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## Agricultural research priority setting under multiple objectives: an example from Zimbabwe

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### Abstract

Strategic priorities are assessed for the agricultural research system in Zimbabwe in a situation characterized by multiple objectives, farm-types, and agro-ecological zones. Economic surplus analysis is used to rank research programs by commodity and research program areas in total and disaggregated by large and small farms in high and low potential regions. No funding, current funding, and 50% more funding are allowed for each program in the analysis. An optimal research portfolio is developed, first with all weight placed on efficiency, and second with increasing weights placed on benefits going to small-holder farmers. Even with no additional weight placed on small-holders, research programs for both small farms and low potential areas enter into the optimal research portfolio. As more emphasis is given to small-holders, the reduction in overall efficiency gained due to research is relatively modest. Maize and cotton were the highest ranked commodity research programs of the 36 commodities considered for both large and small farms. Agronomy and soils research are relatively more important for small-holders, while plant breeding and crop protection are relatively more important for large-scale farmers. © 1999 Elsevier Science B.V. All rights reserved.

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### 1. Introduction

Economists are increasingly asked to devise methods to assist with priority setting for agricultural research. In most cases, this task requires consideration of multiple objectives and regional variation in agro-ecological conditions (Mills, 1997). It usually involves priority setting at the strategic level (e.g. by commodity or broad program area) and occasionally at the project or problem levels. Methods are needed

that are practical, consistent with economic theory, and capable of illustrating the trade-offs involved if efficiency alone is emphasized in the research portfolio as compared to placing weight on distributional or other social objectives as well (e.g. emphasizing small-holders or marginal areas).

Current economic problems and structural adjustment in Zimbabwe have created a financial crisis within the agricultural research system there. The budget of the Department of Research and Specialist Services (DR&SS), the primary government-supported agricultural research institution in the country, has been reduced at the same time the research

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mandate has been expanded to give additional emphasis to the small-scale (communal) farming sector. In this paper, we present a procedure developed to assist DR&SS in setting strategic level research priorities. Drawing on approaches suggested by Alston et al. (1995), it uses economic surplus analysis and multiple-objective mathematical programming (MP) to develop optimal research portfolios and illustrate opportunity costs in a situation characterized by multiple objectives, farm-types, agro-ecological zones, and levels of funding. The results illustrate the size of the trade-offs involved if public research places additional emphasis on small-scale farms as opposed to ignoring where the benefits fall. The issue of relative emphasis on small-holder versus large-scale farms has been debated in Zimbabwe and elsewhere in the region for years, but has remained unresolved due, in part, to limited empirical evidence on opportunity costs.

## **2. Background**

Zimbabwe's agricultural sector is highly dualistic, with farm size and income disparities greater than elsewhere in Africa, except in South Africa. The majority of the people in Zimbabwe live in rural areas, mostly on small farms in the less-favored agro-ecological zones. The split between large-scale commercial and small-scale communal farms primarily divides along racial lines, heightening the political sensitivity of the size and income disparity issue. Since independence in 1980, moderate improvement in small-holder agriculture in Zimbabwe provides some evidence that small-holders, given access to more resources and incentives, can make a net contribution to agricultural and economic development. However, the stated change in government policy in favor of small-holders has not translated into sufficient public investments, including in research, to lead to meaningful agrarian reform (Rukuni, 1996).

The DR&SS was created in 1948 and was initially primarily focused on diversified commercial agriculture. The DR&SS was organized along commodity and discipline lines, and from 1948 to 1970 released several improved crop varieties and crop and livestock practices. Tobacco research was conducted separately by the Tobacco Research Board. In 1970, an Agricultural Research Council (ARC) was established to

give farmers a greater role in research planning and priority setting. This 12-member council initially had an advisory role and was responsible for reorganizing the DR&SS into its current divisional structure of crops research, livestock and pastures, and research services. Its research stations and institutes were given specific mandates by commodity, agro-ecological zone, and discipline.

