PN-ABR-953
89221

NRMP-IEA Input-Output Working Paper No. 6

CASE STUDY OF THE RICE SECTOR

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Jakarta

February 1993

Preface

NRMP-IEA Technological Scenarios

The Natural Resources Management Project (NRMP) assisted by USAID in association with the Institute for Economic Analysis (IEA) at New York University is carrying out a modelling exercise to project the economic, employment and environmental consequences of different development paths for the Indonesian economy. The purpose is to provide advice to the Indonesian National Planning Agency (BAPPENAS) to assist in the development of the next five-year plan (Repelita VI) and the next Long-Term Development Plan. The first stage of this work has already been completed with the support of the Environmental Programming Support Services Project of CIDA.

The analysis, of which the present paper is a component, will provide advice on the trade-offs and complementarities between the growth of income and employment on the one hand, and the levels of natural resource depletion and degradation of the natural environment on the other. For instance, it is important for policy makers to know how the development of the pulp and cement industries over the next 20 years is likely to affect air and water pollution and how costly or cost-saving it will be to adopt cleaner technologies than are being used now.

The analytical framework includes a dynamic input-output model covering all economic activities. The model is dynamic in two senses. First, it incorporates a representation of investment in which levels of sectoral investment depend on expected growth of output, the technology in use and levels of capacity utilisation. Secondly, the model is dynamic in that it explicitly incorporates projections of changes in technology for a range of sectors in the economy, including agricultural sectors, forestry, energy sectors and key manufacturing sectors.

Technological scenarios are developed for each of these sectors using detailed information about likely technological and institutional changes obtained from technical experts. They include expected changes in intermediate inputs, notably energy and raw materials, capital stocks and human resources of different skill types as well as expected changes in natural resource usage and environmental degradation associated with current and alternative future technologies.

This paper is one of a series of working papers prepared by NRMP and IEA researchers in collaboration with industry experts. The papers will form a vital part of the data base for the numerical computations. In addition, they will be valuable as stand-alone analyses of technological futures for a range of important industries in Indonesia.

It should be noted, however, that some of these working papers (especially those on manufacturing sectors) were prepared under severe time limits and should not be taken to represent the last word on technological change in the industries in question.

I Introduction

This case study describes current and future technologies in the Indonesian irrigated rice production (paddy) sector (Sector 1 in the NRMP-IEA 30-sector classification system). Irrigated rice production, which accounted for 95% of total production in 1985 (the remainer coming from upland rice), is most affected by changes in production technology. This sector covers only the technolgy of cultivating and harvesting of rice (*padi* and *gabah*), and does not include the processing of rice to an edible form (*beras*). The study also makes estimations of natural resource demands (land and water) and of some impacts on the natural environment by rice production.

Most rice in Indonesia is grown in irrigated fields (*sawah*) on landholdings averaging 0.25 ha. Traditional, sustainable technology has been largely replaced since the introduction of new seed-fertiliser technology in the 1970s (the Green Revolution). The current technology depends on a changing range of fertiliser-responsive rice varieties, based on seed types developed by the International Rice Research Institute (IRRI). The new varieties' high yields (compared to some traditional yields) require carefully timed applications of nitrogen (urea) and phosphate (TSP) fertilisers, skillful pest control and more reliable and timely irrigation.

The great majority of farmers still rely on human and draft labour for land preparation, transplanting, crop maintenance (fertilising and weeding) and harvesting. Post-harvest operations of rice milling and polishing (not covered here) have been almost totally mechanised since the 1970s.

Mechanisation of field operations is limited to land preparation, for which some farmers hire hand-tractor services to reduce time required. Despite attempts by government to encourage use of hand tractors, including subsidised credit, their use is limited by steeply terraced terrain and small field size. Tractors are widely used only in regions with extensive areas of flat land (where plot sizes are generally larger) and availability of irrigation is tightly scheduled, requiring rapid land preparation.

In 1985 total national production of unmilled rice was 39 million tonnes, and approximately 94% of this total was grown on lowland ricefields (irrigated and rainfed) with an average yield of 4.2 tonnes/ha (t/ha). By 1990, total production had risen to 45 million tonnes, 93% of which was grown on lowland ricefields, with an average yield of 4.6 t/ha. Production on irrigated lowland ricefields, about 80% of total production, achieved markedly higher yields, in the range 4.5-5.5 t/ha in 1985 and 4.8-5.8 t/ha in 1990 (BPS 1991a), with the highest yields achieved on-Java. During this period, the number of crops per year (cropping intensity) on-Java increased from 1.44 to 1.48 (0.54% p.a.), while off-Java there was a slight decline in intensity. The result being that the area of lowland rice harvested grew from 8.8 in 1985 to to 9.4 million ha in 1990 (1.36% p.a.).

Studies by the World Bank (1992), Winrock International (WI) (1992) and the Centre for World Food Studies (SOW) (1991), all anticipate gradual increases in both land and labour productivity in this sector in the years to 2000 and 2010. Discussions with local experts confirm this general trend, with Indonesia remaining self-sufficient in rice production on average (trend self-sufficiency), given expected increases in population and very slowly increasing average per capita consumption of rice.

Indonesia increasingly faces constraints on the area of land available for agriculture, while new agricultural land is being developed off-Java, existing land, particularly irrigated ricefields, is being lost to urbanisation and industrialisation, especially on-Java. In 1985 some 7.5 million ha were used for lowland (irrigated and rainfed) rice production, by 1990 the area has increased to about 8.2 million ha. According to recent estimates, approximately 0.96 million ha of additional land off-Java is potentially suitable for rice cultivation (RePPProT 1990). By 2020 it is estimated that some 1.1 million ha of lowland ricefields, mainly on Java, will have been converted to other uses (SOW 1991). If the potentailly suitable land is developed in the future, the area of land still available for lowland ricefields in the year 2020 will be about the same as in 1990 - 8.2 million ha. This means growth in production will have to come almost entirely from increases in yields and/or cropping intensity.

The Base Scenario (S1), with growth in yield averaging 0.85% p.a. (from 4.2 t/ha in 1985 to 5.7 t/ha in 2020), resulting in production from lowland ricefields (irrigated and rainfed) of about 62 million tonnes, would be sufficient to meet anticipated demand of 154 kg/capita/annum for a year 2020 population of 273 million (WI 1991), before taking into account upland rainfed rice production. The World Bank (ibid) study, extended to 2020, anticipates faster growth in yields (1.23% p.a.) over 1988-2020, resulting in a average yield for lowland (irrigated and rainfed) rice of about 6.9 t/ha by 2020 and production of about 64 million tonnes.[1] Yields for lowland irrigated rice alone would be higher (about 7.5 t/ha), but grow less rapidly (1.16% p.a.).

According to the above studies (and this author), the increase in average yields (to either 5.7, 6.9 or 7.5 t/ha) could be achieved by increasing yields by more efficient crop management and use of fertiliser and water, rather than by greater use of these inputs per unit area.

The High Technolgy Scenario (S2), which anticipates yields on lowland irrigated ricefields increasing to a national average of about 9.4 t/ha by the year 2020, would allow the same total production from irrigated ricefields (55 million tonnes) to be achieved using less land; it uses

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1 The World Bank study was extended by 10 years to 2020, rates of change in crop production factors used for the 2010-20 period mirrored those in the World Bank study.

the World Bank (ibid) study as a starting point.[2] This scenario envisages more rapid growth in yields after the year 2000, resulting in substantial increases in both land and labour productivity for irrigated rice by 2020.

Given the yield increases required in this scenario (about 2.5% p.a. over 2000-20), it makes sense to focus efforts on areas where past investments in infrastructure (irrigation, roads, markets, etc.) have been greatest. What is unknowable at present is the levels of seed, fertiliser and water inputs, and improved farmings skills, necessary to achieve and maintain these yields.

Table 1:
Sector 1 - Paddy Production 1985: Value and Proportion of Intermediate Inputs.

SECTOR NAME	#	M Rp	%
Fertilizer & pesticide	45	491,616	63.5%
Paddy	1	130,153	16.8%
Financial intermediaries	70	58,877	7.6%
Retail & Wholesale trade	62	41,268	5.3%
Livestock products	18	10,672	1.4%
Road transport	65	9,798	1.3%
Fabricated metal products	54	8,871	1.1%
Construction	61	5,741	0.7%
Other crops	17	4,176	0.5%
Other services	74	4,012	0.5%
Textile, leather & apparel	37	2,207	0.3%
Rubber & plastic wares	49	2,088	0.3%
Water transport	66	2,508	0.3%
Services allied to transport	68	1,760	0.2%
Wood	21	388	0.1%
Machines & electrical machine	55	380	0.0%
Railway transport	64	101	0.0%
Air transport	67	204	0.0%
Petroleum refinery	47	284	0.0%
Total Intermediate Inputs	190	774,762	100.0%

Source: BPS 1989.

II Intermediate Inputs to Production

All intermediate inputs to production from the 1985 I-O table are listed in Table 1. These inputs are dominated by fertiliser and pesticide, with paddy (for seed), financial intermediaries, and trade having less significance; all other intermediate inputs each account for 1.4% or less of total intermediate inputs.

2 Production in 2020 from lowland rainfed and upland rainfed ricefields is projected by the (extended) World Bank study to be 13 million tonnes (7.5 and 5.5 million respectively) from 4.4 million ha, with yields of 4.5 and 2.7 t/ha. To achieve national total production of 65-70 million tonnes in 2020, some 52-57 million tonnes would need to come from lowland irrigated production.

III Changes in Technological Coefficients to 2020

Two scenarios are described for the year 2020. First, a Base Scenario (S1) with a continuation of current trends in improvements in use of inputs to production and slowly rising yields; no substantial increase in mechanisation is anticipated. Second, a High Technology Scenario (S2) examines the potential for increasing labour and land productivity by exploiting the yield potential of new rice varieties which, according to IRRI, should be available by about the year 2000.

Base Scenario - Continuation of Current Trends

With a continuation in current trends, improvements in yield will result in a 35% increase by 2020. Estimated changes in technological coefficients for intermediate inputs, labour, land and environmental impacts are discussed below and summarised in Table 2. (See Annex 2 for details.)

The increase in yields results from incremental improvements in use of inputs (e.g. fertiliser and water) and results in a general decline in inputs required per unit of production. The increase in yields is wholly responsible for increases in land and labour productivity.

Fertiliser and pesticide: More efficient use of fertiliser (better placement and slow release formulations) and the growing adoption of integrated pest management (IPM) result in a decline in the amounts need per unit of production.

