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Agricultural Systems 92 (2007) 201–222
AGRICULTURAL SYSTEMS
www.elsevier.com/locate/agsy

Impact pathway evaluation of an integrated *Striga hermonthica* control project in Northern Nigeria

Boru Douthwaite [a,*], Steffen Schulz [b], Adetunji S. Olanrewaju [c], Jim Ellis-Jones [d]

[a] *Centro Internacional de Agricultura Tropical (CIAT), AA 6713, Cali, Colombia*
[b] *Intercooperation (SSMP), G.P.O. Box 688, Kathmandu, Nepal*
[c] *International Institute of Tropical Agriculture (IITA), Oyo Road, PMB-5320 Ibadan, Nigeria*
[d] *Silsoe Research Institute, Silsoe, Bedford, United Kingdom*

Received 13 September 2004; received in revised form 10 March 2006; accepted 14 March 2006

Abstract

This paper evaluates a project that developed and introduced integrated *Striga* control (ISC) in Northern Nigeria. Adoption of ISC increased from 44 participating farmers in four pilot areas to more than 500 farmers in 16 villages and hamlets in three seasons. On average, farmers adopted 3.25 different *Striga* control options from a basket of six "best bets". Resource-poor and -medium farmers were more likely to adopt than resource-rich ones. Adopting farmers enjoyed livelihood improvements, largely through selling ISC soybean. Women in most adopting households benefited through selling food products based on soybean. Adoption of ISC can be attributed to four factors: (1) farmer-field-school-type training that explained how the technologies worked; (2) incorporation of at least one technology in the ISC package that gave quick benefits to sustain farmer interest in adopting and learning other components whose effects took longer to become evident; (3) allowance for farmer experimentation and adaptation to local conditions; and, (4) use of a monitoring and evaluation component that identified and incorporated farmer modifications to continually improve the ISC package. These principles are likely to be valid for research and extension approaches

* Corresponding author.
E-mail address: b.douthwaite@cgiar.org (B. Douthwaite).

doi:10.1016/j.agsy.2006.03.007

for similar integrated natural resource management (INRM). Impact pathway evaluation methodology used for the evaluation helped give the project a greater impact focus; helped design and reporting of the evaluation; and, by identifying early adoption pathways, has provided a firm basis for any future ex post impact assessment of ISC in Northern Nigeria.

Keywords: Impact assessment; Natural resource management (NRM); Integrated pest management (IPM)

1. Introduction

Monitoring and evaluation (M&E) is increasingly seen as crucial to the success of rural research and development projects because it supports the real time feedback and learning required to successfully implement projects in complex and unpredictable environments (Bayerlee and Alex, 1998; Sayer and Campbell, 2001; Probst, 2002; Douthwaite et al., 2005). Writing in this journal, Douthwaite et al. (2003) proposed the use of impact pathway evaluation (IPE) to guide project M&E and subsequent ex post impact assessment. In the M&E stage, a project develops an impact pathway for itself, which is an explicit theory or model of how the project will achieve impact. The project then uses the impact pathway to identify performance indicators. Monitoring of these indicators provides information to guide project management and update the impact pathway itself. In the ex post impact assessment, which occurs some time after the project has finished, the evaluator seeks to establish plausible links between the project's impact pathway and subsequent developmental changes, such as poverty alleviation.

This paper presents data from the first implementation of impact pathway evaluation. The evaluation was of a project that carried out on-farm research, development and extension of integrated *Striga hermonthica* control (ISC) methods in Kaduna State in Northern Nigeria. The paper has three objectives: (1) to assess the actual and likely future impact of ISC on rural livelihoods, especially for women and the poor; (2) to identify the characteristics of an extension system suitable to scaling out ISC; and, (3) to evaluate the impact pathway evaluation (IPE) method itself.

1.1. Introduction to *S. hermonthica* and the project to control it

S. hermonthica (Del.) Benth., a root-parasitic flowering plant, is endemic in Africa and constitutes one of the most severe constraints to cereal production in sub-Saharan Africa (Dashiell et al., 2000). Research at the International Institute of Tropical Agriculture (IITA) and elsewhere has shown that *Striga* control requires an integrated approach that attacks *Striga* from several sides (Schulz et al., 2003) because the genetic plasticity of *Striga* means that the weed can adapt and overcome control measures employed singly (Dashiell et al., 2000). A key technology in integrated *Striga* control (ISC) is the use of a legume crop (e.g., soybean, cowpea, groundnut) that induces a proportion of *Striga* seeds to germinate, which then die because they cannot parasitize legume roots. This is called 'trap cropping', and to be effective requires legumes that are screened to stimulate germination of local *Striga* ecotypes. Other ISC control measures are: legume rotation with *Striga*-resistant maize; seed-cleaning to remove *Striga* seeds; improved soil fertility; and, weeding of *Striga* before it sets seed (Schulz et al., 2003).

The Agronomy Unit at the International Institute of Tropical Agriculture (IITA), led by the second author, began working in 1999 in Northern Nigeria to develop locally adapted ISC, using participatory research approaches (Schulz et al., 2003). The work began with 19 participating farmers in three pilot areas, Rimau (10.42N, 7.77E), Mahuta (11.20N, 7.67E), and Kaya (11.25N, 7.27E). In 2000, 17 additional farmers were included, and 8 farmers from a fourth pilot area, Ankwa (9.85N, 7.88E) joined the project, making a combined total of 44 participating farmers. The Agronomy Unit chose the pilot areas (see Fig. 1) on the basis of having severe *Striga* problems, and to allow convenient access for a technician based in Zaria (11.10N, 7.71E) and another based near Rimau (Schulz et al., 2003). The Agronomy Unit then used the problem census and solving approach (Schulz, 2000), beginning with a community meeting to list and rank production constraints.

