Is Investment in Rice Research in Nepal Adequate and Balanced Across Production Environments? Some Empirical Evidence

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Abstract

This study analyzes the patterns of public resource allocation in rice research in Nepal. The resource allocation for rice research was approximated based on the full-time equivalent (FTE) of researcher time spent on rice research. A simple congruence model modified by expected rate of research progress and equity criteria was used to investigate the gap between the actual and normative investment patterns across different types of rice production environments. The results show a substantial under-investment in rice research in general but more so in rainfed areas and in the Terai agroecological zone. The use of modifiers amplified the extent of underinvestment in rainfed environments. The options for addressing these imbalances and the overall implications for resource allocation for rice research in Nepal are discussed.

Keywords: congruence analysis, public investment, resource allocation, rice research
JEL: Q 160, Q 190

1 Introduction

Public investment in agriculture is essential to generate productivity growth and reduce poverty in developing countries (PARDEY et al., 2006; FAN et al., 2007; BEZEMER and HEADEY, 2008). A strong link exists between public investments in research and agricultural productivity growth (THIRTLE et al., 2003; FAN et al., 2007; HAZELL, 2008; WORLD BANK, 2008). However, in recent years, public-sector investment in agricultural research in the developing world has been slowing down as a result of public policies and priorities being diverted toward structural reforms, environmental concerns, and human health (ALSTON and PARDEY, 2006; PARDEY et al., 2006). In spite of the well-known documented evidence of a higher rate of return from investment in agricultural research and development (ALSTON et al., 2000), underinvestment in agricultural research is a pervasive problem, particularly in low-income developing countries (PARDEY et al., 2006; OPM, 2007; WORLD BANK, 2008).

Underinvestment is also a pervasive problem in agricultural research in Nepal. Estimates show that current agricultural research investment intensity[1] in the country is very low, about 0.20% of the agricultural gross domestic product (AGDP). Rice research intensity is even lower, with about 0.021% of the value of rice output being invested in research. Both agricultural research and rice research investment intensities have further declined in recent years. For instance, the share of agricultural research in total agricultural investment in Nepal decreased from 7.5% in the year 2001-02 to 3.9% in 2008-09. Similarly, the share of rice research in total agricultural research investment decreased from 5.7 % in 2001-02 to 2.21% in 2008-09 (NARC, 2009). Decisions on investments in agricultural research and allocation across commodities are based on past spending patterns, without much analysis of the potential impact of research. Given this scenario, there is a need for scientific, more explicit, and evidence-based processes for empirical analysis of research investment patterns to inform and influence policy decisions on research investments in Nepal. The purpose of this study, therefore, is to contribute toward a more informed decision-making process in agricultural research through an analysis of the allocation of resources to rice research across production environments. Rice is chosen for this study because it is the principal food crop and a major source of livelihood for two-thirds of the rural households in Nepal.

The paper is organized as follows. Following the background information in section one, the paper provides an overview of the importance of rice, the production environments and description of rice research organizations in the second section. This is followed by a discussion of the current resource allocation patterns for overall agriculture and for rice research in Nepal. The methodology for assessing resource allocations is then outlined in the fourth section. The results of the congruence analysis are then presented in the fifth section. Finally, the conclusions and implications of the findings are discussed.

2 Rice Research and Production Environment

2.1 The Importance of Rice in Nepal

Agriculture is the main source of the national economy and the livelihood of the Nepalese people, accounting for 32% of the GDP and employing 70% of the population in the country (MOF, 2009). Rice is the most important food crop in terms of area,

[1] Research intensity of investment is defined as the ratio of research investment to the value of agricultural production. This measure is preferred to absolute levels of expenditure to make the country's agricultural R&D efforts easily comparable within international contexts (BEINTEMA and STADS, 2008).

production, and livelihood. It is currently grown on half of the total cropped area and accounts for more than half of the total food grain production in the country (MOAC, 2008). It is also the main source of livelihood for more than two-thirds of the farm households (70%) and accounts for one-fifth (20%) of the agricultural GDP in the country (MOF, 2009). Rice also supplies about 40% of the food calorie intake, with an annual per capita consumption of about 100 kg of milled rice (FAOSTAT, 2008).

2.2 Rice Production Environments

The rice production environment in Nepal is broadly categorized into ecosystems (irrigated, rainfed lowland, and rainfed upland) and broader ecology-related regions (Mountains, Hills, and Terai). There may be similarities within the same ecosystem in the Terai[2] or Hills, but because of climatic differences caused by altitudinal variations, the same ecosystem of the Hills and the Terai may have different production systems and technological implications (JMA/APPROSC, 1995; GILL, 1996). Therefore, rice production conditions and growing environments are influenced not only by ecosystem but also by broad ecology (climate, topography, altitude)-related factors. These two types of rice production environments are briefly discussed below.