It is estimated that per unit production requirements for fertiliser will decline by some 13% by 2020 and pesticide use by 195% per tonne of production. Incremental price increases for fertiliser, caused by a progressive removal of subsidies, are already encouraging a more efficient use of fertiliser (BPS 1991b), the compete elimination of subsidies on pesticides since 1986 is having a similar effect, and is being further stimulated by a national integtrated pest management programme.

Paddy: Increases in yields will reduce the amount of seed paddy required to produce a tonne of rice at about the same rate as yields increase. This implies a decline in (seed) paddy requirements per unit production of some 26%.

Financial intermediaries: It is forecast that increasing requirements for crop credit, given that the major cash outlay for fertilisers will no longer be subsidised, will reduce per unit requirements for production credit more slowly than yield increases.

It is estimated that per unit requirements will decline by about 15% to the year 2020.

Table 2:
Base Scenario - Summary of Changes in Technological Coefficients by 2020 -Inputs per tonne of Rice (Paddy).

Input	Sector	1985	Change
Fertilizer & pesticide	45		-13%
Urea (kg)		43.725	
Other fertilisers (kg)		18.376	
Pesticides (kg)		0.611	-195%
Paddy	1		-26%
Seed (kg)		9.366	
Financial intermediaries	70		-15%
Retail & Wholesale trade	62		0%
Labour			-26%
Human labour (person-years)		0.0885	
(person-days)		26.542	
Draft Labour (cattle-days)		0.149	
Tractors (machine-days)		0.007	
Water			-28%
Irrigation (cubic metre)		2,367	
Land			-26%
Ricefield (ha)		0.2367	
Methane			-26%
gas generated (kg/t)	41.983-83.966		
1985 Unit price (Rp/t)		182,941	

Notes: Data for this table for 1985 is drawn from Annex 1, which presents details on the estimation of technological coefficents for the rice (paddy) sector.

Retail and wholesale trade: Given the increasing complexity of agricultural input supply and food distribution - due in part to greater urbanisation - it is anticipated that it will require more resources to supply inputs to (and distribute and market) rice production than in 1985. This may be balanced by improvements in transport (fuel) efficiency. On balance, no change is anticipated.

Labour Requirements

Labour productivity in rice production is closely related to yields. Assuming that current crop cultivation practices continue to improve, per tonne labour requirements will fall at the same rate, some 26% by 2020.

Natural Resource Inputs.

Other than land, the main natural resource required for rice production is irrigation water.

Water requirements: Increases in unit area yields and cropping intensity will tend to reduce unit production irrigation requirements at the same rate. Improvements in irrigation delivery efficiency from the current level of about 25 per cent (World Bank 1992) would decrease the volume of water needed per crop even further. However, to some extent the efficiency gains in existing systems are likely to be balanced by declining efficiencies, caused by greater infiltration rates and leakages, as irrigation is extended to new areas. Overall, it is estimated that irrigation delivery efficieny will double to 50 per cent by 2020. In conjunction with yield and cropping intensity increases, this implies a reduction in water use per tonne of production of 53 per cent..

Land requirements: Land requirements are totally dependent on crop yields and cropping intensity. Increases in yields and cropping intensity will reduce per unit production land requirements by some 35 per cent by the year 2020.

Environmental Impacts

Soil erosion: Soil erosion is not considered to be an issue for irrigated rice production, given a continuation of current technological trends (Euroconsult 1989). However, intense, short-term will occur during the establishment of new ricefields, we are currently unable to quantify this impact.

Methane generation: Methane, a greenhouse gas, is generated by the anaerobic decomposition of organic matter in flooded rice fields. The amount produced is closely linked to the area of land flooded by irrigation and rice yields. It is estimated that cropping intensity will increase by about 14% by 2020, hence there will be a relative decline in the total area of irrigated (flooded) land used per unit of output per annum. Increases in yield will lead to an decline in methane generated per unit of production of about 26% by 2020.

High-Technology Scenario

Under the above scenario, agriculture in Indonesia will continue to absorb a very large share of the workforce, perhaps as high as 40% in the year 2020. A large decline in the share of agriculture in total employment will require a large improvement in labour productivity, in the order of 100%. The means by which this might be achieved in rice production are discussed next.

One of the main aims of the Indonesian government's agricultural policies is to improve farm incomes (WI 1991). However, recent studies by WI (ibid) and SOW (1991) both suggest that given present trends it is likely that farm incomes in the next 20 years will fall relative to non-farm, particularly urban, income levels. One approach to improving farm income is by significantly increasing labour productivity, particularly for rice production. A goal of doubling labour productivity by 2020 in the rice sector will require rapidly increasing yields

after the year 2000 (land-saving) and may require greater mechanisation (labour-saving) of production.

A World Bank (1992) study anticipates yields for irrigated lowland rice on-Java increasing from 4.8 t/ha to 7.00 t/ha and 6.20 t/ha off-Java by 2010, wholly through improved management in the use of the current range of inputs. Continuing these rates of increase (1.2% and 1.3% p.a. respectively) to 2020 by the same methods, would result in a average yields of about 7.5 t/ha for lowland irrigated rice. Assuming human labour inputs per hectare remain constant, this would result in labour productivity increasing by 45% well below what would be required to double labour productivity from yield increases alone. This represents a 31% decline in labour requirements per unit output between 1985 and 2020.

Rising per capita income in the coming decades, will lead to changes in diet resulting in growing demand for vegetables, fruit and meat, these products will require additional land area for production (World Bank 1992). Land requirements for urban and industrial uses continues to increase nationwide, mainly on-Java, and the annual loss of agricultural land (commonly irrigated) is expected to total one million ha over 1990-2010 (SOW 1991). To balance the loss of agricultural land two courses are open: opening up of new areas, or intensification of production on the remaining land. This choice is particularly relevant for rice production, where the cost of developing new irrigated land is very high (estimated as US$ 2,500-3,000 per ha by v.d. Zande (1989) and US$ 5,000 per ha by Alirahman et al (1992)).

Thus, a land-minimising scenario for rice production was devised. This scenario foresees a steady decline in the area of lowland irrigated ricefields on-Java of 2.5% p.a. and no increase in irrigated area off-Java. To maintain and increase production, the loss of irrigated land is balanced by an equally rapid increase in yields of irrigated rice on- and off-Java. In the scenario, over 2000-2020, the area of irrigated ricefields on-Java declines by about 1.1 million ha and the area off-Java remains stable. In addition, this scenario eliminates the need for a rapid increase in cropping intensity on-Java, thus minimising demand on scarce water resources and reducing the level competition for water between agriculture and other uses.

Based on the population projections by BPS to the year 2010 (World Bank 1992) and extended to 2020, a population of 273 million is estimated. Assuming a slow growth in per capita rice demand to about 170 kg/annum of milled rice and a population of 273 million in 2020, total rice production from all areas would need to be about 68 million tonnes (unmilled). Based on the (extended) World Bank projections, 7.5 million tonnes of this total would come from rainfed lowland ricefields and 5.5 million tonnes from rainfed upland areas - leaving some 55 million tonnes to be produced on lowland irrigated ricefields. (See Annex 3 for details.)

If yields for irrigated lowland rice production in the period 2000-20 increase by 2.5% p.a. (a very high growth rate to sustain over 20 years), resulting in an average yield in 2020 of about

9.4 t/ha (10.2 t/ha on-Java and 8.9 t/ha off-Java), this results in labour productivity almost being doubled. Land productivity increases by 82% and cropping intensity by 24%, reducing land required per annum per tonne of production by 56%. And, assuming labour inputs per hectare remain constant, labour productivity increases by the same amount: 82% - close to the doubling target. The increases in yields of irrigated rice, on which this scenario depends, are the goal of the current research programme at IRRI.

IRRI's research programme aims to: increase yields by 20-30% by developing hybrid rice not requiring additional inputs (next 10 years); reduce the number of tillers (stems) from 20-15 to 4-5 productive ones with larger seed-bearing panicles (10-15 years); markedly improve inbred disease and pest resistance; and improve crop management practices, including fertiliser applications (deep placement, slow release) and use of fertility maintaining crop rotations (World Bank 1992). The long-term goal is to achieve a yield of 15 t/ha.

No information is currently available about the actual level of fertiliser inputs needed to achieve yields of 10 t/ha. According to IRRI World Bank 1992), use of hybrid seed should provide a yield increases of 20-30% over 1990 levels without additional fertiliser inputs per hectare. However, it is clear increases in fertiliser use per hectare and use efficiency will be essential, plus increases in other soil fertility maintaining supplements.

Halving human labour inputs per hectare by mechanisation of field operations (land preparation, planting, weeding and/or harvesting), could also double (direct) human labour productivity. However, given limited success of previous efforts to widely mechanise land preparation, it is hard to envisage how this might be achieved. Mechanisation of weeding and harvesting presents both technical problems (getting the equipment into steeply terraced fields, and for weeding ensuring that weeds not rice plants are removed) and social barriers, high-paying (in cash or kind) manual harvesting and threshing is still an important method of income redistribution in many areas.

During 1985 some 16,000 two-wheeled tractors were nominally available for land preparation (BPS 1986c). With a per tractor capacity of approximately 29.4 ha per season and three crops cultivated per annum, this results in a maximum estimate of 1.4 million ha of land prepared by tractors, leaving some 7.4 million ha (or about 84%) requiring draft cattle. This means mechanised land preparation played a minor role nationally, despite its importance in some areas where cropping intensity was much higher than average, e.g. the coastal plains of Java.

Assuming an improvement in machine capacity to 40 ha per season by 2020 and three cropping seasons per annum, each additional million hectares of cultivation would require approximately 8,300 tractors. Large sums of capital would be needed to provide equipment for mechanisation, and large amounts of energy (fossil fuels) would be needed to operate it. In addition, an expanded pool of skilled labour would be needed for operating and maintaining

equipment. Farmers would need to mobilise (e.g. borrow) much larger amounts of fixed and working capital to pay for machinery and crop inputs, the consequences of crop failures would be more severe than at present (or in the Base Scenario) for farm families.

Summarising the impacts of the High Technology Scenario: labour requirements will decline by about 45% per unit of output, but skilled labour requirements will probably double. Fertiliser requirements will decline, but by less than the increase in yield; a decline of 25% per unit of production may be feasible. Per unit output generation of methane will decline in line with yield and cropping intensity increases (about 56%). Water consumption per unit of output will decline by about 73%. The intense, short-term soil erosion caused by establishing new irrigated areas will be almost completely eliminated.