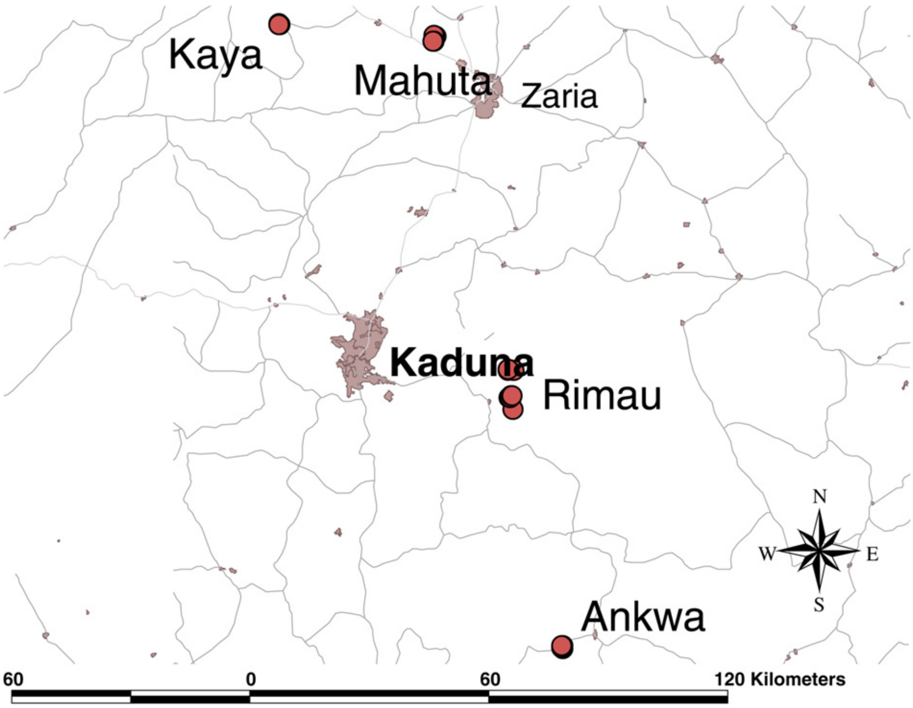

Fig. 1. Position of the pilot areas in Northern Nigeria.

If *Striga* was identified as major problem a second meeting was held a few days later to discuss control options, identify participants, and to design experiments with these participants to evaluate the control options.

The experimental design agreed with farmers is summarized here from Schulz et al. (2003). Each farmer agreed to establish one ISC plot and one control plot. The ISC plot consisted of a legume trap crop, either soybean (TGx 1448-2E or TGx-1864) or cowpea (IT-90K-284-2) in the first year followed by *Striga*-resistant maize (TZL Comp 1) in the second year. The treatment reduced *Striga* by depletion of the *Striga* seed bank through both suicidal germination and lack of a cereal host in Year 1, and then rotation with a maize variety that does not allow much *Striga* to germinate in Year 2. Average plant densities were 44,000 plants ha^{-1} for the legume trap crop and 34,000 plants ha^{-1} for Striga-resistant maize. The control plot consisted of farmers‘ traditional cropping practice (sole cereal crop or cereal-legume intercropping or fallow) in the first year, followed by local sole cropped maize in the second year.

The Agronomy Unit hypothesized that the adoption of these *Striga* control options would be enhanced if farmers had a basic understanding of *Striga* biology and of the *Striga* control technologies. Therefore, training sessions were organized over the two-year period, applying aspects of the farmer field school (FFS) approach (Kenmore et al., 1995).

In 2000 it became clear from feedback that farmers were expanding their use of at least some components of ISC from their experimental plots to their other fields, and that other farmers were also adopting them. At the same time, some apparent constraints to adoption were emerging. As a result, IITA's Adoption and Impact Unit, led by the first author, became involved to monitor and evaluate adoption processes.

2. Methods

The project impact pathway (Fig. 2) shows how the project output ''validation and adaptation of ISC options in farmers' fields'' will ultimately lead to the project goal of improved livelihoods for the 100 million people in Africa that are affected by *Striga*. The shaded boxes are the outcomes that were monitored and evaluated. The unshaded boxes will be evaluated in the ex post impact assessment, if and when it is conducted.

We implemented three surveys to monitor and evaluate the outcomes shown in the shaded boxes. The way the outcomes relate to the surveys is shown in Table 1.

2.1. Survey 1

The first survey mapped the adoption of ISC within and beyond the four pilot areas. An enumerator interviewed key informants to identify who had adopted aspects of ISC. The key informants included the two Agronomy Unit technicians, project village assistants and participating farmers. The enumerator then visited each field mentioned, recorded its position with a hand-held global-positioning system

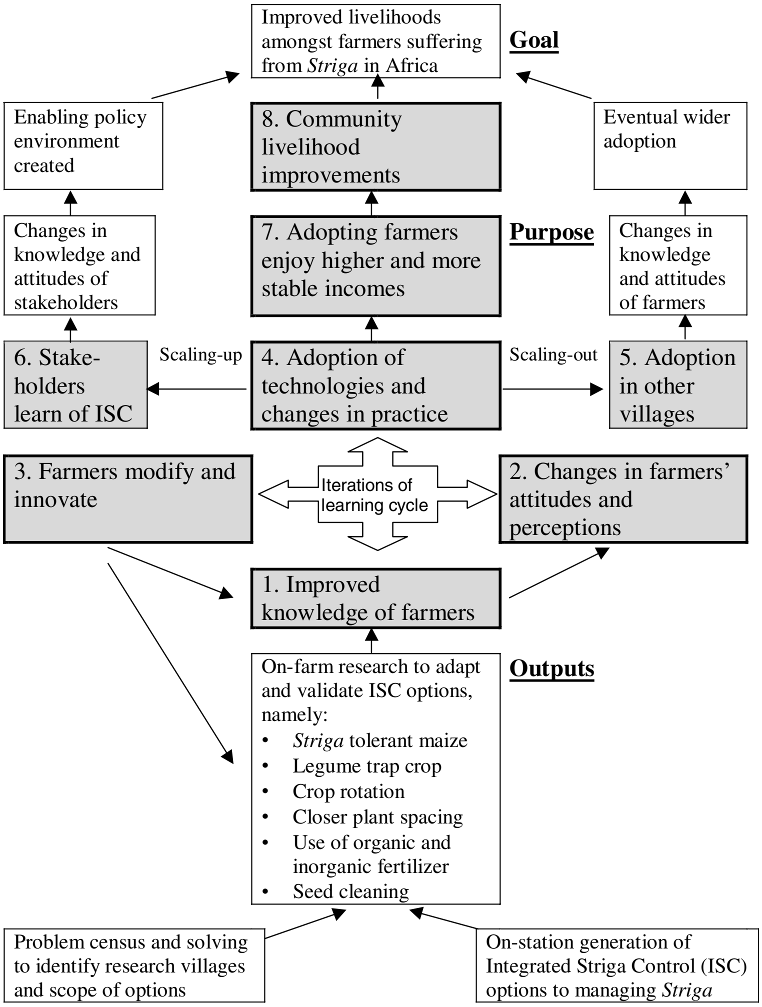

Fig. 2. Impact pathway for an Integrated *Striga* Control (ISC) Project in Northern Nigeria (from Douthwaite et al., 2003).