In 1976, the ARC assumed direct responsibility for agricultural research within the DR&SS. All government expenditures on research were channeled through the ARC, and commercial farmer associations, representing large-scale producers, provided annual grants and played a role in determining research priorities. After independence there was a policy shift that called for emphasizing research relevant to small-holders to a greater extent, and an on-farm research program was initiated. In 1982, the ARC reverted to an advisory-only role with small-holder and commercial farmers represented equally, while a separately administered Agricultural Research Fund was created to receive funds from producer associations. However, commercial farmers associations failed to support the fund and created their own Agricultural Research Trust with a farm for research and demonstration for commercial farmers. Contributions to the DR&SS declined sharply, with the budget shrinking by 25 percent in real terms in the 1980s, forcing administrators to scale back on-farm research activities. In the 1990s, the budget crisis worsened as outside donors cut back support and as structural adjustment programs led to further reductions in government spending on agricultural research.

In 1997, the DR&SS was left with 13 research stations in the various agro-ecological zones, with a continued emphasis on the high potential areas. Land was not fully utilized on the stations due to financial constraints, and only about 30 percent of the roughly 125 researchers had graduate degrees. The research system was clearly in crisis. A decision was made by the government to reconstitute the ARC with more authority over the Agricultural Research Fund and DR&SS programs in an attempt to split off research activities that might be better completed in the private sector and to prioritize public agricultural research in a more demand-driven process. This change in role of the ARC was not seen as an independent event, but as one component of a strategy to build more effective

coalitions of small-holders, and to restructure government institutions to make them more accountable to rural society.

With this background in mind, including the scarcity of funds for the DR&SS, there is a need to design priority setting mechanisms to assist both the ARC and DR&SS in setting priorities by program and by problem or project. Those mechanisms must consider the objectives of the research system and help provide information at the strategic level on the recommended relative size of research programs, and at the operational level on which problems of farmers should be addressed first by the public research system. The presence of private research (such as that undertaken by ART farm, by tobacco and swine boards, and by companies like Cargill) and of international public research (e.g. by CIMMYT) must also be considered. The research reported in this paper is an attempt to address the need for a mechanism to assist with priority setting in the public research system at the strategic level. It does not address the question of research problem selection, but provides information on opportunity costs at the level where decisions are made on broad program selection and size; for example, the trade-offs involved when numbers of scientists and research budgets vary by commodity or discipline for small-holder versus large-scale commercial farms. The priority setting mechanism, which draws on information from both scientists, extension, and representative farmers, in no way makes or provides decisions. It provides information, and that information is only useful to the extent that the leaders of the ARC and DR&SS are linked to farmers and other stakeholders so that they can place the trade-offs in perspective. It is only one component of a broader priority setting process.

### 3. Methods

Several steps were imbedded in the strategic priority setting process. The first step involved working with the leadership in the DR&SS and the ARC to identify the objectives for the research system. In short, those objectives included (1) improving agricultural productivity and efficiency while sustaining the natural resource base and (2) increasing the well-being of small-holder farmers. The second step was to

develop a list of some 37 commodities and 11 research program areas (such as soils, agronomy, plant breeding, plant protection), and to define the agro-ecological zones and farm-types. Zimbabwe can be divided into five natural regions and four farm-types (large-scale commercial, small-scale commercial, resettlement, and small-scale communal). The regions were aggregated into two categories (low potential and high potential) for purposes of analysis and the farm types were combined into two (large scale and small scale).

The third step involved collecting two basic types of data and information: market-related data and technology-related data. Market-related data included such items as quantities, prices, supply and demand elasticities, and agricultural policy information. Technology-related data included estimates of likely yield changes, production cost changes, probability of research success, technology adoption and depreciation rates, time to conduct research, research costs, expansion or contraction of land area and animal numbers, etc.

