum domains. This indicates the success of the collaboration between ICRISAT and Indian NARS in reducing G × E interactions and developing widely adaptive cultivars in India.

Table 11.8. Regression results of potential spillover at the Sorghum Research Domain level using AICSIP trial data, 1975-96.

Independent variables	SRD1	SRD2	SRD3	SRD4	SRD5	SRD6	SRD7
Constant[1]	2302***	2965***	1472***	2423***	2400***	2388***	2880***
Dummies for year							
R^2 change[2]	0.04	0.04	0.27	0.08	0.10	0.04	0.03
F change[3]	-79.03	-161.13	-5.91	-49.94	-70.56	-127.04	-3.78
Mill's ratio (MR)[1]	-109475***	-197034***	-79704***	-239804***	-240648***	-345329***	-209760***
Origin, DORIG[1,4]							
DORIG1		320***	305*	27	117	423*	38
DORIG2	-257**				54	1303***	-431*
DORIG5	-492	-311				5	-90
DORIG6		4			-143*		
DIDC	354***	418***	576***	103	466***	-4	-389
Number of observations	2048	10851	635	1575	2644	3278	466
R^2	0.16	0.10	0.11	0.11	0.18	0.21	0.22
F value	102.71***	230.15***	27.89***	66.75**	116.49***	174.53***	27.34***

1. Estimated coefficient (kg ha^{-1}).
2. Change in R^2 when a given set of dummy variables is included in the equation that includes all the other variables.
3. Change in the F-ratio when a given set of dummy variables is included in the equation that includes all the other variables.
4. Origin groups DORIG1 to DORIG6 represent cultivars developed by national programs for the respective domains. DIDC indicates cultivars developed at ICRISAT-Patancheru.

* = P<0.05, ** = P<0.01, *** = P<0.001.

Source: Authors' estimate.

Table 11.9. Average yield (kg ha^{-1}) of sorghum obtained in AICSIP trials, 1975-96.

Origin of cultivar	Sorghum Research Domains where cultivars were tested							
	SRD1	SRD2	SRD3	SRD4	SRD5	SRD6	SRD7	Outside
SRD1	2054	3175	1686	2297	2339	2406	2652	1910
SRD2	1928	2943	1434	2276	2368	3551	2179	1523
SRD5	1717	2545			2172	2098	2710	
SRD6		2954			1999	2153	2759	
ICRISAT-Patancheru	2220	3271	1960	2392	2664	2405	2402	2028

Table 11.10. Estimated spillover matrix for sorghum improvement research at the Sorghum Research Domain level (computed from AICSIP trial data, 1975-96).

Origin of cultivar	Sorghum Research Domains where cultivars were tested							
	SRD1	SRD2	SRD3	SRD4	SRD5	SRD6	SRD7	Outside
SRD1	1.00	1.08			1.08	1.12		
SRD2	0.94	1.00			1.09	1.65		
SRD5	0.84	0.86			1.00	0.97		
SRD6		1.00			0.92	1.00		
ICRISAT-derived cultivar	1.08	1.11			1.23	1.12		

11.4. Spillover Impacts

Brennan and Bantilan (1999) quantified the spillover impact of ICRISAT research on breeding programs and agricultural production in Australia. They identified ICRISAT germplasm lines released in Australia and grown by farmers there. In the case of sorghum, ICRISAT's most significant contribution to Australian agriculture has been the introduction of improved midge-resistant lines combined with desirable white grain and tan-colored plant (ICSV 745 and PM 13654). There are several advanced breeding lines that have incorporated midge resistance and a combination of other useful characteristics from ICRISAT-derived material. As a result, experts from the sorghum industry expect hybrids with midge resistance to be available in the near future, and that the resistance of such material will have a significant economic impact on the industry. Assuming that such resistance is likely to increase yield by 5% in 50% of the crop affected by midge each year, the expected yield gains to Australia are estimated at 2.5%. This translates into a cost reduction of \$4.02 ton^{-1} or an annual cost saving of \$4.69 million at current average production levels.

Brennan and Bantilan (1999) also assessed the impact of ICRISAT's global research on Australia, via an impact on prices. ICRISAT's global research has increased production and decreased sorghum price. Given finite supply and demand elasticities, ICRISAT's research is likely to have a downward impact on prices for the predominantly export-oriented sorghum industries in Australia. Thus, Australian industries face lower prices and increase in yield. An economic analysis of those spillover impacts in an economic welfare framework revealed that the overall net effect for Australia was a reduction in benefits gained by producers. Australian sorghum producers will lose more through lower prices than through the benefits they gain from higher yields, resulting in an overall loss of A\$ 0.55 million per year. These losses occur because Australian producers are unable to make use of the productivity gains from ICRISAT's research as much as producers in the rest of the world. Hence, other producers experience greater cost reductions than do Australian producers. On the other hand, Australian consumers of sorghum (ie, primarily the livestock sector) will gain an average of A\$1.69 million per year. Overall, the net gain to Australia as a result of ICRISAT's sorghum research effort averages A\$1.14 million per year, or an aggregate of A\$27.3 million (in 1996 dollars) over the period to 2022.

Actual spillover benefits have accrued in sorghum-growing countries. Macia, a variety released in Mozambique, was also later released in Botswana, Tanzania and Namibia (Table 11.11). Similarly, S 35 was developed in India and adopted by farmers of Cameroon and Chad. ICSV 111 was developed in India and released in Burkina Faso, Chad and Nigeria. ICSV 1079 BF was developed in Burkina Faso but is now cultivated by farmers in Mali. SPV 475 developed for India is now cultivated in Malawi, Swaziland and Zimbabwe. Seredo was developed for Uganda but also cultivated by farmers of Ethiopia, Kenya and Tanzania.