Table 1
Sources of evaluation information used to monitor the project outcomes

Outcome	Sources of evaluation information
1. Improved knowledge of farmers about ISC	Surveys 2 and 3
2. Changes in attitudes and perceptions towards ISC	Surveys 2 and 3
3. Farmers modify ISC technologies	Surveys 1, 2 and 3
4. Adoption of ISC and changes in practice	Surveys 1, 2 and 3
5. Adoption of ISC in other villages (scaling-out)	Surveys 1, 2 and 3
6. Other stakeholders hear of ISC (scaling-up)	Project documentation
7. Farmers adopting ISC enjoy higher and more stable incomes	Survey 3
8. Communities adopting ISC enjoy livelihood improvements	Survey 3

(GPS), and recorded the ways the ISC options were being applied, making particular note of any modifications from project "good practice" recommendations. This survey took place from October 2001 to January 2002 and identified 336 fields owned by 271 farmers in 16 hamlets and villages.

The survey identified three levels of adoption:

Evaluation: Participating farmer with only an experimental plot;

Expansion: Participating farmer with experimental plot and one or more expansion plots (fields where he or she has expanded the use of one or more of the ISC technologies);

Scaling-out: Non-participating farmers who have adopted one or more ISC technologies.

2.2. Survey 2

The second survey was a semi-structured interview of a sub-set of the 271 farmers identified in Survey 1. All the participating farmers were interviewed to avoid some feeling left out. Half the scaling-out farmers were interviewed giving a total sample size of 152. The purpose of the survey was to collect socioeconomic data to allow farmers' households to be ranked according to their resource use, as well as to ask questions to determine the achievement, or lack of it, of outcomes 2–5 shown in Fig. 2. The same enumerator carried out Survey 2 between February and June 2002.

The resource ranking method we used was an adaptation of one used by Okike et al. (2002) in the same area. Households were ranked based on ownership of land, livestock and assets as shown in Table 2.

A household was rated poor if their combined score was 0 or 1, medium 2–4, and rich 5–6.

2.3. Survey 3

Survey 3 constructed individual adopter case studies, using case study methodology (Yin, 1989), to assess the impact of ISC on farmers' incomes and livelihoods.

Table 2
Scoring system used to rate households according to resources owned

Household score		
0 points	1 point	2 points
• Less than 4 field parcels	• 4–9 field parcels;	• 10 or more field parcels
• Less than \$128-worth of livestock (the value of 3 goats and 10 chickens)	• \$128 to \$800 worth of livestock	• More than \$800 worth of livestock
• One or less assets (e.g., bicycle, radio, etc.).	• 2–4 assets	• 5 or more assets

The survey took place in February and March 2003 of 25 households purposely selected from the Survey 2 sample to be representative of the pilot areas. Survey 3 also served to triangulate data from the other two surveys. Six households were selected from Kaya, Mahuta and Ankwa, and eight from Rimau. Ten poor households, 12 medium and 3 rich were interviewed. Of these, 12 were expansion farmers and 13 were scaling-out farmers. All had two or more seasons' experience with ISC.

An enumerator facilitated the head of each household to construct and discuss a resource map (Guijt and Woodhill, 2002) to quantify the level of adoption of ISC technologies, and the benefits and costs of using them. Farmers drew their farms on a piece of paper and described what they had grown in each field in the four seasons from 1999 to 2002. Construction of the case studies was guided by the Sustainable Livelihoods Framework (Scoones, 1998). Impacts on financial capital were assessed by asking farmers about the costs and benefits of adoption of ISC compared to traditional practice. Impacts on natural capital were assessed by asking about effects on soil fertility. Influence on social capital was addressed by asking farmers whether they had given ISC seed and/or information to other farmers, and the relationships the farmers had with these people. Giving seed is a way of building social capital and reducing vulnerability (Christinck, 2002). The enumerator also explored what it meant to be a participating farmer in terms of prestige and relationships with other farmers and farmer groups. Human capital impacts were examined by asking one or more women in each household how adoption of ISC has affected family nutrition and use of family labour.

2.4. Baseline survey

The baseline data on adoption levels of different crops, varieties and management practices comes from a survey reported elsewhere (Douthwaite et al., unpublished data) and conducted as part of another project. The survey used the GPS transect walk method (Van der Meer et al., 2001) to measure the adoption of different crops, varieties and cropping patterns in 10 villages in the same area of Northern Nigeria. Kaya was part of the GPS transect walk survey.

2.5. Statistical analysis

Statistics allow the analysis of survey data to establish whether trends observed in the sample are likely to be true for the population from which the sample was drawn. In our case, the population was the farmers who had adopted ISC. Of these we sampled all the participating farmers and half of all of the scaling-out adopters identified in Survey 1. Given this large sample size in relation to the total population, findings from the sample can be assumed to apply to the population without the need for statistical tests. We use cross-tabulations together with the Pearson χ^2 to test for significance between categorical variables, in particular whether adopters' access to resources and the area in which they lived, affected their adoption behaviour. We only use the word 'significant' to signify statistical significance following the standard convention (significant: $^{*}p \leqslant 0.05$; highly significant: $^{**}p \leqslant 0.01$).

Wealth ranking using an existing method, and with reference to other studies in the area, allowed us to gauge the extent to which the sampled adopters are typical of their wider community, at least with respect to access to resources. Adopters were asked why other farmers might not adopt to identify differences between the adopters and non-adopters.

3. Results

We present the results according to the outcomes monitored (Fig. 2) after first describing the socio-economic profile of the adopters.