A total of 90 scientists (including two economists), research and extension directors, agribusiness leaders, farm group representatives, and other knowledgeable people were interviewed for the technology-related data. Three rounds of interviews were conducted in an iterative fashion in which summarized results from earlier rounds were presented and discussed with farm and agribusiness representatives, research administrators, and extension leaders to arrive at a consensus on technology-related assumptions. A pre-test with four scientists was conducted initially, followed, in the first round, by interviews with 66 scientists and extension officers. Respondents were asked to estimate yield and other changes under three levels of funding: current, 50% more, and none. Estimates were obtained for 37 commodities, by farm-type, by region, and by research program area. Copies of the questionnaire forms are available from the authors.

In the second and third rounds, other knowledgeable scientists, administrators, farmer's union representatives, and others with broad knowledge across commodities were interviewed to help refine responses from earlier rounds that appeared too optimistic or pessimistic. Not all individuals were asked to respond with respect to every category of data. For example, the extension respondents focused primarily on adoption questions, while economists were asked

about expected production expansion or contraction for particular commodities, irrespective of research. The main purpose was to draw on the best expertise to arrive at an overall consensus on key variables that enter into the analysis. Additional details on interview procedures are presented in Mutangadura (1997).

The fourth step involved an economic analysis that included economic surplus calculations, benefit–cost analysis, and mathematical programming. Spreadsheets were used to estimate changes in economic surplus due to research, using the market- and technology-related data and the formulas presented in Alston et al. (1995). Net present values (NPVs) of research benefits were then calculated to project the economic efficiency gains over the next 15 years for the different commodities and research program areas by farm-type and region with current and with 50% more funding. Finally, mathematical programming was used to project the optimal allocation of research resources among the various research programs under alternative weights on objectives and with current and with 50% more funding. This latter step provided information on the opportunity costs associated with the alternative allocations.

The markets for most of the commodities were modeled as small open economies. The wheat market

also was assumed to include an irrigation subsidy. Markets for indigenous fruits and vegetables, multi-purpose cattle, and draught animals were represented by closed economy models. Not all commodities are represented in each farm-type or region, but the total number of economic surplus changes calculated (and also NPVs) totaled 400 (200 surplus models under current funding and 200 with 50% more funding).

The NPVs were imbedded in the MP model presented in summarized form in Fig. 1. This model includes two objectives: (1) efficiency ( $x_1$ ) and (2) distribution of benefits to small-holder farmers ( $x_2$ ). The activities in the model, the  $c_{ij}$ , are research program alternatives where  $i$  is the commodity and  $j$  is the funding level. The units for the  $c_{ij}$  are units of research expenditures in Zimbabwe dollars. The  $R_{ij}$  are the maximum funding levels for each research program. In addition, total expenditures on all research programs must be less than or equal to  $R$  and the sum of all maximum individual  $R_{ij}$ s must be greater than  $R$  (it is profitable to spend up to the total available).

The  $a_{11}, a_{12}, \dots, a_{n2}$  represent the contributions to the efficiency objective (discounted economic benefits) associated with the  $n$  research programs and their corresponding level of support;  $b_{11}, b_{12}, \dots, b_{n2}$  repre-

	Research Programs									
	Objectives		Commodity 1		Commodity 2			Commodity n		
Equation description	$x_1$	$x_2$	$c_{11}$	$c_{12}$	$c_{21}$	$c_{22}$	...	$c_{n1}$	$c_{n2}$	RHS
1. Objective function	1	$w_2$								
2. Contributions to objectives	-1		$a_{11}$	$a_{12}$	$a_{21}$	$a_{22}$	...	$a_{n1}$	$a_{n2}$	= 0
		-1	$b_{11}$	$b_{12}$	$b_{21}$	$b_{22}$	...	$b_{n1}$	$b_{n2}$	= 0
3. Total resource limit			1	1	1	1		1	1	≤ R
4. Program resource limits			1							≤ $R_{11}$
			1	1						≤ $R_{12}$
					1					≤ $R_{21}$
					1	1				≤ $R_{22}$
							...			....
								1		≤ $R_{n1}$
								1	1	≤ $R_{n2}$