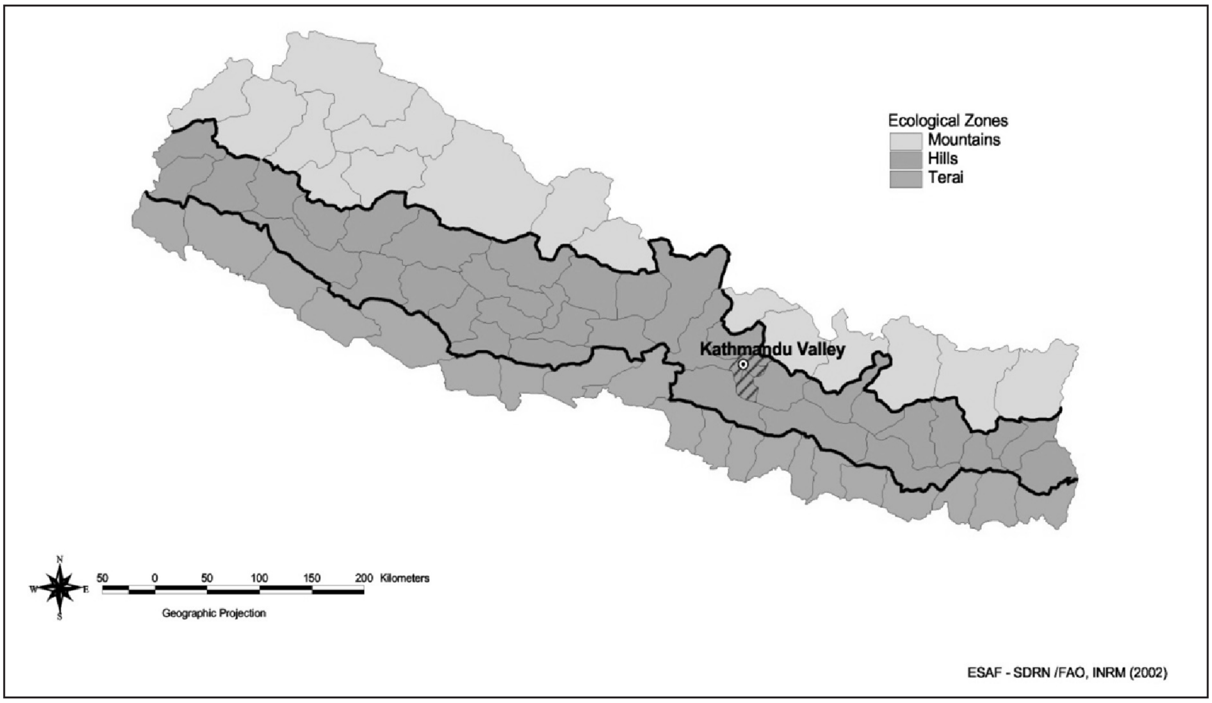
2.2.1 Agroecological Environments

Rice is grown in different ecological environments in Nepal (fig. 1), from the lowland in Terai (50-300 m asl) to the Hills (>300-1500 m asl) and Mountains (>1500-3000 m asl). The share of rice area, production, and yield varies by these ecological regions (table 1). Rice is largely produced in the Terai as it has a flat lowland topography and suitable climatic conditions. In the Hills and Mountains, rice is mainly grown in river valleys, foothills, hill terraces, and mountain slopes, up to as high as 3,000 m asl in Jumla valley of the mid-western mountain region (NARC, 1997).

The Terai has the largest area (71%) and production share (73%), followed by the Hills (24%). The Mountain region accounts for a small proportion of area (4%) and production (3%) in the country. Yield is also higher in the Terai (2.8 t/ha) than in the Hills (2.6 t/ha) and Mountains (2.0 t/ha). Considering the high production potential of the Terai, the national agricultural perspective plan (APP) of Nepal has given special priority to this region for enhancing food production and reducing poverty (JMA/ APROSC, 1995).

[2] Terai refers to the southern, flat low-lying region of the country bordering India, which is a part of the Indo-Gangetic fertile plains. This region stretches in parallel from east to west, covering more than 1,000 km of Nepal.