The problems associated with a mechanical, as opposed to biological (yield increasing), approach to increasing labour productivity, favour the latter. In addition, the biological approach goes a long way towards developing an active, as opposed to reactive, response to the loss of irrigated land to other non-agricultural uses and increasing land area available for meeting rapidly increasing demand for vegetables, fruit and meat.

Summary of Technological Coefficients for 1985 and 2020

The Technological Coefficients for this sector for 1985 and 2020 (S1 and S2 scenarios), based on the foregoing assumptions and estimations, are presented below in Table 3.

Table 3:
Technological Coefficients for Sector 1 - 1985 and 2020.
Paddy (column).

				S1	S2
A MATRIX					
1	Paddy			-26	-45
14	Fertiliser & pesticides			-13	-25
L MATRIX					
Total employment per unit output				-26	-45
B MATRIX					
Total new capital requirements				0	0
UNIT PRICE 1985		Rp/tonne			182,941
N MATRIX					
Water input/output		l/t	2,367,000	-63	-73
Methane		kg/t	60	-35	-56
Land area		ha/t	.2367	-35	-56

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Annex 1

Estimation Procedures and Results for Rice Production Technological Coefficients

Introduction

This annex presents the detailed results of an investigation of the production processes involved in irrigated rice cultivation (*padi sawah*). It focuses on production in 1985 and 1989, with the aim of estimating technological production coefficients for 1985 and developing the Base and High Technology Scenarios for year 2020.

The first part of this annex presents and discusses data for 1985 and 1989. First, there is a discussion of the available data sources on human labour inputs to rice cultivation, this is followed by an evaluation of the natural resources (land and water) essential for rice cultivation. We then turn to estimating use of manufactured inputs (seed, fertilisers and pesticides) in contemporary production. This is followed by a section on the capital goods required for production (cattle and tractors, and agricultural machinery, buildings and irrigation infrastructure). The next section discusses the environmental impacts of rice cultivation, specifically those regarding soil erosion and gaseous discharges. The summary section provides an overview of the results obtained, and compares these with the relevant vector from BPS's 1985 I-O table for the Indonesian economy.

The aim of this annex is to provide information on the major inputs to irrigated rice cultivation in Indonesia in 1985. The major intermediate inputs to cultivation are: human labour, seed, draft labour (cattle and buffalo) and irrigation infrastructure; the main natural resources are water and soil fertility. The main potential or actual impact on the natural environment are water pollution from run-off of excess fertilisers, and the destruction of non-target species by pesticides. The analysis relies upon data from Indonesian government sources, some of which is unpublished.

It should be noted that non-irrigated rice production is not included in this discussion or calculations. The main reason for this is that the production conditions for dryland rice (*padi ladang)* are radically different from those for irrigated rice.

Data Sources

Two main sources of data have been used to compute technological coefficients for rice production in Indonesia. The first is an analysis of survey sample data (unpublished) from the main rice growing areas of Indonesia - Sumatera, Java, Bali and Nusa Tenggara, and Sulawesi - on production inputs and output from 6275 farmers, collected by BPS/BAPPENAS in 1989.

The second source of data, for 1985 production inputs, is from an analysis of similar data

collected annually by BPS/Pertanian and published in *Struktur Ongkos Usaha Tani Padi dan Palawija*. Information from this source has been used to check and compare physical data on non-labour production inputs for 1985. This source provides no information on the physical labour inputs (human or draft) to rice production, but only information on the costs of labour inputs to production.

For the purposes of this exercise it is assumed that there were no changes in human and draft labour inputs per unit land area for production between 1985 and 1989; this was confirmed by a comparison of the costs of labour inputs per hectare between these two years. Despite the lack of change in per unit area inputs of labour between 1985 and 1989, increases in production per hectare mean that the amount of labour per unit of output fell between these two dates. There were notable changes in the per unit area physical inputs to production (seed, fertiliser and pesticide) and changes in unit area outputs (yield) between these two years. Overall, increases in yield between 1985 and 1989 raised the productivity of all inputs to rice cultivation.

The number of decimals to the right of the decimal place in the data and tables that follow should not be interpreted as merely spurious accuracy (which it may well be!) but as an attempt to provide sufficient detail so that quantities that may later be accounted for in units of person-years per tonne of output, for instance, will not revert to zero for lack of significant digits. The user of this data should be aware that these are *approximations* only, and that obtaining better data will require collection of additional information by primary, interview field work for crops of major significance.

Notes on the Data

Table A1 presents data on inputs per unit output of unmilled rice based on the BPS/BAPPENAS 1989 data set, Table 2 presents these figures adjusted to account for changes in yields between 1985 and 1989, using 1985 data on inputs of seed, fertiliser and pesticide, this adjustment and data is based on *Strukture Ongkos Usaha Petani*.

Table A1.
Rice Production Input-Output Data 1989.
Summary of BPS/BAPPENAS National Sample Survey (means).

	AREA ha	LAND ha/t	SEED kg/t	UREA kg/t	OFERT kg/t	PEST kg/t	LAB day/t
ACEH	0.38	0.2231	13.039	27.009	12.211	0.468	30.538
NTH SUMATERA	0.41	0.2028	19.313	28.587	28.252	0.672	[illegible].536
STH SUMATERA	0.62	0.2671	13.857	20.252	15.519	0.299	35.734
LAMPUNG	0.48	0.2382	11.708	40.296	44.582	0.603	26.278
SUMATERA	**0.46**	**0.2238**	**15.562**	**27.726**	**23.126**	**0.528**	**31.567**
CENTRAL JAVA	0.32	0.2002	12.619	54.679	33.027	0.929	20.361
EAST JAVA	0.34	0.1926	16.987	63.909	28.763	0.969	17.316
YOGYAJAKARTA	0.13	0.1898	8.594	55.307	24.992	0.775	31.798
JAVA	**0.32**	**0.1961**	**14.417**	**58.232**	**30.677**	**0.940**	**19.537**
BALI	0.38	0.1764	7.041	43.903	16.292	0.493	21.516
NTB	0.48	0.2601	14.984	66.849	22.568	0.333	16.570
NTT	0.34	0.2544	13.612	20.400	13.428	0.471	32.023
BALI & NT	**0.42**	**0.2147**	**11.329**	**51.314**	**18.737**	**0.419**	**20.556**
NTH SULAWESI	0.41	0.2097	10.185	31.937	17.546	0.364	16.885
STHC. SULAWESI	0.85	0.2866	12.849	15.124	22.833	0.977	21.546
STH SULAWESI	0.60	0.2218	14.093	31.776	19.941	0.539	25.378
SULAWESI	**0.57**	**0.2215**	**13.161**	**30.980**	**19.553**	**0.522**	**23.297**
INDONESIA	**0.40**	**0.2082**	**14.214**	**45.974**	**25.857**	**0.717**	**23.343**

Notes: AREA = Average size of farm, t = tonnes metric, LAND = rice production, SEED = rice seed, UREA = urea fertiliser, OFERT = other fertilisers, mainly TSP and DAP, PEST = insecticides and other pesticides, and LAB = human labour inputs - all inputs are based on output of one tonne of unmilled rice. What is not apparent from this summary table is the wide variation for each of these variables within each province.
Sources: BPS/BAPPENAS 1989 survey data.

BPS/BAPPENAS Data Set

Prior to computing the statistics some basic cleaning-up of the data set was undertaken. Given limited access to the original data set and limited time it was decided to eliminate cases with the following characteristics:

1. All cases where the computed number of days of labour for producing one tonne of unhusked rice (*gabah*) exceeded 100 days;
2. All cases where there was no information on human labour inputs to the production process;
3. All cases where there were no data on human labour inputs for harvesting; and
4. All cases where the total inputs of human labour per hectare exceeded 400 days.

This resulted in approximately 500 cases being eliminated, leaving some 6,000-plus cases.

With regard to the last item above, this still left a considerable number of cases in which (nominal, calculated) human labour inputs exceeded 300 days per hectare, and even more cases in the 200-300 labour days per hectare range. In comparison to some other data on human labour inputs to rice cultivation (including research by this author) these do not seem excessive, but are substantially higher than those accepted by BPS and IRRI (see below). All this means is that the mean figure used may be too high, when compared to various other studies of labour inputs to rice production by BPS and IRRI (see below), but too low when compared to other studies (e.g. PU 1978, Foley 1987). However, given the large number of cases falling into these two ranges (approximately 500 and 1000 overall, respectively) it was decided to include them in the interests of general coverage and maintaining sample size for the smaller provinces (i.e. NTT and south central Sulawesi).

Note should also be taken of the fact that farmers rarely accurately know the area of land that they farm, and the survey method used did not include measuring the land of sample farmers. While errors of 0.02 ha, for instance, will not substantially affect calculations of unit area inputs and outputs for larger farmers (over 0.5 ha, say), they can have a substantial affect on these variables for small farmers (0.1 to 0.2 ha) who make up the majority of the sample.

Struktur Ongkos Usaha Petani

No information is available on the sample sizes for the data from this source. The sampling frame and questionnaire used is identical to that used for the BPS/BAPPENAS data - thus the categories are directly comparable. This data source makes no allowance for either the duration or imputed wages of family labour used in production - reliance is placed on the BPS/BAPPENAS data for this information.

In Table A1 physical inputs presented in terms of quantities necessary to produce one tonne (t) of unmilled rice (*gabah*), except for production AREA, which is the average area farmed by a sample farmer. To modify these quantities to estimate the inputs necessary to produce one tonne of edible, milled rice (*beras*), requires multiplying each input by 1.471 (this assumes a *gabah* to *beras* (milling) factor of 0.68). Identical comments are applicable to Table A2.

In terms of the variables there is a broad similarity within each island-grouping, but with Sumatera generally standing out as having a higher level of inputs per unit output than other islands. The analysis shows that without exception the median for all variables for all provinces and island-groupings is well below the calculated mean. This is a clear indication that the distribution is skewed to the right, and that the mean probably over-estimates actual levels of input; this problem was raised above when discussing the BPS/BAPPENAS data set. However, across all the inputs to production, both physical and labour, it is appears acceptable to use the Indonesia-wide factors as a first approximation - if only because the variation for each input to production within each province is wide enough to encompass the mean of any

other province or island-wide grouping.