These examples show that breeders were successful in generating technology with wide adaptability and technology spillover potential; and do not substantiate the 'location specificity' argument (at least in terms of yields). Sorghum cultivars originating from the collaborative ICRISAT-NARS international research system have proven to be highly transferable within sorghum domains and across different countries around the world.

Table 11.11. Sorghum germplasm spillovers.

Cultivar	Production system[1] and country where originally selected	Spillover into
5D x 160	21 Uganda	21 Rwanda; 20, 21 Burundi
Dinkmash	8 India	19, 20 Ethiopia
Gambella 1107	20 Ethiopia	20, 21 Burundi
Ingazi	8 India	19, 20 Kenya
Macia	20 Mozambique	19 Botswana Tanzania, Namibia
Melkamash	8 India	20 Ethiopia
Seredo	21 Uganda	19 Ethiopia; 20, 21 Kenya; 20 Tanzania
SPV 475	8 India	20 Malawi; Swaziland, Zimbabwe
SRN 39	8 India; 19 Sudan	20 Kenya; 20 Ethiopia
Tegemeo	21 Uganda	19, 20 Tanzania; 20 Burundi
S 35	India	Cameroon, Chad
CE 151	Senegal	Mauritania
CE 145-66	Senegal	Mauritania
Malisor 84-1	Mali	Ivory Coast
BF 83-3/ 48-2-2	Burkina Faso	Senegal
IRAT	Niger	Burkina Faso, Chad
ICSV 111 IN	India	Benin, Ghana, Nigeria
ICSV 1079 BF	Burkina Faso	Mali
ICSV 1083 BF	Burkina Faso	Togo
ICSV 1089 BF	Burkina Faso	Senegal
ICSV 400	India	Nigeria

1. Production system 8 (PS 8): tropical, low rainfall, primarily rainfed, postrainy season crops are sorghum/oilseed and includes the Western Deccan Plateau of India; Production system 19 (PS 19): lowland, rainfed, short season (less than 100 days) and suitable for sorghum/millet/rangeland and located in Sahelian Eastern Africa and the margins of the Kalahari Desert; Production system 20 (PS 20): covers semi-arid area, intermediate season (100-125 days), suitable for sorghum/maize/rangeland and located in Eastern Africa and parts of Southern Africa; and Production system 21 (PS 21): intermediate season (125-150 days), suitable for sorghum/maize/finger millet/legumes and located in Eastern and Southern Africa. The agroecological details of each PS are given in the ICRISAT Annual Report, 1993.

Source: ICRISAT Southern and Eastern Africa Highlights (1996); International Sorghum and Millet Newsletter (1997).

11.5. Determinants of Technology Spillover

To identify the factors responsible for technology spillover, the strengths of different NARS in terms of scientific capability measured through the number of scientists and their formal education level was dwelt on. India and China are the two countries with strong research capabilities in Asia (see Chapter 1). They have a large scientific mass (China - 200 scientists and India - 150). Other countries have a limited number of scientists ranging between 3 (Rwanda) and 50 (Ethiopia). The extent of the formal education of sorghum breeders in a country indicates the country's capability to generate new technology while its number of agronomists, seed technologists, entomologists, pathologists and social scientists reveals its strength in adaptive research. Therefore, it is likely that the larger share of released cultivars from international sources after adaptive trials comes from countries with fewer breeders. On the other hand, countries with a large pool of breeders are expected to release more cultivars from their own crosses. Countries with good research strength are also expected to use large amounts of breeding material from international research centers. This is reflected in the pedigree of their released cultivars. An analysis in Chapter 1 shows that more cultivars are released from ICRISAT-supplied materials in countries with limited research capability than in countries with good research capability.

11.6. Lessons from Spillover Estimates

Many important results pertaining to technology transfer emerge from the estimation of the spillover matrix at the global and country levels. Research evaluation models have often used the spillover matrix to account for the benefits from research conducted by other research programs in similar and different environments. These estimates have been based solely on subjective guesses and on the assumption of location specificity which implies that the values of the off-diagonal elements in the spillover matrix are less than those of the diagonal elements.

The results of our analysis do not substantiate the ‘location specificity’ argument (at least in terms of yield) when the international research system is considered a source of research spillovers. Sorghum cultivars originating from collaborative ICRISAT-NARS research have proven to be highly transferable among sorghum domains and across different countries around the world. The yield advantage of the international research system (located in SD1) was as high as 27% in SD 8.2, 15% in SD1, 13% in SD2 and 7% in SD3. It was found that IDCs generally performed better than NARS-derived cultivars. This scenario holds good for sorghum varieties developed for India. In India, the potential for technologies developed by the Indian NARS for SD1 to spill over to other sorghum domains is high. An analysis also revealed that the extent of technology spillover from finished products is negatively related to the research capability of NARS. The higher the NARS capability, the lower is the possibility of technology spillover from finished products (varieties/ hybrids). This calls for separate breeding strategies at ICRISAT, one for a strong NARS and the other for a weak one. While ICRISAT should continue strategic research and develop intermediate products for a strong NARS, it should also engage in productive partnerships with a weak NARS in order to help them develop finished products (varieties, hybrids).

11.7. References

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