Figure 1. Map of Nepal showing three ecological regions



Source: ESAF-SDRN/FAO, NRM (2002)

Table 1. Triennium average of rice area, production and percent shares by ecological environment (2006-07 – 2008-09)

Ecological region	Rice area		Production		Yield
	(000 ha)	Percent	(000 Mt)	Percent	(t/ha)
Mountain	63.7	4.21	124.9	3.0	1.96
Hills	382.1	25.22	1,005.1	24.1	2.63
Terai	1,068.8	70.56	3037.8	72.9	2.83
Nepal	1,514.7	100.00	4,167.9	100.0	2.75

Source: MOAC (2008)

2.2.2 Rice Ecosystems

Rice in Nepal is cultivated in both irrigated and rainfed ecosystems. Rice ecosystems are categorized as rainfed and irrigated based on field hydrology. The rainfed ecosystem is further subdivided into rainfed lowland, rainfed upland, and deep water based on field hydrology and toposequence (HUKE and HUKE, 1997). Approximately

79% of the rice area in Nepal falls under the rainfed ecosystem, while the rest is in the irrigated ecosystem (table 2). Rice production data, presented by ecosystem, are estimated based on the share of the area of each ecosystem, and yield[3] in irrigated and rainfed ecosystems (MOAC, 2008; IRRI, 2010).

Table 2. Rice area, production, and percent share by ecosystem

Rice ecosystem	Area (%)	Area (000 ha)	Yield (t/ha)	Production (000 t)	Prod. (%)
Irrigated	21	325	3.65	1,188	27.6
Rainfed	79	1,225	2.55	3,122	72.5
Lowland	66	1,023	2.80	2,864	66.5
Upland	5	78	1.60	124	2.9
Deep water	8	124	1.10	136	3.2
Total	100	1,550		4,310	100.0

Source: IRRI (2009) (derived from FAO 2004-06, three years' database); MOAC (2008), and IRRI (2010)

2.3 Rice Research and Organizations

Agricultural research in Nepal has historically been a public-sector responsibility. Private-sector agriculture is nonexistent in Nepal (GAUCHAN et al., 2003; STADS and SHRESTHA, 2006). The Nepal Agricultural Research Council (NARC) is the sole public organization in Nepal that conducts rice research in the country. Rice research in Nepal dates back to the early 1950s with the collection and evaluation of 930 rice germplasm accessions on the agricultural research farms of Parwarnipur and Khumaltar in Bara and Lalitpur districts, respectively (MALLICK, 1981). However, a systematic coordinated rice research program began only in 1972 with the establishment of the National Rice Improvement Program (NRIP) in Parwanipur, Bara District. The NARC central disciplinary divisions located in Kathmandu and regional agricultural research stations located in different ecological and development regions are also mandated to implement their own rice research activities to assist in the national on-station and on-farm varietal testing process as well as to provide technological information to other clients.

[3] The yield of the irrigated and rainfed ecosystem is obtained from the cost of production data for the given years (MOAC, 2008). The yield of the rainfed sub-ecosystems is estimated from the yield data of recent in-country studies carried out by the International Rice Research Institute (IRRI, 2010).

3 Resource Allocation Pattern

3.1 Agricultural Research Expenditures

The current funding method for agricultural research in Nepal is in the form of block grants provided by the government through the MoAC to the public research institute (e.g. NARC). The amount of grant allocated to research depends mainly on the past resource allocation, spending pattern, and total public allocation to agriculture but there is no explicit consideration of research priorities, research productivity, or research planning in general (ITAD, 2005). Estimates show that public allocation to agriculture[4] as a whole currently accounts for less than 3% of the national budget and 4% of the value of agricultural output in spite of its importance in the national economy (SHARMA, 2009; NARC, 2009).

Since agricultural research has a long gestation period and its impact is not immediately observable to policymakers, the resource allocation pattern for agricultural research has historically been low, despite the government's declaration of priority given to the agricultural sector in various plans and policies (YADAV, 1987; THAPA, 1994; UPADHYAY, 1996; ITAD, 2005; SHARMA, 2009). The trend of investment in agricultural research has declined in recent years both as a percentage of agricultural gross domestic products (AGDP) and also in real value terms (table 3).

Table 3. Trend in public agriculture R&D budget (nominal) as a percent of AGDP

Year	AGDP (US$ billion)	Budget for agriculture (US$ million)	Agriculture budget as % of AGDP	Budget for agriculture research (US$ million)	Research share in agriculture budget (%)	Research budget in AGDP (%)
2001-02	2.24	104	4.60	7.81	7.53	0.35
2002-03	2.34	82	3.50	4.23	5.18	0.18
2003-04	2.51	86	3.40	4.06	4.72	0.16
2004-05	2.69	92	3.40	4.21	4.58	0.16
2005-06	2.86	102	3.60	3.98	3.92	0.14
2006-07	3.06	124	4.10	4.79	3.86	0.16
2007-08	3.50	143	4.10	5.61	3.91	0.16

Source: compiled from MoF (2009) and NARC (2009)

[4] Agriculture expenditures in Nepal reflect those allocated for agriculture, irrigation, and forestry. Agriculture specifically covers agricultural research and development (crops, horticulture, livestock, and fisheries), agricultural cooperatives and inputs (seeds and fertilizers).