Fig. 1. Multiple-objective, linear programming model for allocating research resources.

sent the contributions to the small-holder objective. The NPVs for each objective are summed by the model and transferred to the objective function for weighting. In the initial run with the model, a weight of 1 is placed on the efficiency objective ( $x_1$ ) and a weight of 0 is placed on additional benefits to small-holders ( $x_2$ ). The model is then rerun with the weight ( $w_2$ ) on  $x_2$  raised in small increments. New research portfolios are generated and the opportunity costs of placing added weight on the distributional objective are calculated.

#### 4. Results

The economic surplus models generated several sets of results; for example: (1) a ranking of the expected NPVs for all 200 research programs under each of two levels of funding (e.g. plant breeding on maize for small-holder farms in low potential areas is ranked against agronomy research on cotton for large-scale farms in high potential areas with current and with 50% more research resources, etc.), (2) a ranking of the commodity research programs under the two levels of funding, (3) a ranking of the disciplinary research areas under the two levels of funding, (4) a ranking of the research programs across commodities, regions, and funding levels, categorized by farm-type, (5) a ranking by discipline area within each farm-type under two levels of funding, and (6) a ranking by discipline within each commodity by region under two levels of funding. Due to space limitations, only a brief flavor of the results can be presented here, but additional results are presented in Mutangadura (1997).

In Table 1, the commodity ranking is presented with the two levels of funding. It is necessary to allow at least two levels of funding because otherwise the ranking is not helpful to decision makers in deciding on allocation questions. For example, maize, cotton, and groundnuts are the top ranked commodities, and if there were only enough resources to fund the top 10 items on the list, additional research funds should be allocated to these commodities before the first funds go to sunflowers. The top third of the list includes funding both for commodities produced primarily by large-scale producers and for commodities produced primarily by small-scale producers.

An example of the differences in research benefits by farm-type is presented in Table 2. This table, which includes only the top-ranked commodities, illustrates that while maize and cotton research are high priorities for both large- and small-scale farmers, research on commodities such as goats, sunflowers, bambara nuts, and millets are important for small-holders, but not for large-scale producers. Research on wheat, coffee, soybeans, and stonefruit are more important to large-scale farmers. Differences are also evident between low potential and high potential areas.

Turning to priorities by discipline area (not shown in the table), agronomy is ranked highest for small-holders, followed by plant breeding in both high and low potential areas. Chemistry and soils rank somewhat higher in low potential areas than in high potential areas. For large-scale producers, plant breeding ranks highest in both low and high potential areas, while agronomy ranks second in low potential areas and plant protection ranks second in high potential areas. Ranking of research disciplines for livestock is similar for small-holder and large-scale farmers, with nutrition and management ranking at the top (livestock production was separated by farm-type but not by low and high potential regions).

Each of the discipline areas was ranked within each commodity as well for small- and large-scale producers in low and high potential areas. For the seven most important crops to small-holders, agronomy research in low potential areas ranked first out of eleven possible research areas, reflecting in part the need for soil fertility and crop management research. For the most important crop, maize, agronomy ranked first and chemistry and soils ranked second. Plant breeding ranked first for three crops, with agronomy second. For small-holder livestock, management research ranked first for poultry and small ruminants, while livestock nutrition ranked first for dairy and draft animals, and forage (veld and rangeland) ranked first for beef. For large-scale producers, plant breeding or plant protection ranked first for nine of the top 13 crops. Agronomy or chemistry and soils ranked first for the others. Nutrition research ranked first for each of the large-scale livestock categories.