The data on physical and human labour inputs has been compared with data from other sources on inputs to rice production. With regard to the data on human labour inputs for rice cultivation of 326 days/ha (PU 1978) it is apparent that this figure (Table A6, below) is well above that given by a number of contemporary sources (e.g. Flinn and Duff 1985) which place human labour inputs to rice cultivation in the 80-120 days/ha range and draft labour inputs in the 30-40 days/ha range. In contrast to this there are historical and contemporary sources that estimate human labour inputs to rice cultivation in the range 250-300 days/ha - including results based on fieldwork undertaken by this author. For the sake of consistency and despite this wide discrepancy, it has been decided to continue with the data compiled by BPS in *Struktur Ongkos...* as presented in Table A2.

The implication of these differences is that if a figure of about 100 days/ha is accepted and a crop length of about 100 days, then each hectare of irrigated ricefield provides 'full-time' employment for one farmer only. If the higher figure is accepted, then each hectare provides employment for 2.5-3 farmers. The latter figure on labour inputs, of course, means that labour productivity in rice cultivation is much lower than if a figure of about 100 days/ha is accepted.

It should be borne in mind that the data and calculations presented here are for irrigated rice cultivation, and specifically exclude upland (*ladang*), non-irrigated rice cultivation. Nationally, in 1985 upland rice accounted for approximately 11.6% of cropped area but only about 5.1% of nationally production; at a national level yields of dryland rice are about 42% (1.172 t/ha) of irrigated yields. As a result of these differences, mixing data on inputs and outputs for both production systems would, in general, result in an underestimation of labour productivity in irrigated rice and a marked overestimation of the productivity of fertiliser inputs to irrigated rice.

The data in Table A2 are the intermediate input coefficients for the 'A' (intermediate inputs) and 'L' (labour) matrices. In the 30-sector matrix, rice seed is from sector 1 (paddy), and urea, other fertiliser and pesticide from sector 15 (fertiliser). In the 75-sector matrix, rice seed is still from sector 1, but fertilisers and pesticides come from sector 45 (manufacture of fertilisers and pesticides).

Total national rice production (unmilled) in 1985 was 39 million tonnes, of which 37 million tonnes was from irrigated rice fields (*sawah*); approximately two thirds was grown on Java.

Table A2:
Adjusted Rice Production Input Data 1985.

	LAND ha/t	SEED kg/t	UREA kg/t	OFERT kg/t	PEST kg/t	LAB day/t
SUMATERA	0.2746	10.417	26.809	19.528	0.481	38.734
JAVA	0.2115	8.602	52.134	20.321	0.677	21.068
BALI & NT	0.2466	10.545	44.957	10.153	0.451	23.607
SULAWESI	0.2567	10.185	31.078	10.454	0.529	27.006
KALIMANTAN	0.3973	12.964	15.193	10.497	0.505	-
INDONESIA	0.2367	9.366	43.725	18.376	0.611	26.542

Notes: LAND = area of irrigated land (sawah), SEED = rice seed, UREA = urea fertiliser, OFERT = other fertilisers (mainly TSP and DAP), PEST = insecticides and other pesticides, and LAB = human labour inputs . All inputs are calculated on the base of a farmer producing one tonne of unmilled rice.
Source: Table A1 and BPS 1988a.

Natural Resource Inputs/Impacts of Rice Production

In preparing the Base Scenario for the natural resource requirements and impacts of the Indonesian economy for the year 2020, the role of agriculture looms large. Not only is agriculture the most extensive of all sectors of the economy (except forestry) but its productivity depends vitally on the quality of the land that is available for cultivation and, given the importance of rice in the Indonesian diet, adequate water for irrigation. Not all of the natural resource impacts of rice cultivation are benign to the environment, and competition with urban areas and industry for water is already a major issue. Agriculture - of which rice cultivation is a major part - provides employment for about half of the total workforce, thus any major decline in the natural fertility of the soil or disruptions to water supplies will have serious, negative implications for the economic productivity of this sector and the welfare of the millions of farm families who depend on agriculture for a significant part of their livelihoods.

To maintain per capita food supplies with an increasing population, requires that both the intensity and extent of cultivation increases during the next 30 years. In general, this will mean greater strains being placed on the regenerative capacity of natural systems, soil and water in particular. In developing a scenario for (rice) agriculture with a 35-year time horizon it is important to identify and, where possible, quantify human-initiated activities which help or hinder maintaining the health of natural systems, and to identify their links with other parts of the national economy.

There is little quantitative data available on the natural resource requirements of irrigated rice cultivation, with the exception of estimates we have made of the area of land required to grow a tonne of rice. The other major input to irrigated rice cultivation is water. In 1985, some 7.5 million ha of irrigated land is used to grow rice, and an additional 1.15 million ha are used

to grow rice under rainfed conditions.

The generally neutral environmental impacts of traditional systems of rice cultivation is testified to by the longevity of systems of irrigated rice cultivation throughout the tropics which have persisted for over a thousand years in many locations. Traditional systems depended entirely on the inherent fertility of the soil, plant nutrients carried in irrigation water, human and draft labour, and the sun. However, with increasing population and the development of new seed-fertiliser technologies (the *Green Revolution*) there have been radical changes in rice cultivation during the last 25 years; due to lack of data, this discussion excludes consideration of increasing cropping intensity, except to note the rising trend of competition for water. Primary among these, in terms of potential environmental impacts, is the widespread application of manufactured fertilisers (especially urea and TSP) used to apply concentrated doses of major plant nutrients: nitrogen (47% nitrogen by weight) and phosphorus (22% phosphorus by weight). In addition, highly toxic manufactured pesticides are widely (and indiscriminately) used to 'control' insects.

Water - Irrigation

The generally accepted rule-of-thumb for irrigation requirements is that a hectare of rice requires the equivalent of 1m deep of water per crop, over the length of the cropping season - in the case of rice this is some 100 days. This means that one hectare requires 10,000 cubic metres of water per crop. Using the estimate for rice production per hectare for 1985 (4.2 t/ha), results in a water requirement of 2,367 cubic metres per tonne of unmilled rice.

It should be noted that this is a very general figure that makes no allowance for local variations in soil type, insolation (resulting in evaporation) or rainfall patterns, which all affect the infiltration and evaporation (losses) and supplementation (gains). The lower bound of irrigation requirements in the Indonesian climate, based only on evaporation losses, would be about 7,000 cubic metres/ha (Euroconsult 1989). On the other hand, some recent unpublished research on irrigation requirements suggests that the effective requirement in Indonesian conditions may be as high as 18,000 cubic metres per hectare (Walker, pers.comm.).

For the purposes of this study, the figure of 2,367 cubic metres per tonne of unmilled rice be used as an approximation for national-level irrigation requirement for 1985. Increasing per hectare productivity will continue to reduce the unit output requirements of irrigation, although unit area requirements will remain constant.

Chemical Fertilisers and Pesticides

The environmental impact of widespread applications of nitrogenous and phosphorus fertilisers is difficult to quantify. The main environmental impact of interest - resulting from the run-off of nitrogen and phosphorus dissolved in irrigation water - is the addition of large quantities of

plant nutrients to watercourses. This can have two effects: first, stimulation of the growth of aquatic plants (mainly due to phosphorus) to the point where they may physically block water courses and the biological demands of the plants uses available dissolved oxygen to the point where other aquatic organisms (e.g. fish) cannot survive and reproduce; second, especially with nitrogen fertiliser run-off, raising levels of dissolved nitrates and nitrites to the point where they become harmful to humans and other animals drinking the water. On the positive side, the dissolved nutrients are carried away in the run-off water which irrigates downstream farms, thus supplementing available plant nutrients. No data is available on the level of these chemicals in watercourses draining irrigated rice farming areas.

Most of the pesticides currently used in Indonesia on rice are organophosphates or carbamates - both of which are highly toxic to humans and all other organisms depending on the transmission of nervous impulses to control functioning, e.g. all mammals, birds, insects and spiders, amphibians, reptiles and fish. It is generally accepted, but unquantified, that the widespread use of pesticides during the last 20 years has resulted in a marked decline in the population of other species that traditionally, coexisted in irrigated areas. Traditionally these species (frogs, mud fish, eels, land snails, shrimp, etc.) provided supplementary protein; these sources of high quality food had almost entirely disappeared by the early 1980s. Again, there is no quantitative data on the impact of pesticides on the general environment, humans or other species.

There are also other, less noticeable, effects resulting from the use of chemical fertilisers and pesticides. The long-term heavy, application of nitrogen fertilisers results in the acidification of the soil, which in turn more tightly binds other (minor) plant nutrients to soil particles and makes them less available to plants (Euroconsult 1989). Thus, while manufactured nitrogen fertiliser makes one major nutrient abundant, it can also result in a decline in the availability of a spectrum of other necessary plant (micro)nutrients. In addition, the application of nitrogen fertilisers also has an adverse effect on soil structure and quality, in general reducing crumb size and slowing the natural production of organic matter within the soil complex. Furthermore, the use of pesticides reduces, to an unknown degree, the variety and abundance of many small organisms (e.g. earth worms, ants) that play a role in maintaining soil fertility and creating new soil.

It is not even vaguely possible to quantify these effects on the long-term fertility and productivity of irrigated rice fields. It may be possible that the negative effects on rice production are minimal, in part because of the higher proportion of necessary (minor) nutrients available in irrigation water, and in part because the flooded soil in rice fields is *puddled* to a fairly uniform state and, as a result, has little structure in the first place.

Capital Goods Inputs to Rice Production

Within the input-output framework, the capital goods used in rice production are hand tools and cattle for draft labour, and hand tractors, where mechanical soil preparation is used. For physical infrastructure (buildings and irrigation systems) we have only national financial estimates of value, moreover this data lumps together the rice and non-rice food production. Other equipment used for the milling, transport and storage of rice are accounted for other sectors of the economy.

Draft Labour - Cattle and Tractors

There is no simple way of estimating the proportions of irrigated area ploughed by cattle or tractors, or what proportion is prepared by hand using only a hoe. A rough estimate of how much is prepared by tractors can be made by dividing the number of tractors available by the ploughing capacity per tractor, and then subtracting this area from the total area to be planted, the assumption being that the remainder of the area is ploughed by cattle. This approach fails to account for the area of land prepared by hoeing.

It should be noted that this approach assumes that a given area of irrigated land is cropped only twice a year with rice, i.e. that there are only two land preparation periods each calendar year. However, in areas where irrigation is available, 2.5 and sometimes 3 crops are planted and harvested each year.