In 2000-01, the government allocated about 8% of its agricultural expenditures in research, which then declined to around 4% in 2007-08. Similarly, the share of public research expenditures in AGDP allocated to NARC declined from 0.35% in 2001-02 to 0.16% in 2007-08. This current share of public research expenditures is very low relative to the investment of 0.6% on average in developing countries and 2.35% in developed countries (BEINTEMA and STADS, 2008). Over the last eight years, one of the principal reasons for the drop in agricultural research spending was the lack of major donor support for agricultural research after the termination of the World Bank-funded Agricultural Research and Extension Project in 2002.

3.2 Rice Research Expenditures

The budget for rice research depends on the total amount of the block grant that NARC receives annually from the government and the number and quality of the research proposals submitted by researchers within the organization. At present, there is no clear scientific process for allocation of core research funds to rice research in the country. The proposals and budget proposed for rice research have to compete with other commodities and sectors. These are screened internally through the annual program review. The current budget allocated to rice research is extremely low, which has also declined in real value terms in recent years (table 4).

Table 4. Allocation of rice research budget (real price*) to total agri-research budget (US$)

Year	Budget for agricultural research (US$ 000)	Operational agricultural research budget (US$ 000)	Operational food crop research budget (US$ 000)	Operational rice research budget (US$ 000)	Rice research to operational agri-research budget (%)
2001-02	7,808	2,541	739	146	5.7
2002-03	4,073	1,222	306	50	4.1
2003-04	3,792	1,253	463	47	3.8
2004-05	3,769	1,273	498	66	5.21
2005-06	3,355	947	373	41	4.27
2006-07	3,773	1,182	417	51	4.34
2007-08	4,095	1,318	453	49	3.69
2008-09	4,668	1,200	334	27	2.21

* Note: Real price is obtained by using GDP deflator for 2001 as a base year (IMF, 2009). The local currency NRs is converted to US$ using the prevailing exchange rate of US$1=NRs 74.

Source:compiled from NARAC (2009)

For the period of 2001-08, about 2-6% (average of 4%) of the total operational[5] agricultural research budget went to rice despite the vital share of rice output (20%) in national AGDP. According to NARC, the allocation for rice in 2008-09 (in constant price) was 2.21% of the actual operational research budget, which was less than the budget allocated for fishery, commercial crops, and other commodities that are nationally less important (NARC, 2009).

Recent data (2001-08) indicate that, within agriculture, food crops constitute about 50% of the total value of output in agriculture (MOF, 2009), but they receive less than one-third of the real agricultural research budget. Estimates also show that rice research receives about 13% of the total food crop research budget and 4% of the total agricultural research budget despite its share of half of the food crop output and 20% of the AGDP. Furthermore, the share of rice research expenditures in both total food crop and agricultural research expenditures has declined over the years. In real (constant) price, the share of operational rice research budget is even lower, that is, about 2% of total research budget in 2008. Moreover, this public spending declined from 2001-02 to about 2% in 2008-09. Past evidence also shows that the proportionate share of rice research budget in total crop budget was higher in the early 1970s and 1980s than in the 1990s (UPADHYAY, 1996). The big gap between total agricultural research budget and actual operational agricultural research budget shows that a higher proportion of resources are allocated to staff salary and administrative expenditures than to real research activities. This operational agricultural research budget is about 30% of the total budget allocated for agriculture in recent years (average of 2001-08). This indicates that, within the limited budget, actual expenditures allocated to and available for research in agriculture and in rice are very low.

4 Methodology

4.1 Assessment of Rice Research Expenditures

This study employs an analysis of resource allocations for rice by production environments encompassing both ecological region (Terai, Hills, and Mountains) and rice ecosystem (irrigated, rainfed lowland, upland) for the reference year 2008-09. We used a proxy measure for research expenditures, namely, the total scientific time invested in rice research on a full-time equivalent (FTE) basis, because data on actual research expenditures on rice by ecosystem, ecological region, discipline, and thematic area are

[5] The operational budget in agricultural research and rice research includes the actual amount allocated for core research activities after deducting from its staff salary, capital, and administrative expenditures. The disaggregated data for rice research budget by staff salary, administrative, and capital costs are currently not available.

currently not available in Nepal. The FTE estimates were obtained by a survey of rice researchers (n=37) involved in the main public research organization in Nepal. Estimation of full time equivalents (FTEs) through surveys is a standard practice in the literature (BEINTEMA and STADS, 2010) due to lack of other alternative satisfactory ways of reliably estimating these. The scientists were requested to consider their time invested in rice research only, not in management and other research activities.[6]