Optimal allocation of research resources, given the two objectives, were assessed in a series of runs with the mathematical programming model. A sampling of the results when the model was run with (1) all weight

Table 1

Projected aggregate economic benefits (NPV) from research under current funding and with 50 percent more funding allowed<sup>a</sup>

Rank	Commodity	Funding Level	NPV 000Z\$	Rank	Commodity	Funding Level	NPV 000Z\$
1	Maize	Current	603,703	37	Finger Millet	+ 50%	12,309
2	Maize	+ 50%	259,128	38	Pearl Millet	+ 50%	12,294
3	Cotton	Current	147,045	39	Beans	Current	11,915
4	Groundnuts	Current	95,362	40	Tomato	+ 50%	11,701
5	Beef	Current	79,579	41	Stonefruit	+ 50%	9,992
6	Cotton	+ 50%	66,874	42	Indigenous veg	Current	9,614
7	Wheat	Current	63,252	43	Broilers	+ 50%	9,158
8	Dairy	Current	62,465	44	Soybeans	+ 50%	8,841
9	Bambara nuts	Current	50,837	45	Sorghum	+ 50%	8,434
10	Groundnuts	+ 50%	43,039	46	Onions	+ 50%	8,184
11	Sunflower	Current	38,835	47	Cattle draft	+ 50%	8,025
12	Beef	+ 50%	36,951	48	Roses	+ 50%	7,613
13	Coffee	Current	34,294	49	Cowpeas	+ 50%	7,566
14	Goats	Current	31,002	50	Sheep	Current	7,291
15	Dairy	+ 50%	27,289	51	Sweet potato	+ 50%	6,928
16	Tomato	Current	26,489	52	Layers	+ 50%	6,720
17	Cow peas	Current	25,790	53	Donkey draft	Current	6,718
18	Pearl millet	Current	25,005	54	Potato	+ 50%	6,039
19	Finger millet	Current	24,767	55	Cabbage	+ 50%	6,016
20	Wheat	+ 50%	24,328	56	Apples	+ 50%	5,802
21	Broilers	Current	21,246	57	Beans	+ 50%	5,244
22	Stonefruit	Current	20,599	58	Indigenous veg	+ 50%	4,738
23	Bambara nuts	+ 50%	19,648	59	Indigenous fruit	Current	3,345
24	Soybeans	Current	19,474	60	Peas	Current	3,209
25	Onions	Current	18,472	61	Sheep	+ 50%	3,174
26	Sunflower	+ 50%	18,246	62	Donkey draft	+ 50%	2,853
27	Sorghum	Current	18,164	63	Macadamia	Current	1,693
28	Cattle draft	Current	17,711	64	Indigenous fruit	+ 50%	1,620
29	Cabbage	Current	17,566	65	Fish	+ 50%	1,598
30	Layers	Current	17,272	66	Peas	+ 50%	1,213
31	Roses	Current	16,133	67	Strawberry	Current	1,067
32	Coffee	+ 50%	15,093	68	Ostriches	Current	819
33	Potato	Current	14,874	69	Macadamia	+ 50%	780
34	Sweet potato	Current	14,709	70	Strawberry	+ 50%	508
35	Apples	Current	13,300	71	Ostriches	+ 50%	298
36	Goats	+ 50%	12,891	72	Castor bean	Current	– 280

<sup>a</sup> Net present value with + 50% funding refers to the incremental benefits (NPV) obtained from adding 50 percent more funding to the current level.

placed on the efficiency objective and (2) double weight placed on benefits going to small-holders is presented in Table 3. When the overall budget constraint allows for up to 50% more funding than the current budget, castor beans, fish, and ostriches are not funded in either run for small- or large-scale producers. Certain others are not funded for one group or the other. When all weight is placed on efficiency, small-holder maize followed by large-scale cotton, beef, dairy, and maize emerge as the top-ranked commodities. When additional weight is placed on small-

holders, the results are similar but small-holder goats, beef, and dairy rise significantly on the list and large-scale dairy is dropped. The rankings are similar when the weight on small-holders is increased gradually to even higher levels.