A generally accepted figure for the work capacity of draft cattle is that one pair is capable of ploughing approximately 0.04 ha per hour, or 0.2 ha per workday (5 hours), or 0.1 ha per head per day. This is approximately 1.5 hectares per head total during the 2 weeks available for soil preparation. (This estimate is in good agreement with the 1989 BAPPENAS/BPS survey data, used previously to estimate human labour inputs to rice cultivation, which gives an average of 10 days per hectare.) This results in an estimate of 0.667 head of cattle per hectare per crop, and 0.158 head of cattle per tonne of rice production for 1985. As cattle were used to prepare approximately 94% of all irrigated land (see below), the input requirement for draft labour was approximately 0.149 cattle per tonne of unmilled rice.

Two-wheeled tractors are estimated to be twice as rapid as cattle in land preparation, moreover for contractual work (the normal method) they are usually used for a full (8 hour) day. This results in a 'raw' capacity of 0.4 ha per hour or 3.2 ha per day; over a two week land preparation period this gives a capacity of 29.4 ha per season. However, time lost for maintenance and breakdowns is significant, and usually reduces effective capacity to two thirds of the maximum or about 2.1 ha per day. Thus, one hectare requires approximately 0.476 two-wheeled tractors for cultivation, and producing one tonne of rice requires 0.113 hand tractors.

A significant proportion of the agricultural land in Indonesia is cropped more than one a year, i.e. the cropping intensity is greater than one. In 1985 in Indonesia some 8.8 million ha of irrigated rice were harvested (this does not allow for area planted but not harvested due to crop damage or destruction) from a total irrigated area of 7.5 million ha; thus, overall cropping intensity was 1.167. During 1985 there were some 16,000 two-wheeled tractors nominally available for preparing irrigated land (BPS 1986c) With a per tractor capacity of approximately 29.4 ha per season and cropping intensity of 1.167 this results in a maximum estimate of 0.549 million ha of land prepared by hand tractors, leaving 8.206 million ha (or about 94%) requiring draft cattle.

In general, mechanised land preparation played only a minor role overall, despite its importance in some areas where cropping intensity was much higher than average, e.g. the coastal plains of Java. This translates into an average input of 6% of 0.113 tractors per tonne of production, or 0.007 tractors/t.

Agricultural Machinery, Buildings and Irrigation Infrastructure

Data is available from BPS estimating the rupiah value of capital stock employed in agriculture, but no data is available on the physical quantities of these items related to agricultural production. A central difficulty in making sectoral estimates is that this data from BPS lumps together all food crops (rice and non-rice) under one heading, whereas these are separate sectors in both the 30- and 75-sector I-O matrices. Moreover, for the irrigation infrastructure the fact that it is used for crops other then rice means that it would be difficult, even if physical data were available, to estimate specific technical coefficients on the basis of infrastructure contributions to production.

To use the Rupiah values of capital items several simplifying assumptions are made. First, that the irrigation infrastructure is used only in the production of irrigated rice - even though a proportion of secondary crops are grown on irrigated areas, and sometimes receive irrigation. Second, because no sub-sectoral breakdown is available, it is assumed that the proportion of the capital value of machinery and buildings assigned to each sector or sub-sector is directly proportional to the physical amount of output.

The rupiah value of capital stock from other sectors of the economy is presented below (Table A3). Given national food production of 68.2 million tonnes (37 million tonnes of unmilled rice and 31.1 million tonnes of non-rice food crops (see below)) in 1985, the per unit value of capital stock is estimated by dividing the contribution from each sector by this amount. The results of this estimation are presented in Table 3 below.

Agricultural public works (sector code 142) makes-up the great majority (86%) of capital used in food production. Within the combined rice and non-rice sectors it is probably the capital invested in irrigation infrastructure that accounts for the bulk of this capital, although we have

no means of apportioning the capital between irrigated rice and all other food crops.

Table A3:
Capital Stock Contributions to National Food Production in 1985.

Sector Name	Sector Code	Rupiah (billion)	Value/t output
Agric.tools	115/116	32.00	469
Motor vehicles	120	213.04	3,125
Car body	128	41.18	604
Motor cycle	129	5.28	78
Non-resid. buildings	141b	422.86	6,203
Agric. public works	142	4,448.75	65,261
Unspecified	169	6.35	68
Total		5,169.46	75,833

Source: Stok Kapital Menurut Jenis Barang 1985, BPS pers.comm.

Environmental Impacts of Rice Production

Soil Erosion

The dyked fields that make-up irrigated rice terraces act as settling ponds for suspended particles of all types, including soil. Thus rice fields serve to prevent the complete loss (to the ocean) of eroded soil from upstream dryland agriculture on sloping land, for instance. On the other hand, there are major soil losses during construction of irrigation facilities that require large-scale excavations and earth works for dams and irrigation channels. These are, however, one-off losses. In general, it is reasonable to accept that established irrigated rice cultivation has no negative impact on soil conservation and, generally, serves to slow down losses of nutrients contained in soil eroded for land upstream.

Gaseous Discharges

The flooded soils of irrigated rice fields produce methane gas, as a result of the anaerobic decomposition of organic matter. Methane has achieved recent notoriety as a *greenhouse* gas, contributing to the general warming of the earth's atmosphere. An expansion in irrigated area will lead to increased production of methane. Deriving a general figure (for methane production per tonne of rice) is complicated by a number of interacting factors - duration of flooding, organic content of the soil, temperature, soil type - in addition to accounting for differences in rice production per hectare. No detailed information is available on the precise factors which affect the rate of methane production, though from general principles one may deduce that higher levels of organic matter in the soil and higher soil temperatures both act to increase the rate of production.

A global estimate of methane produced by irrigated ricefields in 1980 was 30-60 million

tonnes per annum (Crutzen and Graedel 1986); in 1980 the worldwide total area of irrigated ricefields was estimated at 145 million hectares (ibid). This results in an estimate of methane production of 207-414 kg/ha/yr - without making any allowance for the proportion of the year for which the soil is flooded or dry. Given a national cropping intensity of 1.167 irrigated rice crops per year in 1985 and a yield of 4.2 t/ha, this equals a per unit area productivity of 4.931 t/ha/yr, and a range of methane production per unit of output of 41.983-83.966 kg/t of unmilled rice.

Summary

The results of the previous estimations of the labour and physical inputs used in 1985 for the production of one tonne of unmilled rice are summarised in Table A4.

Table A4:
Physical Inputs to Rice Production per Tonne of Output - 1985.

Input	From sector	Quantity
Seed (kg)	1	9.366
Urea (kg)	45	43.725
Other fertilisers (kg)	45	18.376
Pesticides (kg)	45	0.611
Human labour (person-years)		0.0885
(person-days)		26.542
Draft Labour (cattle-days)	18	0.149
Tractors (machine-days)	56	0.007
Natural Resources		
Land required (ha)		0.2367
Water required (cubic metres)		2,367
Capital (Rp/t)	various	75,833
Environmental Impacts		
Soil Erosion		0
Methane production (kg/t)	41.983-83.966	

Notes: Person-year = 300 working days.
Sources: Various tables in this annex.

In Table A5A the monetary values of inputs to production are presented, together with technological coefficients for rice production estimated by BPS (1986).

Table A5:
Values of Physical Inputs to Rice Production - 1985.

Input	From sector	Value (Rp)
Seed (kg)	1	2,040
Urea (kg)	45	4,256
Other fertilisers (kg)	45	1,786
Pesticides (kg)	45	1,031
Human labour (person-years)		26,221?
Draft Labour (cattle-days)	18	?
Tractors (machine-days)	56	626

Notes: Based on costs listed in Struktur Ongkos Petani...1985, BPS 1986.

Table A5A:
Inputs Coefficients at Producer Prices (After BPS) - 1985.

Input	From sector	Coefficient
Seed	1	0.018227
Other crops	17	0.000585
Livestock	18	0.001495
Wood	21	0.000054
Fertilisers and pesticides	39	0.068847
Petroleum refining	41	0.000040
Rubber and plastic wares	42	0.000292
Fabricated metal products	47	0.001242
Construction	52	0.000804
Trade	53	0.005779
Rail transport	55	0.000014
Road transport	56	0.001372
Water transport	57	0.000351
Air transport	58	0.000029
Financial intermediaries	61	0.008245
Other services	65	0.000562

Source: Tabel Input-Output Indonesia 1985, BPS 1989.

Base Scenario for 2020

Introduction

At present, the consensus among agricultural experts regarding Indonesia is that increases in rice production productivity, for both labour and land, will occur slowly and steadily. There also appears to be consensus that the rates of change in land and factor productivity will slow as time passes. Parallel to these changes, assuming that real incomes continue to increase, there will be a distinct shift in the mix of the bundle of food commodities consumed by the population, the general trend being towards a stabilising of growth in rice consumption per capita and increasing consumption of non-rice and processed foods. In addition, increasing consumption of meat products (mainly chicken) will mean that a rapidly increasing proportion of staple crops such as maize, cassava and soybean will be used as animal feedstuffs.

Increases in the scale and intensity of staple crop agricultural production for domestic consumption needs to be directed to meeting the estimated consumption needs of the Indonesian population. For rice, in particular, this depends mainly on the size of the population and estimated annual per capita consumption. In addition, agricultural production and development is crucially dependent on the availability and quality of land for growing crops; in this respect it is unlike the industrial and service sectors. These are two factors which must be taken into account when making estimates of likely technological production coefficients for rice production: population and land availability. The problem is, therefore, recursive. We cannot know how hard to 'push' the limits of rice cultivation technology without a reasonably good understanding of the demands that will be placed on the production system.

To take account of these two central factors, the following sections briefly review available information on population growth and land availability in Indonesia. These are followed by a section in which these are used to estimate how vigorously it may be necessary to intensify rice production to meet domestic demand for rice in the year 2020.

Population and Rice 1985-2020

Estimates by the Demographic Institute of the University of Indonesia (LDUI 1990) anticipate that the Indonesian population will have increased to about 254 million by the year 2020, an increase of about 54% over 1985-2020 or average rate of increase of 1.21% p.a.; this is considered somewhat optimistic by this author. Alternatively, projections use by the World Bank (1992) (which are based on unspecified BPS estimates) suggest that by 2020 population will have increased by an average of 1.46% p.a. to some 273 million, a total increase of about 66% (Table A6). In all of the estimations of change to the year 2020 we have used the World Bank estimates.

Table A6:
Size and Growth Rate of the Indonesian Population 1985-2020.