4.2 Congruency Method

Various economic methods and tools that are mainly founded on the application of the economic surplus approach are currently available for guiding the allocation of research resources (BYERLEE and MORRIS, 1993; ALSTON et al., 1998; PANDEY and PAL, 2007). The approach demonstrated by FUGLIE (2007) provides an example of a more complete economic surplus model and the data intensity needed to implement such an approach. These models obviously cannot be applied for Nepal because of a lack of relevant data. In addition, policymakers and research managers in a small developing country such as Nepal, who make resource allocation decisions often, value simpler, easier, and more transparent methods than more complex and advanced quantitative ones. A simple, transparent, and commonly used procedure is based on the economic congruency rule, which generally implies that the importance of a commodity in agricultural research should be proportional to the importance of the commodity in the national economy. This rule maintains that research resources should be allocated in proportion to their contribution to the value of production across ecosystems, production regions, and commodities, and among disciplines. Following BYERLEE and MORRIS (1993) and PANDEY and PAL (2007), congruency can be measured as

$$C = 1-\sum_i (R_i - V_i)^2,$$

where R_i is the share of the ith region in the total rice research budget and V_i is the share of the ith region in the total value of rice output.

6 Except for a few scientists who are exclusively assigned to a particular line of research in a commodity, most scientists in Nepal manage a portfolio of research and administrative tasks that can span several commodities or areas of work. The time allocation of such staff across various activities is not always clearly defined and tends to be somewhat flexible. Hence, estimates of time allocations are best obtained from scientists themselves. Any potential biases in such subjective assessments were minimized in the elicitation as (i) the principle author, who is a senior staff of NARC and has a personal rapport with concerned scientists, was directly involved in interviews and (ii) the interview responses were cross-validated with researchers' supervisors (or research managers).

The greater the mismatch between the value of production and research expenditure shares, the lower the value of C (index). By definition, the value of C is between 0 and 1. This standard congruency analysis is based on the current share in the value of production of rice as the sole indicator of the relative economic importance across rice production environments in the future. Standard congruence analysis, however, does not take into account the differential rate of future research progress, likely adoption rates, and likely differential impact on equity and the environment across production environments (BYERLEE and MORRIS, 1993; ALSTON et al., 1998; PANDEY and PAL, 2007).

4.3 Modified Congruence

To account for the future rate of research progress and incidence of poverty (equity), the simple congruence model was modified using two weighting procedures. The first one consisted of an efficiency criterion related to the expected payoffs to rice research expenditures, while the second one is an equity criterion related to expected distributional effects of technical change. Scoring rules as proposed by ALSTON et al. (1998) provide ways of incorporating suitable weights to the current value of production to account for these considerations. These weighted shares are then used instead of the simple production shares to apply the congruency rule specified above. The two major considerations used to modify the simple congruence rule are outlined below.

4.3.1 Rate of Expected Research Progress

The expected rate of research progress is commonly used as one modifier to the simple congruence rule (BYERLEE and MORRIS, 1993; PANDEY and PAL, 2007). This modifier takes into account the expected rate of future progress in generating suitable technologies. It is derived by considering the size of the production gain (e.g., targeted yield achievement) from the development of a given technology. Since research progress historically varied among the ecological regions (Hills, Mountains, Terai) and between rainfed and irrigated ecosystems, a modification in congruence analysis was made based on estimates of expected future progress in rice technology development in each of the ecological regions and in each ecosystem. The expected rate of future progress was based on expert knowledge of the scientific staff involved in research and research managers who considered the current trends in productivity growth in different production environments, the technologies that are in the pipeline and the relative potentials for productivity gains across production environments. In an ex-ante analysis such as the current one, expert judgment is probably the best approach for estimating the likely future yield growth across production environments. Experts consulted for this were experienced rice breeders and research managers capable of making informed judgments on the likely scientific possibilities for future yield gains.

A group consensus estimate was used for the analysis. A sensitivity analysis was conducted with respect to the estimated expected yield gains to examine the robustness of results.

The Terai region is more likely to have a higher rate of research progress because of its flat topography, abundance of groundwater resources, and potential for commercialization (ITAD, 2005; GILL, 1996; UPADHYAY, 1996; JMA/APROSC, 1995). This region also has higher potential for productivity gains in rice from the dry-season cropping. The mountain region has the lowest expected research progress because of its harsh climatic (low temperature), physiographic (steep slopes), and market (inaccessibility) constraints. The expected yield gains relative to the current values were estimated through expert consultation as 30% for Terai, 20% for Hills, and 10% for Mountains.

Between the irrigated and rainfed environments, it was assumed that the expected research progress in rice production in the future in Nepal is likely to be higher in rainfed environments due to recent technological developments to address the key abiotic constraints of drought, submergence, and a relatively high current yield gap (defined as the yield difference between what is achievable on farmers' fields versus farmers' actual yield) in rainfed environments and the limited possibility for yield improvement in irrigated environments owing to current attainment of higher yield (IRRI, 2007). Drought and submergence are major abiotic stresses that have constrained the yield growth in rainfed environments of Nepal. Recently, rice varieties tolerant to such stresses have been developed for rainfed areas of India. This indicates that similar varieties could be developed for rainfed environments of Nepal also. In the light of these developments, the anticipated yield gains elicited through expert panel were 30% and 20% of the current values for the rainfed and irrigated ecosystems, respectively. Within the rainfed areas, no distinction was made between rainfed upland and lowland with respect to this parameter.