When the overall budget constraint is reduced to the current level of funding for the DR&SS, and the weight on small-holders is increased to a very large number, the total efficiency gains (discounted future economic benefits) sacrificed because of the portfolio distortion are only about 4 percent. This 4 percent

Table 2  
Ranking of research benefits by farmer type, agro-ecological zone, and level of funding (top 30 for each farm-type)

Smallholder Farmers					Large-Scale Farmers				
Rank	Commodity	Zone <sup>a</sup>	Funding Level	NPV 000 Z\$	Rank	Commodity	Zone <sup>a</sup>	Funding Level	NPV 000 Z\$
1	Maize	LP	Current	195,123	1	Maize	HP	Current	146,271
2	Maize	HP	Current	131,156	2	Maize	LP	Current	128,373
3	Maize	LP	+ 50% <sup>b</sup>	71,769	3	Beef		Current	79,579
4	Maize	HP	+ 50%	64,513	4	Maize	HP	+ 50%	63,416
5	Cotton	LP	Current	62,512	5	Maize	LP	+ 50%	57,734
6	Groundnuts	LP	Current	47,769	6	Cotton	HP	Current	36,397
7	Dairy		Current	38,619	7	Coffee	HP	Current	34,294
8	Groundnuts	HP	Current	36,936	8	Wheat	HP	Current	33,154
9	Sunflower	LP	Current	33,334	9	Wheat	LP	Current	30,098
10	Goats		Current	31,002	10	Dairy		Current	27,695
11	Cotton	HP	Current	29,808	11	Stonefruit	HP	Current	20,599
12	Bambara nuts	HP	Current	29,727	12	Soybeans	HP	Current	17,900
13	Cotton	LP	+ 50%	29,414	13	Cotton	LP	Current	17,047
14	Pearl millet	LP	Current	25,005	14	Cotton	HP	+ 50%	16,661
15	Finger millet	LP	Current	24,767	15	Roses	HP	+ 50%	16,133
16	Groundnuts	LP	+ 50%	23,566	16	Coffee	HP	+ 50%	15,093
17	Bambara N.	LP	Current	21,110	17	Wheat	HP	+ 50%	13,414
18	Sorghum	LP	Current	18,498	18	Apples	HP	Current	13,300
19	Cattle draft		Current	17,711	19	Dairy		+ 50%	12,605
20	Goats		+ 50%	16,286	20	Wheat	LP	+ 50%	10,914
21	Dairy		+ 50%	16,176	21	Stonefruit	HP	+ 50%	9,992
22	Groundnuts	HP	+ 50%	16,064	22	Beef		+ 50%	9,411
23	Sunflower	LP	+ 50%	15,749	23	Layers		Current	8,512
24	Cotton	HP	+ 50%	13,898	24	Tomato	HP	Current	8,508
25	Beef		Current	13,770	25	Soybeans	HP	+ 50%	8,137
26	Cowpeas	HP	Current	13,755	26	Broilers		Current	7,847
27	Broilers		Current	13,399	27	Groundnuts	HP	Current	7,793
28	Finger millet	LP	+ 50%	12,309	28	Potato	HP	Current	7,241
29	Pearl millet	LP	+ 50%	12,294	29	Cotton	LP	+ 50%	6,901
30	Cowpeas	LP	Current	11,920	30	Apples	HP	+ 50%	5,802

<sup>a</sup> HP stands for high potential region and LP stands for low potential region.

<sup>b</sup> + 50% stands for the current level of funding plus an incremental 50 percent. The benefits shown are the incremental benefits.

efficiency cost of focusing on small-holders is an interesting result because it implies that the DR&SS can follow its expanded mandate without a substantial drop in total economic benefits from its research program. An additional series of runs was made with the model with successively more constraining overall budgets. When the budget was reduced by 20 percent, heavier weighting of small-scale producers reduced efficiency by 8 percent. When the budget was reduced by 50 percent, these efficiency losses were 12 percent.