Period	Growth Rate pa	Population (millions)
1985-1990	1.84%	164.1
1991-2000	1.82%	216.1
2001-2010	1.31%	246.1
2011-2020	1.04%	273.0

Source: World Bank 1992.

The estimated demand for rice is directly influenced by changes in the amount consumed per capita. Given increasing real per capita incomes, it is assumed that the income-elasticity of demand for rice will decline from its current national average of about 0.3 to zero by about the year 2000 (Fletcher and Altmeier 1992). In 1985, national average consumption was about 142 kg/capita/year, this rose to 150 kg/capita/year by 1990. In the modeling exercise that follows the next section, it is assumed that the demand for rice is slowing, so that after the year 2000 average demand per capita will remain stable at about 155 kg/capita/year. Thus, the rate of increase in production needed to meet domestic demand and marginally increase average per capita consumption is only slightly more than the rate of population growth over the whole study period.

On the basis of these two figures - population size and per capita rice consumption - we can estimate the 'target' production required to meet domestic consumption in the year 2020. On this basis, the target production for the year 2020 is about 62 million tonnes of unmilled rice.

Land Resources

One of the main issues confronting the development of scenarios for agricultural production in Indonesia is the extent and distribution of potential agricultural land, even within Java. There has been a continuing debate within the professional community on this issue, and general dissatisfaction with the contradictory and inconsistent data available from various official sources. In this respect we are fortunate that recent data from RePPProT (1990) are available. Although most experienced professionals have reservations about one or another aspect of these land use and land potential data, there seems to be a general consensus that they are: a) a great improvement on all previous data sets and b) congruent with the broad, field-based experience of agricultural and landuse professionals in Indonesia.

Data on land use in the late-1980s is presented below (Table A7), prior to discussing estimates of the area potentially suitable for agricultural expansion. It is clear that most of the expansion in agricultural area during the 1980s has taken place off-Java, with the area of ricefields (and estates) on Java contracting, largely as a consequence of expanding urban and industrial areas.

Table A7:
Land Use in Indonesia 1988-90 and Trends 1980-88

x 1000 ha	On-Java	Off-Java	Indonesia
Ricefields	3,161.3	4,505.1	7,666.4
change p.a.	-0.17%	3.38%	1.99%
Estates	2,509.1	5,177.9	7,687.0
change p.a.	-1.50%	3.81%	2.57%
Upland	2,273.0	3,048.5	5,321.5
change p.a.	2.76%	5.37%	3.08%
Settlements	1,765.5	2,076.1	3,841.6
change p.a.	1.06%	0.81%	0.44%
Total Area of:			
Intensive Use	9,708.9	14,807.6	24,516.5
change p.a.	0.49%	3.62%	2.19%
Extensive Use	1,915.8	30,571.8	32,487.6
change p.a.	0.93%	0.71%	0.63%
Forest	1,245.0	118,428.4	119,673.4
Other	349.3	13,837.4	14,186.7
Overall Total	13,219.0	177,645.2	190,864.2

Source: SOW 1991.

Nationally, rapid expansion in all categories of agricultural land use have been taking place, especially off-Java. Expansion of the area of irrigated ricefields off-Java has been increasing at a rate more than sufficient to compensate for losses of irrigated area on-Java (and faster than national population growth). It is very doubtful whether either the rate of expansion in irrigated area (1.99% p.a. during the 1980s) can be maintained over the next 30 years, for two basic reasons. First, as expansion of area continues, land of decreasing quality has to be developed and it is questionable whether the cost of developing this lower quality land is economically justified. Second, continued expansion of irrigated land at this rate will soon exceed the *maximum* area of land potentially suitable for irrigation (at about 2% p.a. the irrigated area would double every 35-40 years, i.e. within the time horizon of this study).

In making estimates of land suitable for agricultural expansion, the RePPProT (1990) study took into account two main factors in determining the extent of potentially suitable land:

> *technical suitability* (e.g. soils, slope, rainfall); and
> *land availability* - whether or not it was already allocated for another use (e.g. forestry, mining, urban), but it not did take into account customary land rights.

In determining potential development sites they also applied minimum contiguous size limits: for irrigated crops 10-15,000 ha, for dryland arable and tree crops 15-25,000 ha.

RePPProT, in developing the criteria for Recommended Development Areas (RDA), took into account major physical factors (soils, slopes, size of area, etc.) affecting agricultural suitability

and productivity, including the adequacy of water supplies. Thus, it is reasonable to assume that water is not a major constraint on the extent of RDAs listed in the table above.

Most importantly, from the perspective of the actual area of suitable land likely to be available, they note that, on the basis of experience in going from the level of a reconnaissance survey (like RePPProT) to detailed local field studies, only some 35% of the land initially identified as suitable for arable crops (wet or dry) and about 70% of the area identified as suitable for tree crops proves to be usable in practice. This we refer to here as the *minimum* extent of land potentially suitable for agricultural expansion. Thus, we have an upper, optimistic, bound on the area of land suitable for agricultural extension - particularly for arable crops - and a lower, conservative, bound. This lower bound, the *minimum* extent, is judged by this author to be closer to what might be achieved in practice. These caveats are particularly important when proper account if taken of the proportion of the *maximum* potential area located in areas with an extended and variable dry season, or on poorly researched soils in very remote areas of Irian Jaya, for instance.

Drawing on data developed by RePPProT, we can define the *maximum* and *minimum* extent of land suitable for different types of agricultural exploitation (Table A8), from a base period of 1988-90. In presenting these data, we (and RePPProT) draw attention to a number of issues that will reduce the actual extent of suitable agricultural land available, in addition to the two criteria mentioned above:

> continuing occupation of large areas of land by traditional owners (Kalimantan and Irian Jaya);
> the dangers to the health of settlers in malaria prone areas (Irian Jaya); and
> the reduction in biodiversity that will result from the destruction of forests and coastal and swamp resources (generally important);

With regard to Irian Jaya in particular, which accounts for some 60% of the potential wetland arable area (irrigated land), 41% of dryland arable area and about 32% of total potential area - all of the above constraints singly or in combination may well reduce potential area by at least one-half.

With regard to the loss of agricultural land to urbanisation and industrialisation, on Java in particular, we note that annual losses of 20-40,000 ha are already occurring (SOW 1991). Most of these losses are taking place on the most productive, irrigated coastal plains, e.g. irrigated land to the east, west and south of the Jakarta metropolitan area. Additionally, these are the areas with the most well developed transport and communications infrastructure. It should be noted that the cost of expanding agricultural areas off-Java will require substantial investments in these types of infrastructure (and markets), in addition to the direct costs of establishing irrigation systems. If the land requirements for urban and industrial uses continues to increase at about 7.5% p.a. nationwide, the annual loss of agricultural land could reach about 80-90,000 ha p.a. by 2010, or more than 900,000 ha over 1990-2010 (SOW

1991). This is approximately equal to the minimum area of land potentially available for wetland rice production (0.96 million ha).

Table A8:
Recommended Development Areas by Type and Region

Region million ha	Wetland arable	Dryland arable	Tree crops	Mixed t&a	Total
Sumatera	0.69	0.04	0.95	0.82	2.50
Kalimantan	0.21	1.32	5.12	0.41	7.06
Sulawesi	0.0	0.02	0.11	0.0	0.13
Irian Jaya	1.65	1.18	1.44	0.46	4.77
Maluku	0.11	0.14	0.0	0.03	0.28
Nusa Tenggara	0.01	0.15	0.02	0.0	0.18
Total - Maximum	2.73	2.86	7.64	1.71	14.95
Minimum	0.96	1.00	5.35	1.20	9.70

Notes: Mixed t&a = mixed tree and arable crops. The (minimum) area is the total (maximum) area multiplied by 0.35 for arable crops and 0.7 for tree and mixed crops.

Source: RePPProT 1990.

Note should also be made of the cost of developing new irrigated land, which is estimated as between US$ 3-2,500 per ha by v.d. Zande (1989) and at US$ 5,000 per ha by Alirahman et al (1992). These are only the direct, agricultural infrastructure costs and do not include the costs of roads, inputs and produce markets, or establishing new agricultural extension and other farm services. The *replacement* of this highly developed land on Java with newly developed land off-Java has major capital sufficiency ramifications, i.e. replacing 20-40,000 ha/annum will require investing an additional US$ 50-200 million/annum. In addition there are the 'hidden' costs of medium-term losses in rice production - it requires 5-10 years before new ricefields approach their potential productivity, due to a complex mixture of environmental, agronomic and organisational factors.

In summary, a maximum of some 2.73 million ha is available for expansion of irrigated area and a minimum of 0.96 million ha, from a base period of 1988-90. In practice, it is probable the feasible extant of expansion is closer to this lower bound of 0.96 million ha. Any expansion beyond this area will probably result in both increasing development costs per hectare and lower marginal returns to rice cultivation. Thus, in framing the scenarios that follow we have used this lower bound as a guide and a constraint in assessing their viability.

Rice Production - Base Scenarios 1985-2020

Three, interacting factors determine how much irrigated rice can be produced annually. First, the total amount of irrigated land available - area. Second, given certain labour and physical inputs, production per unit area - yield. Third, the number crops that can be harvested in one

year - cropping intensity. Multiplying these three factors together gives an estimate of total annual production. In addition to irrigated rice production, there is an annual contribution to supply of some 2.3 million tonnes in 1985 from dryland rice cultivation, this is ignored in the estimations below.

For this exercise we have separated both the quantities and rates of change for each of these three factors into on-Java and off-Java components. We have assumed that the target production of milled rice in the year 2020 is about 62 million tonnes.

For the Base Scenario four models were developed for the period 1985-2020. These have more conservative (lower) assumptions about rates of change in irrigated area, yields and cropping intensity for the post-1990 period than occurred during the 1985-90 period and those used for the High Technology Scenario.

Despite the conservative nature of the assumptions, the first of these scenarios resulted in an expansion of irrigated area (to 9.8 million ha), increased average yield (6.8 t/ha) and cropping intensity (1.39 crops/year) for the year 2020. In terms of additional wetland resources off-Java, this scenario required some 3.5 million ha - well in excess of the maximum potential available land of 2.7 million hectares. This first model resulted in total rice production exceeding estimated demand by about 50% (93 million tonnes).