3.1. Adopter profile

The great majority (80%) of adopters were household heads and men (94%), which reflects the Muslim culture of the pilot areas. Only 4% of adopters were rich (Table 3), compared to 13% in the similar Okike et al. (2002) survey, suggesting that ISC is more attractive to poor- and medium-resourced farmers. Education level was relatively low with only 5% of the adopters having attended secondary or tertiary education. Thirteen percent had received no education.

Cropping systems were cereal- and legume-based (Table 4). *S. hermonthica* parasitizes all the cereals grown in the area but its effects can be minimized by the use of inorganic fertilizer. The amount of cereal a farmer grows depends on access to inorganic fertilizer. One Kaya farmer, Sherihu Maaika, explained: "If I can get fertilizer then I would prefer to plant cereals. If I can't afford fertilizer then I plant legumes."

Farmers generally preferred to grow more than one crop in their fields. In the southern pilot areas—Ankwa and Rimau—farmers tended to mix several crops in one field in no particular pattern. In Mahuta and Kaya further north farmers commonly used the *gicci* and strip-cropping patterns. *Gicci* usually involved planting sin-

Table 3
Resource ranking of farmers adopting ISC technologies in four pilot areas in Northern Nigeria

Pilot area	Resource ranking			Total number of farmers
	Poor	Medium	Rich	
Ankwa	3	14	0	17
Kaya	7	42	5	54
Mahuta	11	22	0	33
Rimau	19	28	1	48
Total	40	106	6	152

$N = 152$ respondents; data from Survey 2.

Table 4
Crops grown and types of fertilizer applied to them by farmers in four pilot areas in Northern Nigeria

Crop	Grown (%)	Type of fertilizer applied to crop (%)			
		Inorganic fertilizer	Farmyard manure	Ash	Kitchen waste
Sorghum	100	98	35	20	7
Maize	99	99	43	21	9
Soybean	95	25	3	0	1
Cowpea	88	2	0	0	0
Rice	55	98	1	0	0
Groundnut	39	3	0	0	0
Millet	34	73	8	0	0
Yam	32	47	20	10	2
Sweet potato	14	64	23	9	0
Cocoyam	14	52	48	26	9
Ginger	9	100	7	0	14
Hungry rice	3	25	0	0	0

$N = 152$ respondents; data from Survey 2.

gle rows of sorghum, perpendicular to the ridges of legumes, at row spacings of 2–5 m. Strip-cropping involves several rows of legume followed by several rows of cereals. Farmers' reasons for using both *gicci* and strip-cropping included: ''otherwise my land will be empty after harvesting soybean'', and ''to guard against crop failure''.

3.2. Improved knowledge of farmers about ISC (Outcome 1 of impact pathway)

An important source of information about ISC was training carried out by the project which all participating farmers, and 42% of the scaling-out farmers, had attended. Farmers who attended training sessions were asked what they had learnt. Participating farmers, who had attended more training sessions than scaling-out farmers, listed significantly more topics, on average 3.3 compared to 2.6 answers. Farmers appreciated the training, in particular question and answer sessions. As one farmer said: ''I asked questions and got other farmers' suggestions.'' They also appreciated learning that there are several ways to control *Striga*, that ISC helps them get higher yields, and that this can be done at low cost.

Another way we evaluated farmer knowledge about ISC was asking them what information they passed on to other farmers. Nearly half gave at least one instruction on management practice to another farmer. The most common message was to plant the legume trap crop closely, and to use it on *Striga*-infested plots (Table 5).

Participating farmers were significantly more likely to give other farmers instructions on ISC than scaling-out farmers. Also, the number of messages they gave were significantly higher—2.7 compared to 2.0. Neither pilot area nor access to resources influenced whether farmers gave instructions, or the number they gave.

To guide recommendations for a future ISC extension approach we asked farmers about contact with other extension agencies and their preferences for receiving information. Only 16% of farmers said that they had contact with village extension

Table 5
The instructions the adopters of aspects of integrated *Striga* control (ISC) gave to other farmers about ISC, in four areas in Northern Nigeria

Instructions	%
None	51
Close planting for legume trap crop	32
Plant on *Striga* infested plots	21
Rotate cereal with legume	16
Narrower ridge spacing	9
Plant on plots with poor soil fertility	6
What they see on my plot	6
Timing of weeding and/or fertilizer application	5
Weed *Striga*	2
Plant legume on both sides of the ridge	2
Other	10

$N = 151$ respondents; more than one answer allowed per respondent; data from questionnaire survey.

agents, most commonly with the Kaduna Agricultural Development Project (KADP). The village extension agents were the least preferred information channel. Farmers said they preferred to receive new information from research institutes, i.e., IITA and Institute for Agricultural Research (IAR), and other farmers, by word of mouth supported by pictures and posters.

The great majority of farmers, 84%, listened to the radio. The preferred listening time was 6–8 a.m. In contrast, less than one third (29%) said that they read newspapers or magazines.

3.3. Changes in attitudes (Outcome 2)

One of the best measures of farmer attitudes to new germplasm is whether they save and give seed (David et al., 1997). Nearly all farmers (95%) saved ISC seed: 85% saved soybean seed; 40% saved maize seed while only 7% saved cowpea seed. The same trend was evident in gifts and sales of seed. Nearly two thirds (62%) gave or sold ISC seed: 60% gave soybean, 16% gave maize, while no one gave cowpea. The recipients of the seed were generally relatives, friends and neighbours, half of whom lived in other villages.

A second measure of farmer attitudes is whether they modify and adopt new technology (Douthwaite et al., 2001).

3.4. Farmers modify ISC technologies (Outcome 3)

In general, farmer modification involved partial adoption of "best practice" recommended by the project. The most common modifications were to the "sole-cropping" and "close plant spacing" recommendations (Table 6). There was, however, one farmer innovation that the project subsequently adopted as "good practice". A farmer in Mahuta planted ISC soybean on either *side* of his ridges, spaced traditionally at 70 cm, thus achieving the 35 cm row inter-row spacing recommended by

Table 6
Modifications made to researcher-recommended usage of integrated *Striga* control (ISC) options

Modification	Pilot area (%)				Total (%)
	Ankwa	Kaya	Mahuta	Rimau	
None (mono crop)	59	10	35	73	35
Gicci	3	46	24	3	26
Strip-cropping	0	34	1	0	15
Inter-cropping	38	2	6	21	11
Relay-cropping	0	2	9	3	13
Planting on both sides of ridge	0	0	1	0	0
No. of fields surveyed	32	126	72	66	296

$N = 296$ fields; data from Survey 2.

the project. The project recommendation had been to plant one row per ridge and use a 35 cm spacing between ridges, something that farmers found very difficult to achieve with the animal-drawn ploughs and hand-hoes used in Mahuta and Kaya, and Rimau and Ankwa, respectively.