There are several reasons for the relatively modest drop in benefits as more weight is given to small-

holder research, even under a tight budget. First, the level of funding for any particular research program was capped in the analysis at the current level plus 50%. In some cases, additional research resources might have been productively employed in a program, but additional funding was not allowed. The implication of the cap is that the budget suffices to fund programs well down the list. Second, many of the bottom-ranked programs are projected to generate so few benefits that they do not replace research programs for large-scale producers, even when given the advantage of being counted several times through the weighting process. Third, many of the top programs,



Table 3

Results of the mathematical programming analysis with all weight placed on efficiency and with double weight given to small-holders (top 30 commodities)

All weight placed on efficiency <sup>a</sup>			Double weight given to small-holders <sup>b</sup>		
Rank	Commodity	Farmer-type	Rank	Commodity	Farmer-type
1	Maize	Small-holder	1	Maize	Small-holder
2	Cotton	Large-scale	2	Beef	large-scale
3	Beef	Large-scale	3	Goats	Small-holder
4	Dairy	Large-scale	4	Maize	Large-scale
5	Maize	Large-scale	5	Cotton	Small-holder
6	Cotton	Small-holder	6	Wheat	Large-scale
7	Wheat	Large-scale	7	Beef	Small-holder
8	Groundnuts	Small-holder	8	Groundnuts	Small-holder
9	Coffee	Large-scale	9	Dairy	Small-holder
10	Soybeans	Large-scale	10	Sorghum	Small-holder
11	Cattle draft	Small-holder	11	Coffee	Large-scale
12	Sorghum	Small-holder	12	Cotton	Large-scale
13	Pearl millet	Small-holder	13	Beans	Small-holder
14	Tomato	Large-scale	14	Cattle draft	Small-holder
15	Sunflower	Small-holder	15	Pearl millet	Small-holder
16	Bambara nuts	Small-holder	16	Sunflowers	Small-holder
17	Finger millet	Small-holder	17	Bambara nuts	Small-holder
18	Roses	large-scale	18	Finger millet	Small-holder
19	Apples	Large-scale	19	Roses	Large-scale
20	Stonefruit	Large-scale	20	Apples	Large-scale
21	Onions	Large-scale	21	Stonefruit	Large-scale
22	Cowpeas	Small-holder	22	Cowpeas	Small-holder
23	Potato	Large-scale	23	Tomato	Large-scale
24	Broilers	Large-scale	24	Potato	Large-scale
25	Groundnuts	Large-scale	25	Broilers	Large-scale
26	Tomato	Small-holder	26	Tomato	Small-holder
27	Groundnuts	Large-scale	27	Groundnuts	Large-scale
28	Donkey draft	Small-holder	28	Donkey draft	Small-holder
29	Indigenous vegetables	Small-holder	29	Onions	Large-scale
30	Onions	Small-holder	30	Indigenous vegetables	Small-holder

<sup>a</sup> Each of these commodities should receive current funding plus 50% except for large-scale beef and soybeans, and smallholder sorghum.

<sup>b</sup> Each of these commodities should receive current funding plus 50% except for large-scale beef, cotton, tomatoes, and onions, and smallholder goats, beef, dairy, and beans.

even when no additional weight is given to small-holders, are in fact small-holder programs and therefore those programs are already in the suggested portfolio. Fourth, programs that are currently or are expected to be undertaken by the private sector (and these programs are primarily for commercial farmers) were excluded from the analysis, and respondents to the questionnaire were asked to project the incremental changes due to the effects of DR&SS research, taking the effects of private research as given. While the DR&SS still conducts research important to large-scale farmers, some high pay-off research for the large-scale commercial sector is already outside the

purview of the DR&SS (e.g. tobacco and swine, but parts of other commodity programs as well).