4.3.2 Incidence of Poverty

The standard congruence analysis was also modified based on equity considerations as the poverty rate varies between irrigated and rainfed ecosystems as well as among the Hills, Mountains, and Terai ecological regions. Official statistics in many countries show that poverty incidence is higher in rainfed areas than in irrigated areas. Similarly, the incidence of poverty in Nepal is higher in the Hills and Mountains than in the plain region or Terai (NLSS, 2004). One of the major justifications for investing in research targeted at unfavourable environments is the higher incidence of poverty in these less favoured environments (BYERLEE and MORRIS, 1993; PALMER-JONES, 2000; IRRI, 2007).

Since rice is an important crop of Nepal and is mainly grown in the rainfed environment, growth in productivity is a critical entry point for poverty reduction. The poverty consideration is therefore included in the model by assigning a greater weight to the value of production for unfavourable (e.g., rainfed and Hills and Mountains) production environments. The official statistics on current poverty rates based on the Nepal Living Standard Survey (NLSS) of 2003-04 were used in the model. This is the source of most recent official estimates of disaggregated poverty incidence by ecological regions and by rural and urban areas. This shows that the poverty rate in the Mountains (35%) and the Hills (33%) is higher than in the Terai region (28%). Based on these reference data, the relative poverty weights of 1 for Terai, 1.25 for Hills, and 1.20 for Mountains were used. However, accurate official statistics on a separate poverty rate for rice ecosystems (irrigated and rainfed) are not currently available in Nepal. Hence, the poverty rate for these ecosystems was estimated based on interaction with knowledgeable people in Nepal and available poverty data for rural and urban areas. We used a 50% higher poverty weight for the rainfed ecosystem relative to the irrigated ecosystem.

5 Findings

5.1 Resource Allocations in Rice Research

NARC is the sole public organization involved in rice research in Nepal. Public research resources in NARC for rice and other agricultural commodities are allocated at present based on proposals from researchers who propose to work on a particular thematic area, discipline, production region, or ecosystem. Human resource capacity in rice research is currently limited, even though NARC has a fairly good number of researchers [7] in total (474). Of these, data show that only 50 researchers are involved in rice research across the country either full- or part-time (table 5). Out of 50 researchers currently involved in rice research, only 10 were involved on a full-time basis. The rest (40 researchers) provide less than half of their time in rice research. Plant breeding and agronomy accounted for the highest proportion of the FTE researchers.

At present, NARC has a uniform level of research support across regions and ecosystems even on a per FTE basis; hence, the expenditures with a unit of researcher time remain constant over Nepal. The analysis of the budget expenditures allocated to

[7] Researchers in NARC currently include technical staff both at the level of scientists and technical officers with a bachelor's degree in agriculture. There were about 167 scientists and 307 technical officers working in NARC in 2009 (NARC, 2009). In 2003, 331 FTE researchers were working in NARC (STADS and SHRESTHA, 2006).

rice research per FTE researcher was estimated to be about US$5,930 at current price. This budget covered current operational research costs, salary, research support staff, and administrative and capital costs. Staff salary accounted for a large share of total costs (51%) although the amount allocated for a researcher's salary is very small by regional and international standards. The per scientist resource allocated for rice research in a neighboring developing country (India) was estimated to be $15,780 for eastern India and $21,110 for the rest of India in FY 2000 (PANDEY and PAL, 2007). This was much higher than the figure estimated for Nepal.