3.5. Adoption of technologies and changes in practice (Outcome 4)

A conservative adoption estimate is that the project was able to scale-out ISC from 44 participating farmers to an additional 458 farmers in three seasons. This is calculated as follows. Survey 1 identified 271 adopters. Survey 2 found that nearly two thirds of adopters (62%) gave or sold ISC seed directly to an average of 2.75 other farmers. Assuming that only 50% of farmers who received this seed went on to adopt gives an additional 231 "second generation" adopters and a total of 502 adopters, of which 44 were participating farmers. This estimate does not include the third generation adopters who adopted via the second generation adopters.

The great majority (84%) of participating farmers expanded the use of at least one ISC technology from their experimental plot to their farm, and all the scaling-out farmers had adopted ISC techniques because this was the basis for selecting them. Both participating and scaling-out farmers had adopted an average of 3.25 ISC options out of a total of 6. Resource poor farmers had adopted on half of their farms compared to one third on the farms of resource medium and rich farmers. However, farmers' resource ranking made no difference to what farmers chose to adopt, or the number of technologies they adopted.

Households of scaling-out farmers who adopted ISC were usually clustered around the homes of participating farmers (Fig. 3). However, in some cases, adoption of ISC jumped when farmers gave seed and know-how to friends and relatives living in other villages.

The most popular technology was ISC soybean (Table 7). The soybean variety TGx 1864 was introduced into Ankwa while TGx 1448-2E was introduced into the three more northern pilot areas. The resource use mapping showed that on average farmers in Mahuta, Rimau and Ankwa grew soybean on 16% of their land

and ISC varieties of soybean made up 75% of that area. The baseline survey (Douthwaite et al., unpublished data) found that farmers grew legumes (soybean, cowpea, groundnut) on only 12.5% of their land of which 1% was soybean. Hence the project led to a 25% increase in legume production and an 11-fold increase in area of soybean. In Kaya, where ISC soybean had been grown for a number of years prior to the project, the project increased soybean area by 50%, from 14% to 21%.

There was a big difference between the measured and reported amount of adoption of *Striga* resistant maize. The case study findings [Survey 3] support the lower mapping estimate [Survey 1]. Overall all three surveys found that ISC soybean is highly popular, TZL Comp 1 maize less so, and ISC cowpea (IT-90K-284-2) was almost universally unpopular.

The adoption of close legume spacing was assessed by measuring plant spacing in the field during the mapping survey. Soybean plant spacing was measured in 151 farmers' fields of which 27% had adopted the recommended plant spacing of 20 cm or less instead of the normal legume plant spacing of 30–45 cm. The low adoption rate was because farmers found close planting too labour intensive or they thought that their low soil fertility would not support such close spacing.

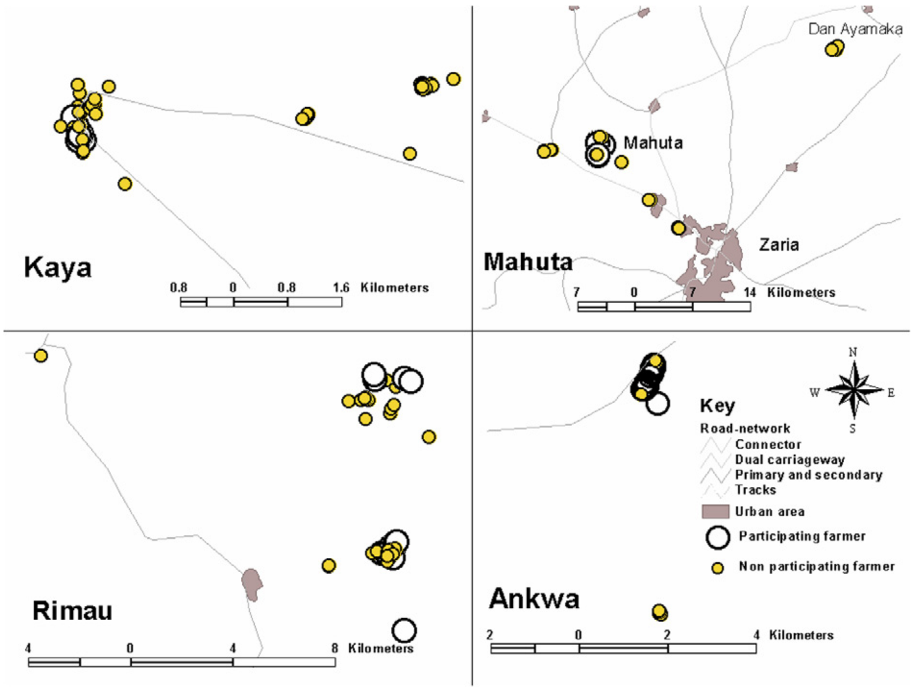

Fig. 3. Maps showing the position of the households of farmers who adopted ISC in four pilot areas in Northern Nigeria (from Ellis-Jones et al., 2004).

Table 7
Adoption of ISC technologies *reported* by adopters in four pilot areas in Northern Nigeria

Technology	Ankwa (%)	Kaya (%)	Mahuta (%)	Rimau (%)	Average (%)
ISC soybean	77	93	71	100	89
Weeding of *Striga*	53	82	90	88	82
Rotation of legume and cereal	41	84	94	83	81
ISC maize	6	41	55	48	42
Sole crop of legume	24	11	26	23	19
ISC cowpea	6	2	19	4	7
Sole crop of cereal	6	4	3	6	4
Average number of technologies adopted	2.12	3.20	3.58	3.50	3.25
N	17	54	31	48	152

$N = 152$ respondents; data from Survey 2.

Weeding of *Striga* is the main local control method, but only 4% of farmers in the sample said that they adopted weeding prior to 1999 when the project began. Hence, 95% of farmers who adopted did so largely as a result of project training, which taught them taught that weeding reduces the number of *Striga* seeds in the soil.