The second model used more conservative assumptions, particularly with regard to expansion of irrigated area off-Java, more than halving the 1990-2020 growth rate, and moderating rates of increase in yields and cropping intensity. This resulted in estimated supply in 2020 meeting 99% of estimated demand (ignoring dryland rice), but with irrigated area only increasing by about 0.5 million ha to 8.2 million ha and cropping intensity increasing from 1.17 to 1.23 crops/year. This model required an additional 1.1 million hectares of new land off-Java over the period 1990-2020, exactly balancing the loss of irrigated area on-Java (about 1.1 million ha). The level of average yield achieved (6.1 t/ha) was high, even compared to 1990 yields on-Java (5.2 t/ha).

The third model used extremely conservative constraints, further reducing rates of increase in yield and cropping intensity, but maintaining expansion of irrigated area, as in the second model. This set of assumptions resulted in annual production only reaching 88% of estimated demand, but required yields to increase only moderately (to 5.7 t/ha), with cropping intensity remaining stable over the period at 1.17 crops/year. It is considered that this level of increase in yields is attainable and, moreover, sustainable over the study period. But it is considered it should be possible to increase cropping intensity above 1.17 crops/year, to compensate for the estimated 10% shortfall in supply. This increase in cropping intensity formed the basis for the fourth model.

It is considered that the two foregoing scenarios represent upper and lower bounds on the production of irrigated rice for the 1985-2020 period for the Base Scenario. It should be clear that the same levels of aggregate production can be obtained by varying the relative contributions from area, yield and cropping intensity. Given the bounds on the extent of land potentially available for irrigated rice cultivation, the cost of extending irrigated area, and the fact that Indonesia's population will continue to increase beyond the year 2020, it would be unwise to anticipate using any beyond the minimum necessary additional area to meet projected demand for 2020. Of major note is the fact that all of the minimum potentially suitable land for wetland rice cultivation will need to have been bought into production by the year 2020, if only to balance the loss of irrigated area likely to occur on-Java.

In the fourth model used estimates of expansion of area from the second and third model (which are identical), kept the level of yield increase the same as in the third model and increased only the rate at which cropping intensity increases. The result, is that total production for the year 2020 meets 99% of estimated demand (see Annex 2 for details). Estimated nationwide yield for the year 2020 is 5.7 t/ha (on-Java 6.5 t/ha and off-Java 5.2 t/ha), this is the figure used in the analysis that follows.

It is extremely important that it appears possible to meet the (slowly) increasing demand for rice with such modest increases in the major factors governing production. Furthermore, the moderate level of increase in yields and cropping intensity needed to meet estimated demand, indicates that demand for additional irrigation water will also be moderate, and that adverse environmental impacts (fertiliser runoff, pesticide use and methane generation) per unit of production can also be minimised.

It is not suggested, even by implication, that achieving **and** maintaining these levels of increase in yields and cropping intensity will be simple. In essence, achieving and maintaining these increases, and preserving the natural resource base necessary for the post-2020 period, will require assisting rice farmers to make much more efficient use of the factors of production available to them, especially water and fertiliser.

Natural Resource Requirements

Land Resources

In developing the technological coefficients that follow, and in line with the results of these models, we have assumed that national average yields for irrigated rice will increase to 5.7 t/ha by the year 2020 and cropping intensity increase by 14% to 1.33. This implies that, on average, the land required for producing one tonne of (unmilled) rice will be 0.1539 ha. This is equivalent to a decline in land required for one tonne of rice production by 35% over the study period.

Water Resources

In 1985, water use per tonne of rice production was estimated at 2,367 cubic metres/t (cm/t) (on-Java 2,115 cm/t and off-Java 2,806 cm/t). It is expected that between now and the year 2020 efficiency of water use will continue to improve. The World Bank (1989) optimistically expects fairly continuous 1% p.a. improvements in water use efficiency. In this study we will use more conservative figures of 0.75% p.a. during the first decade to the year 2000, 0.5% p.a. in the second decade and 0.25% p.a. in the final decade to 2020. This slowing in improvements in water use efficiency occurs because marginal improvements become progressively more difficult to achieve and maintain. Overall, we estimate that efficiency of irrigation delivery will double from 25 to 50 per cent by 2020.

The improvement in efficiency and increased yields have the effect of reducing the amount of irrigation water needed to grow a tonne of rice and/or increasing the number of crops that can be grown in a year with the same volume of water passing through an irrigation system.

On this basis, by the year 2020, water use per tonne of rice production is estimated to decline to 876 cm/t nationwide. This represents a 63% decline water usage per tonne of production. This decline is partly due to increased yields and cropping intensity and partly to more efficient delivery and use of available water resources.

Human Labour Inputs to Production

A previous analysis of the correlation between human labour inputs to production and yield indicated that there is no statistically significant linkage (this analysis was based on the nationwide BPS/BAPPENAS data for 1989). Thus, per unit land inputs of human labour are maintained at their 1985 levels of 112 days/ha.

On the basis of increasing yields this results in human labour inputs per tonne of rice production declining to 19.7 days/t. Achieving and maintaining yield increases will require the farmer to devote additional time to crop management. On this basis, human labour inputs are estimated to decline by 26% over the study period.

Other Inputs to Production

Above, we have dealt extensively with the land implications of increasing rice production, but have not made any estimations regarding the other factors of production that will be necessary to achieve these levels of production. The changes in the physical inputs required are discussed below, in the same order as for 1985.

Seed

The is no reason for the amount of seed rice required to plant each hectare to increase beyond 1985 levels to achieve the yield or production increases described above. Indeed, given that

the emphasis in the years to 2020 is on increasing the efficiency of use of resources, it may be possible to reduce to amount of seed required. Improvements in seed quality, germination rates in particular, should help farmers economise on seed use. More generally, improvements in irrigation timing and reliability should result in lower early-crop failures caused by late or insufficient water supply at planting time.

Thus, conservatively, seed use rates per hectare of rice planted have been maintained at the 1985 level of 39.6 kg/ha. Because of yields increases, the amount required per tonne of production is estimated to fall to 6.9 kg/t. This equivalent to a decline of 26% over the study period.

Urea

Current data (WI 1992 and SOW 1991) indicate that, for a mixture of biological and economic reasons, application rates for fertiliser (Urea and TSP, in particular), which increased until the mid-1980's, have markedly slowed in recent years. Even without price increases farmers have discovered for themselves that too much fertiliser can damage their crops (and soil) without giving higher yields. The progressive removal of fertiliser subsidies and the complete elimination of subsidies on pesticides in the last few years have added economic disincentives to biological ones.

In 1985 an average of 43.7 kg of urea was used to produce one tonne of rice (Table A2). In the same year farmers (on average) on-Java required 52.0 kg and farmers off-Java only 29.1 kg for each tonne produced (BPS 1988a). According to BPS (1991) by 1989 the average requirement had fallen to 48.7 kg/t on-Java, and off-Java risen to 37.4 kg/t. There are two contrasting patterns of use: on-Java urea use per tonne is declining, off-Java it is still rising.

It is unlikely, given that a moderate increase in yields is still desired, that use rates on-Java can fall much below about 250 kg/ha, to ensure that this major nutrient is replaced. With a yield of 6.5 t/ha, this is equal to 38.3 kg/t. Off-Java, assuming that application rates increase to an average of 200 kg/ha (an increase of 92% over 1985 and 42% over 1989), and yields increase to 5.2 t/ha, this is equal to a rate of 48.4 kg/t.

In the year 2020, when approximately 60% of the harvested area is located off-Java national average rates application rates will be approximately 220 kg/ha - an average increase of 19% per ha over 1985. Nationally, with average yields of 5.7 t/ha this is equal to 38.6 kg/t. This is equal to an average reduction of 13% per tonne of rice production compared to 1985.

TSP/DAP and Other Fertilisers

Phosphate fertilisers (TSP or DAP) are the other main other fertiliser in use by rice farmers. A much more limited number of farmers use smaller amounts of potassium fertiliser (KCL) and an even smaller number use minor amounts of sulphate fertiliser or synthetic growth

stimulants. The 'other fertilisers' category contains a mix of manufactured fertilisers in unknown proportions. There is little field-based evidence that most of the fertilisers in this group make a noticeable contribution to plant growth or yield under Indonesian conditions. No information is available on quantities of green manures or composts used.

Between 1985 and 1989 average Indonesia-wide use of TSP/DAP grew from 73.2 kg/ha (on-Java 93.5 kg/ha and off-Java 46.4 kg/ha) to 100.0 kg/ha (on-Java 119.7 kg/ha and off-Java 76.5 kg/ha). At 100 kg/ha TSP/DAP use is at about the recommended maximum level for most areas of Indonesia. As with urea, subsidies for TSP/DAP fertiliser are declining. Thus, it is thought that future application rates on-Java are unlikely to increase much above the present level of 120 kg/ha, while application rates off-Java are likely to rise to about 100 kg/ha. This results in an Indonesia-wide average of 110 kg/ha of TSP/DAP for the year 2020.

On this basis, average Indonesia-wide use of TSP/DAP per tonne of rice produced in 2020 is estimated to be 19.3 kg/t (on-Java 16.9 kg/t and off-Java 21.3 kg/t). Given the increasing importance of off-Java production during years to 2020, and the somewhat lower yields achieved off-Java, it is thought that average use is likely to be closer to 21.3 kg/t of rice, and this is the estimate that is used. This is equivalent to an increase in TSP/DAP use per tonne of rice production of 14%.

Average, Indonesia-wide use of 'other' fertilisers increased substantially between 1985 and 1989, from 4.7 kg/ha (on-Java 2.6 kg/ha and off-Java 7.0 kg/ha) to 37.1 kg/ha (on-Java 47.4 kg/ha and 24.7 kg/ha off-Java). On this basis, Indonesia-wide use in 1985 was 1.1 kg/t (on-Java 0.5 kg/t and off-Java 1.9 kg/t). By 1989 this had increased to 8.2 kg/t (on-Java 9.2 kg/t and off-Java 6.5 kg/t).

Some of the fertilisers in the category are subsidised (KCL) others are not, but the general elimination of subsidies will make their use less attractive economically. However, because relatively small quantities are applied per hectare, their purchase and transport have only a minor impact on production costs and labour inputs.

For the purposes of this study, and lacking better information, we have assumed that by the year 2020 use of these fertilisers will not be greater than current rates of use on-Java of about 47 kg/ha. Given the estimated yield increases by the year 2020, use per tonne of rice production is estimated to be 8.2 kg/t. Over the study period this is equivalent to an increase in use per tonne of production of 43%.

Because of the preponderance of estimated use of urea and TSP (300 kg/ha out of 377 kg/ha applied) in 2020, overall reduction in fertiliser per tonne of production is estimated at 13%.