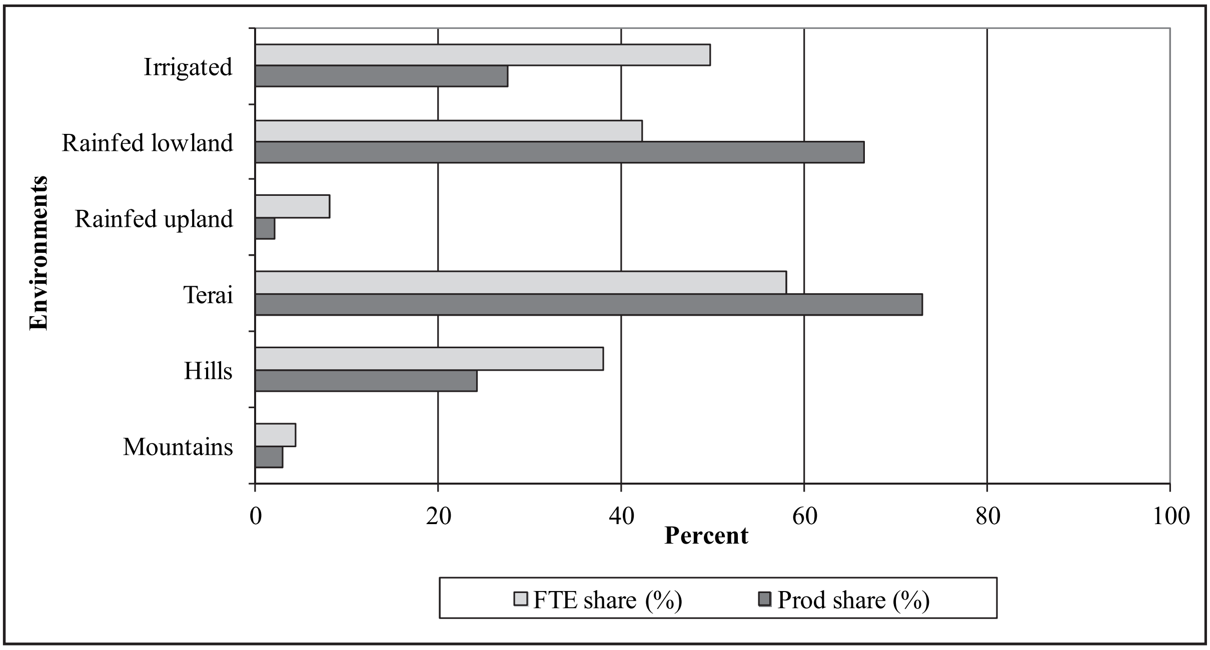
Table 5. Number of FTE researchers and expenditure per researcher

	Number of researchers involved in rice research	Percent allocation of time in rice research	Budget/ researcher (US$)
Full-time in rice research	10	100	–
Part-time in rice research	40	38.6	–
All	**50**	**49.6**	**5,932** (NRs 444,964)

Note: US$1=NRs 74.0
Source: own analysis

The current pattern of allocation of rice resources in terms of FTE indicates that the Terai region received fewer resources (58%) compared with its area and production share (73%) in the country (fig. 2). The Hill region received more resources (38%) than its share of production (24%). The Mountain region also received slightly higher resources in terms of production share but it was almost comparable in terms of area share at the national level. Among rice ecosystems, less research resources in terms of FTE were invested in the rainfed lowland than in the irrigated ecosystem. The rainfed lowland has about two-thirds of the production share (66%) but receives less than half (42%) of the resources. At present, the irrigated area has less than one-third of the area and production share but receives about half (50%) of the rice research resources. The rainfed upland is also slightly overinvested compared with its share in area and production. However, rice research resources are underinvested in rainfed lowland in terms of both FTE researchers and researchers per million hectares.

Figure 2. Share of rice production and FTE Resources



Source: own analysis

5.2 Results of Congruence Analysis

The results of congruence analysis across agroecological regions and rice ecosystems are presented in table 6. The aggregate resource allocation reported here is based on FTE of researchers employed by NARC which implements all public research (irrespective of whether the source of funding is national or international) in Nepal. Private rice research in Nepal is almost non-existent. Any additional funding from international agencies such as the International Rice Research Institute (IRRI) is channeled through NARC which responds to increased funding by allocating more resources, including staff time. Thus, the FTE estimate as used in this paper captures the total research effort, irrespective of the source of funding. Any targeted allocation of funding from international organization to a specific ecosystem/region is thus captured in the estimated FTEs.

5.2.1 Congruence for Agroecological Environments

A higher congruence value (95%) for the agroecological regions was obtained from the analysis of simple congruence rule. This indicates that FTE allocations in rice research among agroecological environments were pretty close to their respective actual (unadjusted) shares in the value of output produced (table 6). The analysis also showed that the Terai region was underinvested by 15 percentage points (it received

58% of its resources versus 73% of the production share). However, the Hill region received moderately higher resources (14% points) of the FTE allocation compared with its actual production share. The higher allocation of resources currently in the Hill region reflects the concentration of many disciplinary research programs and the bulk of the scientists in the Kathmandu valley (Hill region) and a very low number of full-time rice scientists working in the Terai region.

The congruence results are affected somewhat in the Terai and Hill regions by the use of a modifier for equity and potential for research progress. When the effects of equity weights and the weights assigned for research progress were combined, this improved the congruence value to 97% from the original FTE value of 95%. However, when only the effect of research progress was considered, the pattern of underinvestment in the Terai was amplified, resulting in a lower congruence value of 95% and 17 percentage point lower allocation of resources. The imbalance in research resource allocations to the Terai and Hills was reduced slightly when adjusted for equity. The investment pattern in rice research for the Mountains almost coincided with its value of total rice production. Clearly, the analyses based on adjusted weights indicate the need for a slight reallocation in favor of the Terai against the Hills.