Significant differences existed in adoption rates reflecting socio-economic, agro-ecological and cultural preferences (Table 7) between the pilot areas. ISC soybean was more popular in Kaya and Rimau than in Ankwa and Mahuta. Adoption was constrained in Ankwa by distance to market (20 km along a bad road) while farmers in Mahuta had a cultural preference to grow cowpea. Rotation was much less popular in Ankwa which had a lower population density and more land available for fallow than the other three pilot areas.

One quarter of farmers had learned about ISC technologies from sources other than the project. In Kaya farmers had been introduced to ISC soybean (TGx 1448-2E) and the concept of cereal–legume rotation by other projects. Some farmers said they had adopted rotation and weeding as early as 1980. Nearly three quarters (70%) of farmers named weeding of *Striga* as one of their local control methods.

The resource mapping revealed that much of the adoption of rotation registered in Survey 2 was only partial compared to the ideal of changing from cereal to legume every year. For example some farmers adopted rotation in one field while continuously mono-cropping cereals in other fields. In other cases farmers grew a legume break crop after three years of cereals.

3.6. Adoption of ISC in other villages (Outcome 5)

ISC was clearly spreading from the four pilot areas (Fig. 3). Survey 1 found that ISC technology had spread to an additional 12 hamlets and villages. One third of the recipients of ISC seed lived outside the village of the giver, up to 200 km away. Farmers in the two southern areas of Rimau and Ankwa were highly-significantly less likely to give or sell seed outside of their village.

3.7. Other stakeholders hear of ISC (Outcome 6)

The work reported in this paper was pivotal in the success of an IITA project proposal to the British Government (DFID) for a 3-year project, "Realising Sustainable Weed Management to Reduce Poverty and Drudgery Amongst Small Scale Farmers in the West African Savannah", which ran from April 2001 to March 2004. This DFID-funded project worked on two weeds, one of which was *S. hermonthica*, and built on the work reported in this paper. It worked in Kaduna State, where all four pilot areas are situated, to train 28 extension workers in elements of the Participatory Extension Approach (PEA) (Hagmann, 1999) which incorporated the elements of the approach used in this project, including farmer-field-school-type training and the use of participation of lead farmers with a responsibility to share their knowledge and new varieties more widely. By March 2004 the Kaduna State agricultural research and extension system, comprised of the Institute for Agricultural Research, Kaduna Agricultural Development Project (KADP) and the Local Government Area (LGA) extension network, had adopted the main ISC soybean (TGx 1448 – 2E) and maize varieties (ACR 97 TZL Comp1) used in this project. The KADP has adopted the DFID project's participatory extension approach, although implementation is limited by lack of funds. The participatory extension approach was also adopted by a Canadian-funded project that is currently working in Borno State, Nigeria. The DFID project led to adoption of ISC by an additional 240 farmers by 2004 (Franke et al., in press).

3.8. Farmers enjoy higher and more stable incomes (Outcome 7)

It was too early to measure community-level benefits of ISC (Outcome 8 in Fig. 2). Instead Survey 3 focussed on identifying and understanding the effects of ISC on adopters' livelihoods.

3.8.1. Impact of ISC on financial capital

The largest impact of ISC came from the adoption of ISC soybean because it was adopted by more farmers than any other ISC component technology, and on a larger area. More than one third of farmers sold ISC grain at market, nearly all of which was soybean. Farmers sold on average 700 kg for $0.37 per kg (FAO, 2005), giving an average gross income from soybean of $259. Most of these farmers came from Kaya which is more commercially orientated than the other pilot areas. Farmers in Kaya sold an average of 1150 kg of soybean compared to 250 kg in Mahuta and just 100 kg in Rimau and Ankwa.

Balarabe Musa, a rich expansion farmer in Kaya, gives an example of the impact soybean has had on his household:

> "Since I started planting [ISC] soybean my production has increased from 600 kg per year to 4000 kg per year. The extra income from selling soybean has allowed me to buy 2 oxen and 2 ox-ploughs as well as corrugated sheets to re-roof my house. The money is also helping me to keep my six children in primary school."

Farmers in the survey explained that soybean is harder to process into food than cowpea or maize, and only a small amount is consumed in the household. Therefore, the main benefits of growing soybean only occur when farmers sell surplus in the market. Hence, it may be difficult for resource-poor farmers, used to growing food largely for home consumption, to fully benefit from growing soybean.

Women, particularly in Kaya, mentioned a number of improvements that they had noticed since their husbands started growing more soybean. These included tin roofing to replace the straw or mud roofs on their houses, new clothes for themselves and their children and that school fees could be paid more easily. The wife of Lawal Shaibu, a resource-poor farmer in Kaya said:

> "There have been spectacular changes since the household started to grow improved soybean. For example, we were able to buy new clothes for the last Ramadan festival for the whole family and we can now buy fertilizer easily."

The women in half of the households in Kaya, and all but one of the households in Ankwa, were selling products made from ISC soybean in the market. Soya cheese (tofu or *awara*) was the most common. The women said this income allowed them to buy things for themselves, like clothes and soap, and made them less dependent on allowances from their husbands.

3.8.1.1. Labour requirement for ISC. ISC requires farmers to plant at two and three times the traditional maize and soybean plant densities, respectively. ISC also requires farmers to weed more rigorously and place fertilizer in a hole and cover it rather than placing it on the ground. Two thirds of Survey 3 farmers said that the additional labour requirement was a constraint to adoption. Many thought that the close plant spacing of ISC was just not practical on large plots and two suggested that larger trial plots would be more realistic. Joshua Gaya, a participating farmer from Ankwa expressed the opinion of many:

> "Some farmers may see some aspects of ISC as too tedious and time consuming. A poor farmer with little or no money to hire labour, limited household labour—just one wife and few children—may not find it possible to adopt ISC crop management practices."

Farmers estimated that it required 56% and 83% more labour to grow ISC soybean and maize respectively, using ISC recommended practice (Tables 8 and 9). The largest and least popular increase in labour requirement was the more than doubling of the time required for planting at a time when labour is in short supply. There were some complaints about the weeding of *Striga* being tedious but the general consensus was that the approach was worth the effort. Nearly one in 10 adopters volunteered the opinion that weeding was the best method of controlling *Striga*. There were no complaints about the additional labour required for harvesting and threshing.