Shadow prices were generated for all the research programs and, as expected, shadow prices on maize for small-scale and large-scale producers are the highest. Shadow prices for the other programs depend significantly on the level of funding and type of farm. Shadow prices enable the analyst working with the leadership of the DR&SS to answer 'what if'-type questions. The eventual research portfolio selected will be based on considerations in addition to economic returns, and hence it is helpful to know what is being sacrificed in the process.

Table 4  
Funding changes suggested by model when double weight is given to the communal sector and reallocations up to 50% allowed

Commodity group	Commodity	Change in funding compared to current level	
		Communal Sector	Commercial Sector <sup>a</sup>
Cereals	Maize	Increase	Increase
	Wheat	No change (0)	Increase
	Pearl millet, finger millet	Increase	No change (0)
	Sorghum	Increase	Decrease
Cotton and oilseeds	Cotton, sunflower	Increase	Decrease
	Groundnuts	Increase	Increase
	Soybeans, castor beans	Decrease	Decrease
Pulses	Bambara nuts, cowpeas	Increase	Decrease
	Beans	No change	Decrease
Vegetables, fruits, and flowers	Tomato, cabbage, potato	Increase	Increase
	Stonefruit	No change (0)	Increase
	Onions	Increase	No change
	Roses, apples, peas, strawberries	No change (0)	Increase
	Sweet potato	Increase	Decrease
	Indigenous vegetables and fruit	Increase	No change (0)
Coffee and macademia	Coffee	Decrease	Increase
	Macademia	No change (0)	Increase
Livestock	Beef, dairy	No change	No change
	Goats	No change	No change (0)
	Broilers	Increase	Increase
	Cattle, donkey draft	Increase	No change (0)
	Layers	Increase	No change
	Sheep	Increase	Decrease
	Fish	Decrease	No change (0)
	Ostriches	No change	Decrease

<sup>a</sup> Includes small-scale commercial as well for wheat, groundnuts, and flowers.

When results of the research were discussed with the ARC, the results in Table 4 were presented which indicate the direction of change in resource allocation for particular commodities. Rankings are often not as useful as information on the nature of changes implied by the results. Seldom are changes made swiftly and completely, and directions of changes are easy to understand and are useful for debate.

## 5. Conclusion

Even with no additional weight placed on small-holders, research programs for both small-holders and low potential areas enter into the optimal research portfolio. Indeed small-holder maize, cotton, groundnuts, cattle for draft, sorghum, millets, sunflowers, and bambara nuts were among the highest ranked programs. As more emphasis is given to small-holders, the reduction in overall efficiency gain due

to research is modest. Knowing the magnitude of the projected tradeoff from emphasizing small-holders should be useful to those selecting the research portfolio for Zimbabwe, as this issue has been debated for years.

Some of the research programs are projected to have negative NPVs and should be excluded from the research portfolio. Resources for these programs can be reallocated to higher ranked programs. If resources for research become even tighter, resources can also be removed from the bottom-ranked programs. The results of the analysis, not all of which could be presented here, suggest some reallocations for several current programs in order that 50% more funding can be provided to higher ranked programs. The analysis here also suggests that agronomy and soils research are more important on a relative basis for small-holders, while plant breeding and crop protection are relatively more important for large-scale farmers.

The combination method of economic surplus and mathematical programming analysis proved to be a workable approach for analyzing research priorities in a situation with multiple objectives and agro-ecological zones. The approach can provide useful information for strategic priority setting, but is not likely to be useful for project level planning given the sheer number of projects that would have to be assessed, the large number of interviews that would need to be conducted (especially with producers), and the danger of stifling scientist creativity. Less quantitative, participatory appraisal techniques are likely to be more useful for prioritizing research projects and problems. An example of applying such techniques in the Philippines is found in Litsinger et al., 1995.

It should be possible in the future to compare responses of those interviewed in the priority setting process with what actually occurred in terms of research success, yield changes, and so on, thereby improving those estimates when priorities are updated. Additional refinement could also be made with respect to inclusion of uncertainty around parameter estimates.

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