Table 6. Production shares and allocation of rice research resources

Production environment	Production share (%)	FTE share (%)	Normative production share (%)		
			Adjusted for research progress & equity	Adjusted for research progress only	Adjusted for equity only
Ecological regions					
Terai	72.90	57.92	70.24	74.61	68.62
Hills	24.12	37.90	26.82	22.79	28.39
Mountains	3.00	4.28	2.94	2.60	3.39
Congruence (%)		*95.49*	*97.23*	*94.90*	*97.94*
Rice ecosystem					
Irrigated	27.57	49.72	19.71	26.32	20.64
Rainfed lowland	66.46	42.25	77.20	68.75	74.60
Rainfed upland	2.09	8.03	3.09	2.75	3.32
Congruence (%)		*88.86*	*78.53*	*87.17*	*80.82*

Source: results derived from congruence model

5.2.2 Congruence for Ecosystems

The current FTE allocation was quite high (50%) for the irrigated ecosystem and very low (42%) for the rainfed lowland in terms of their respective shares in the value of output produced (table 8). The congruence in resource allocations across major ecosystems was fairly high (89%) despite the current imbalance in resource allocations in the rainfed lowland. The analysis showed that the rainfed lowland ecosystem received 24 percentage points lower resources in terms of FTE shares than its actual (unadjusted) production share. The irrigated ecosystem received 22 percentage points more shares than the production share. The rainfed upland received slightly higher resources despite its smaller area and production share.

However, when the value of production was modified by the equity criterion alone or in combination with expected research progress using the normative congruence rule, the congruence value declined slightly. In both situations, the imbalance in resource allocations was amplified for the rainfed lowland and irrigated ecosystems. The rainfed lowland received 33-35 percentage points lower resources than justified by the normative production criteria. The use of research progress alone, using the normative congruence rule, also slightly increased the imbalances in the resource allocation pattern with a slightly lower congruence value (87%) and lower underinvestment pattern in the rainfed lowland.

One of the options to improve the congruence would be to reallocate some research resources from the irrigated to rainfed environment and from the Hills to the Terai. However, considering the very limited amount of resources currently allocated in both the irrigated ecosystem and the Hill region, it is not very meaningful to shift and reallocate resources from one to the other. Rather, it would be more desirable to increase the FTE and proportionate budget in the rainfed ecosystem and in the Terai region to correct the current imbalances. We also investigated the magnitude of the adjustment using "what if" scenario analyses. Doubling the number of researchers in the rainfed lowland ecosystem from the current 10 to 20 FTE (42% to 59% of the total) rice researchers will eliminate the existing incongruence. Similarly, an increase from the current 14 to 24 FTE (58% to 69%) in the Terai would reduce the imbalance. The additional cost of this strategy would be only US$60,000 at the current price. This is a small investment to correct the existing imbalance but it should be noted that the current level of investment per FTE is still very low at about $6000. This is clearly insufficient given the share of rice in GDP.

To examine the robustness of our key findings, we conducted sensitivity analyses with respect to key parameters such as the expected rate of yield growth and equity weights across production environments/regions. Although this led to some changes in the numerical results, the main conclusion that the overall investment in rice research is too low in Nepal and that the total investment in rice research in Terai, which is the main rice bowl of Nepal, is lower relative to other production environments remained unchanged.

6 Concluding Remarks

The resource allocations in rice research in this paper are approximated by the FTE of researcher time spent on rice research covering both ecosystems and agroecological production environments. The results indicate that there is substantial underinvestment in rice research (and agricultural research in general) in Nepal. In terms of regional and ecosystems-based allocation, rainfed areas in general have received a much lower share than irrigated areas. Similarly, the Mountain and Terai regions have received a lower priority than the Hills. The use of the modifiers slightly altered these results by dampening or amplifying the normative shares, but the overall conclusions remained unchanged.

Although the optimal allocation of research resources across production environments, commodities, and regions is important, it is even more important to raise the overall level of research funding to rice research, which has remained historically low and on a decline in recent years. The past and present trends in research expenditure pattern indicate that, historically, agricultural research in Nepal has received a low priority, in spite of its major role in generating new technology to enhance and sustain productivity growth in agriculture and reduce poverty. There is always the presumption among policymakers and planners that agricultural technologies can be easily borrowed from outside and transferred (YADAV, 1987). Even for borrowing and adapting technologies from the outside, the required minimum technical capacity is limited in Nepal. In addition, investments are needed to develop technologies suited to warmer and more frequent extreme weather situations expected as a result of global climate change. The National Rice Research Program (NRRP) currently has very limited resources and insufficient technical capacity to conduct and coordinate research activities and strengthen ties with national and international centers. Therefore, a substantial increase in investment in agricultural research, including rice research, is warranted.

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