Farmers, estimate of average labour cost was \$2.25 per day. The additional labour costs of producing ISC soybean and maize compared to traditional practice is there-

Table 8
Average costs of land preparation, crop care and harvest activities for ISC and traditional practice in growing soybean in four pilot areas in Northern Nigeria

	N	Person days per ha		Percentage increase (%)
		Traditional	ISC	
Planting	19	22	47	114
Weeding	18	36	55	53
Fertilising	0	0	0	0
Weeding *Striga*	0	0	0	0
Harvesting	16	23	32	39
Threshing	14	29	38	31
Total		110	172	56

$N = 19$ respondents; data from Survey 3.

Table 9
Average costs of land preparation, crop care and harvest activities for ISC and traditional practice for growing maize for four pilot areas in Northern Nigeria

	N	Person days per ha		Percentage increase (%)
		Traditional	ISC	
Planting	9	13	30	131
Weeding	10	25	49	96
Fertilising	6	7	14	100
Weeding *Striga*	8	9	18	100
Harvesting	10	19	30	58
Threshing	9	23	35	52
Total		96	176	83

$N = 10$ respondents; data from Survey 3.

fore $139 per hectare and $180 per hectare, respectively. Given the 2002 farm-gate prices of soybean and maize (FAOSTAT data, 2005) a farmer needed to harvest an additional 376 kg of soybean and 563 kg of maize to pay for the additional labour. These represent a 50% increase above average soybean and maize yields (FAOSTAT data, 2005).

3.8.2. Impact of ISC on natural capital

Legumes fix nitrogen, therefore an increase in the total amount of legumes grown will have a positive effect on soil fertility. All the participating farmers said that ISC soybean had improved soil fertility. Dahiru Sani, a farmer from Kaya, summed up the sentiments of many: "ISC soybean is a wonderful crop. Soil fertility is better, yields are higher and it controls *Striga*."

3.8.3. Impact of ISC on human capital

In terms of family health, the largest impact of ISC came from increased consumption of soybean. Soybean has the highest protein content amongst grain legumes and contains more protein than meat (FAO, 1982). Women in the case-study households were making a variety of foods from soybean for sale and household consumption, including adding powdered soybean to maize porridge that is fed to babies, children and adults. Most of the women interviewed knew that eating soybean was good for their families' health and said they would buy soybean if their husbands did not grow it. They generally ate more soybean if their husbands had produced a surplus. Three households mentioned that sales of soybean had made it easier to pay school fees and send their children to school.

3.8.4. Impact of ISC on social capital

As seen already, participating and non participating farmers valued the seed and training they received from the project, and passed both on to neighbours and friends. Giving seed and information are ways of maintaining or improving social capital. Women tended to share seed and information with other women, and men with men. In Survey 3, participating farmers said that they felt a responsibility to share what they had learnt with other farmers. This quote from Sherihu Maaika, a participating farmer from Kaya, is typical of the sentiments expressed.

> ''Being a participating farmer enabled me to work closely with ISC project staff and learn a few things. The knowledge is now always available to my community and me. I now have the possibility to lead other farmers in experimenting with ISC in the absence of expert researchers. I think I can set up trials that are not too complicated and if I find it too difficult to do by myself I can ask help from other participating farmers in our village.''

4. Discussion

4.1. Impact assessment of ISC

After three seasons of farmer trials it was too early to assess impact at a community level. Nevertheless the project clearly had an impact on individual livelihoods within and beyond the pilot areas in which it worked. ISC technologies were adopted more by poor- and medium-resourced farmers than the rich. Women also adopted where cultural norms permitted. Adoption increased from 44 participating farmers in four pilot areas to more than 500 farmers in 16 villages and hamlets in three seasons. On average, farmers adopted 3.25 different *Striga* control options from a basket of six ''best bets''.

Most benefit came through the adoption of ISC soybean. In the Mahuta, Rimau and Ankwa areas adopting farmers were growing soybean on 14% of their farms compared to an average of just 1% in surrounding areas. In Kaya, where improved soybean has been promoted for longer and by other projects, ISC adopters were growing legumes on 21% of their farms compared to a village average of 14%.

The main impact of ISC soybean adoption was on financial capital through farmers earning extra cash by selling the crop in the market. There was more evidence of this impact in Kaya where farmers grew more soybean. Impacts included improvements to housing, ability to buy more fertilizer; easing the burden of sending children to school; reduction in *Striga* and the labour needed to weed it; better family nutrition; new clothes for the Muslim festival of Ramadan and more luxuries. Women in most adopting households were selling food products based on soybean, and the additional production helped these micro-enterprises. Other ISC components, such as ISC maize, and cereal–legume rotation, contributed to impact, but were less important. The main constraint to adoption of ISC was increased labour requirement for planting soybean and maize at two or three times the traditional plant densities. Three quarters of farmers chose not to adopt close plant spacing, thus making control of *Striga* less effective.

Benefits to human capital of ISC came through the consumption of soybean. Most of the case study households were consuming soybean in small amounts before adoption of ISC soybean but consumption generally increased with adoption of ISC soybean. Nearly all the households understood the benefits of eating soybean and several attributed the good health of their children to this.

Adopters benefited socially by being able to give neighbours, relatives and friends seed and information they had received from the project. These gifts are certain to increase the impact of ISC, both within and beyond the pilot areas, as adoption increases.

Adoption levels in Kaya show that farmers in the other three pilot areas could well increase their soybean production by an additional 50% or so, sell more soybean in the market and the household earn more money as a result. However the stability of this livelihood strategy depends on the stability of the soybean market price. Promotion of foods made from soybean, and the micro-agroenterprises based on producing these foods stuffs for sale, would increase the positive impacts of communities growing more soybean on the well-being of women and children.

The impacts discussed in this section cannot be wholly attributed to this project. There were other sources of innovation. For example, ISC soybean had been introduced into Kaya before the ISC project began, and the idea of crop rotation and weeding of *Striga* has been promoted in the area for tens of years. Nevertheless, project farmer field schools led to additional understanding of the importance of, and reasons for, weeding and this in turn led to adoption, irrespective of the original source of the ideas.

4.2. Requirements of an effective extension method for ISC

The survey results show that farmers adopted and adapted ISC in different ways in the four pilot areas. For example, farmers in Ankwa and Rimau adopted less soybean because they had less access to market. The more isolated nature of these two pilot areas meant farmers were less likely to give or sell seed outside of their village. Farmers in Ankwa also adopted less rotation because their land use intensity was much lower than the other three pilot areas. This finding confirms the idea that Integrated Natural Resource Management (INRM) technologies, such as ISC, require an extension approach that allows farmers to 'unpack' the package of technologies recommended to them by researchers and/or extension, learn about and evaluate the different parts, and then adapt them into something that more closely fits their own systems (Sayer and Campbell, 2001). The importance of regular FFS-type training sessions in increasing farmers' levels of knowledge of ISC confirms findings elsewhere (e.g. Pound et al., 2003) on the need for, and value of, FFS-type training in the scaling-out of complex and knowledge intensive technologies like ISC.

The existing extension system in Northern Nigeria was given a very low rating by farmers in the pilot areas. This is partly because the extension system is chronically under-funded and partly because it is modelled on the World Bank Training and Visit (T&V) system (UNCCD, 2002), which is designed to provide blanket recommendations and does not support local adaptation.

The scaling-up of ISC will require additional funding to the existing extension system. It will also require the adoption of a participatory extension approach, rather than one based on the T&V paradigm. A number of participating farmers felt they had a responsibility to their communities and were considering setting up their own trials, although none had. Further research is required to identify what would be required to identify and support a network of "lead farmers" working with existing extension workers and motivated to help their communities. This network could be the backbone of a relatively cheap but effective participatory extension system in Northern Nigeria. The survey results suggest that this network should include both male and female extension-worker farmers, because men and women have different criteria for selecting technologies, and information sharing between men and women can be poor. There need not be an extension-worker farmer in each village because technologies to spread from village to village, although this spread is more difficult in areas with lower population densities and more isolated villages. Any basket of options should contain one or more component technologies that offer quick and substantial benefit to engage farmers and retain their interest and participation. Finally, more use should be made of the radio to communicate information, particularly in the early morning because this is when many farmers listen.

4.3. Assessment of the impact pathway evaluation (IPE) method

We found the IPE very useful because it encouraged the evaluating group and the project implementation group to jointly unpack the project's process of achieving impact into its component parts, i.e., the intermediate outcomes shown in the impact pathway (Fig. 2). Having identified these intermediate outcomes, and the logic linking them together, it was then much easier to select appropriate survey methods. The impact pathway also helped us structure reporting the results in this paper.

The use of three different surveys helped bolster the internal validity of the results through triangulation. For example, it showed that Survey 2 gave higher adoption levels than the other two as a result of the natural tendency for interviewees to exaggerate adoption levels when the interviewer is perceived to be linked to the implementing project. Analyzing the results from the three surveys revealed a problem in definition of adoption, in particular what constitutes adoption of rotation. Also, the resource mapping and in-depth interviews helped reveal that not all the adoption measured in Survey 1 and Survey 2 could be attributed to this project. Asking farmers to construct their resource maps some years before they claim to have adopted a technology is a good way of seeing what changes have actually occurred since they adopted.

In carrying out the evaluation we confirmed the finding from elsewhere (Douthwaite et al., 2001) that identifying and seeking explanation for adoption and modification is a good entry point to understand changes in perceptions and general knowledge levels. The focus also helped to identify farmer innovation and provided information for the project to adapt its recommended "good practice". For example, the findings about farmer rejection of single hill planting in ISC maize led to the project changing its recommendation. M&E helped project scientists and technicians understand better labour shortage as a constraint to ISC.

Surveys to assess the adoption of new agricultural technologies are usually expensive, and carried out several seasons after the end of the project (David et al., 1997). The cost of data gathering for the impact pathway evaluation reported in this paper was $10,000 – the cost of employing a full-time research assistant, plus travel expenses. Analyzing and writing up the data cost another $10,000 in scientist time. It is hard to gauge whether this is expensive or cheap because published adoption surveys are generally not costed. Nevertheless, the study did contribute findings that changed the course of the project, as already discussed. Such findings are difficult to value, but can make the difference between success and failure for NRM projects operating in complex environments (Sayer and Campbell, 2001; Douthwaite et al., 2005).

Impact pathway evaluation is a two-stage process. This paper presents the findings from the monitoring and evaluation phase that will be of value to any subsequent ex post assessment of work to control *Striga* in Northern Nigeria. This second phase will benefit from knowing where, when and how adoption of ISC started. Continuing the adoption and impact story from where this one stops will make the final impact study easier to implement, and far more plausible.

5. Conclusions

This study found that it is possible to achieve demonstrable impact with relatively complex natural resource management technology packages in a relatively short period of time. This success was based on: (1) farmer-field-school-type training that explained how the technologies worked; (2) incorporation of at least one technology that gave quick benefits to sustain farmer interest in adopting and learning other components whose effects took longer to become evident; (3) allowance for farmer experimentation and adaptation to local conditions; and, (4) incorporation of a monitoring and evaluation component that identified and incorporated farmer modifications to continually improve the "basket of options". These principles are likely to be valid for research and extension approaches for similar integrated natural resource management (INRM).

Training was most successful in changing farmers' perceptions and practices when it complimented what farmers already knew but were not practicing. For example, providing farmers with knowledge about the number of seeds produced by a single *Striga* plant, and the length of time the seeds can remain viable in the soil, led to a high rate of adoption of the little-used local practice of weeding *Striga*.

The methodology used in this paper – impact pathway evaluation – proved useful. It encouraged the evaluation group and the project implementation group to identify the steps between achieving the project outputs and eventual impact, and the logic linking them together. This impact pathway helped the evaluation group to select appropriate survey methods, and it helped structure this paper. The results of the evaluation directly resulted in the project adopting farmer modifications in its recommendations of good ISC practice. It has also helped establish a starting point for any subsequent ex post assessment of ISC impact by signposting early adoption and impact pathways. Finally, the use of three distinct types of survey triangulated results and safeguarded the internal validity of the findings. Comparing and contrasting adoption levels measured in the three surveys showed that farmers are likely to over-estimate adoption in questionnaire-based surveys and that the construction of land-use maps is a more reliable measure.

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