Pesticide Use

Since 1986, Indonesia has adopted Integrate Pest Management (IPM), as a result of Presidential Decree 3/1986, for rice production as a national policy, as an immediate step 57 types of pesticide were banned from use in rice cultivation. The general aim of the policy is to reduce the use of pesticides in rice production to a minimum. By the end of 1992 some 250,000 farmers, mostly on-Java, will have been trained in the use of IPM techniques by the national BAPPENAS/FAO IPM program. Research conducted by the national IPM program in mid-1991, indicated that on average farmers using IPM methods use 60% less pesticide than non-IPM farmers, while still maintaining yields. Since 1987, all subsidies for pesticide have been progressively eliminated.

In 1985 average, Indonesia-wide use of biocides (pesticides and other formulations) was 2.58 kg/ha (on-Java 3.20 kg/ha and off-Java 1.75 kg/ha). By 1989, the national average rate of use had risen to 2.95 kg/ha (on-Java 3.43 kg/ha and off-Java 2.39 kg/ha). In 1985, this is equivalent to 0.611 kg/t nationwide (on-Java 0.677 kg/t and off-Java 0.491 kg/t), which by 1989 had risen to 0.652 kg/t nationwide (on-Java 0.668 kg/t and off-Java 0.629 kg/t).

For the year 2020 Base Scenario we have assumed that pesticide use per hectare, both on-Java and off-Java, declines to 40% of 1989 levels, i.e. to 1.18 kg/ha. This decline is predicated as a result of the expansion of the national IPM programme and the rising cost of (unsubsidised) pesticides. It may be that this assumption is too conservative, as there is growing evidence that pesticides are not a necessary input to rice production, indeed their use tends to reduce yields and increase season-to-season yield variability. In which case, pesticide use in rice production may fall to close to zero by the year 2020 (or before). Nevertheless, the more conservative assumption of 1.18 kg/ha is employed in what follows.

At 1.18 kg/ha, and with an average yield of 5.7 t/ha, nationwide use rates per tonne of rice production in 2020 would be 0.207 kg/t (on-Java 0.182 kg/t and off-Java 0.229 kg/t). Nationwide, this is a decline in pesticide use per tonne of production of 195% over the study period.

Soil Erosion

Because there is no change expected in the physical arrangements associated with irrigated rice cultivation, no change either positive or negative is anticipated in soil erosion. As for 1985, soil erosion is assumed to be zero.

Gaseous Discharges

The data on estimated methane emission by flooded rice fields used in 1985 was 207-414 kg/ha/yr - there is no reason why this unit area generation rate should change. In 1985, methane emissions per tonne of rice produced on a nationwide basis was 41.9-84.0 kg/t.

Increases in yields will, however, reduce the amount of methane per tonne of rice produced at the same rate as yield increases, or -26% by 2020.

Draft Labour - Cattle and Tractors

The ploughing capacity of draft animals is not expected to change between 1985 and 2020. For 1985 we used the estimate of 0.667 days/ha/crop, which resulted in a input per tonne of rice production of 0.158. For 2020, with an average yield of 5.7 t/ha, this is equivalent to 0.117 days/ha, and a decline in use per tonne of production of 26%.

ANNEX 2 - BASE SCENARIO - LOWLAND RICE PRODUCTION PROJECTIONS 1985-2020 .

Based on NRMP estimates.

LOWLAND (Irrigated + Rainfed)	1985 x 1000	1985-90 rate	1990 x 1001	1991-2000 rate	2000 x 1000	2001-2010 rate	2010 x 1000	2011-2020 rate	2020 x 1000	1985-2020 % p.a.	1985-2020 net
ON-JAVA											
Sawah Area (ha)	3,445	-0.18%	3,415	*-1.50%*	2,936	*-1.20%*	2,602	*-1.20%*	2,306	-1.14%	-33.06%
Crop Intensity (times/yr)	1.44	0.54%	1.48	*1.00%*	1.64	*0.75%*	1.76	*0.50%*	1.86	0.72%	28.52%
Harvested Area (ha)	4,973	0.36%	5,063	-0.51%	4,809	-0.46%	4,592	-0.71%	4,278	-0.43%	-13.97%
Yield (kg/ha)	4.727	1.90%	5.194	*1.00%*	5.738	*0.75%*	6.183	*0.50%*	6.499	0.91%	37.49%
Production (unmilled)	23,507	2.27%	26,302	0.48%	27,591	0.29%	28,395	-0.21%	27,806	0.48%	18.29%
OFF-JAVA											
Sawah Area (ha)	4,060	3.46%	4,813	*1.00%*	5,316	*0.75%*	5,729	*0.25%*	5,874	1.06%	44.66%
Crop Intensity (times/yr)	0.93	-0.77%	0.90	*1.00%*	0.99	*0.75%*	1.07	*0.50%*	1.12	0.53%	20.38%
Harvested Area (ha)	3,783	2.66%	4,314	2.01%	5,264	1.51%	6,112	0.75%	6,587	1.60%	74.15%
Yield (kg/ha)	3.574	1.39%	3.830	*1.25%*	4.337	*1.00%*	4.791	*0.75%*	5.162	1.06%	44.43%
Production (unmilled)	13,521	4.09%	16,524	3.29%	22,829	2.52%	29,282	1.51%	34,006	2.67%	151.51%
INDONESIA											
Sawah Area (ha)	7,505	1.85%	8,228	0.03%	8,252	0.09%	8,331	-0.18%	8,180	0.25%	8.99%
Crop Intensity (times/yr)	1.17	-0.46%	1.14	0.69%	1.22	0.52%	1.28	0.33%	1.33	0.37%	13.87%
Harvested Area (ha)	8,756	1.38%	9,378	0.72%	10,073	0.61%	10,705	0.15%	10,866	0.62%	24.10%
Yield (kg/ha)	4.229	1.55%	4.567	0.92%	5.006	0.74%	5.388	0.54%	5.689	0.85%	34.52%
Production (unmilled)	37,027	2.95%	42,825	1.65%	50,420	1.35%	57,677	0.69%	61,811	1.47%	66.93%
Prod'n Beras	**25,179**	2.95%	**29,121**	1.65%	**34,286**	1.35%	**39,220**	0.69%	**42,032**	1.47%	66.93%
Population	164,630	1.84%	180,384	1.82%	216,100	1.31%	246,100	1.04%	273,000	1.46%	65.83%
Consump (Tm/cap/yr)	0.153	1.09%	0.161	-0.17%	0.159	0.04%	0.159	-0.34%	0.154	0.02%	0.67%

Notes: Conversion to milled rice (gabah to beras) is 0.68. Growth rates in italics are those selected by the author, other rates are actual or calculated by the model.

ANNEX 3 - HIGH TECHNOLOGY SCENARIO.

Based on Work Bank's (1992) scenario to 2000, with rapid yield increases over 2000-2020.

LOWLAND IRRIGATED	1988 x 1000	1995 x 1000	1988-95 rate p.a.	1995-2000 % p.a.	2000 x 1000	2001-2010 rate p.a.	2010 x 1000	2011-2020 rate p.a.	2020 x 1000	1988-2020 rate p.a.	1988-2020 net	%d land 1985-2020
ON-JAVA												
Sawah Area (ha)	2,500	2,400	-0.58%	-0.34%	2,360	*-2.50%*	1,832	*-2.50%*	1,422	-1.75%	-43.11%	
Crop Intensity (times/yr)	1.70	1.75	0.41%	0.57%	1.80	*0.00%*	1.80	*0.00%*	1.80	0.18%	5.88%	
Harvested Area (ha)	4,250	4,200	-0.17%	0.23%	4,248	-2.50%	3,298	-2.50%	2,560	-1.57%	-39.76%	
Yield (kg/ha)	5.40	5.70	0.78%	1.70%	6.20	*2.50%*	7.94	*2.50%*	10.16	1.99%	88.14%	-46.8%
Production (unmilled)	22,950	23,940	0.61%	1.93%	26,338	-0.06%	26,173	-0.06%	26,010	0.39%	13.33%	
OFF-JAVA												
Sawah Area (ha)	1,790	1,790	0.00%	0.11%	1,800	0.00%	1,800	*0.00%*	1,800	0.02%	0.56%	
Crop Intensity (times/yr)	1.15	1.32	1.99%	2.59%	1.50	*1.00%*	1.66	*1.00%*	1.83	1.46%	59.16%	
Harvested Area (ha)	2,059	2,363	1.99%	2.70%	2,700	1.00%	2,982	1.00%	3,295	1.48%	60.04%	
Yield (kg/ha)	4.70	5.00	0.89%	1.55%	5.40	*2.50%*	6.91	*2.50%*	8.85	2.00%	88.27%	-46.9%
Production (unmilled)	9,675	11,814	2.89%	4.30%	14,580	3.53%	20,616	3.53%	29,152	3.51%	201.31%	
ON-JAVA + OFF-JAVA												
Sawah Area (ha)	4,290	4,190	-0.47%	-0.14%	4,160	-1.35%	3,632	-1.19%	3,222	-0.89%	-24.89%	
Crop Intensity (times/yr)	1.47	1.57	1.27%	1.29%	1.67	0.35%	1.73	0.50%	1.82	0.66%	23.56%	
Harvested Area (ha)	6,309	6,563	0.79%	1.15%	6,948	-1.01%	6,280	-0.70%	5,855	-0.23%	-7.19%	
Yield (kg/ha)	5.17	5.45	1.05%	1.57%	5.89	2.38%	7.45	2.38%	9.42	1.89%	82.18%	-45.1%
Production (unmilled)	32,625	35,754	1.85%	2.73%	40,918	1.35%	46,790	1.66%	55,162	1.65%	69.08%	
LOWLAND RAINFED												
Sawah Area (ha)	2,280	2,140	-1.26%	-0.28%	2,110	-0.84%	1,940	-0.75%	1,799	-0.74%	-21.09%	
Crop Intensity (times/yr)	0.78	0.81	0.66%	0.70%	0.84	0.57%	0.89	0.48%	0.93	0.54%	18.81%	
Harvested Area (ha)	1,785	1,732	-0.60%	0.41%	1,768	-0.27%	1,720	-0.27%	1,674	-0.20%	-6.25%	
Yield (kg/ha)	2.97	3.26	1.93%	2.58%	3.71	1.13%	4.15	0.77%	4.48	1.30%	50.98%	-33.8%
Production (unmilled)	5,295	5,653	1.32%	3.00%	6,554	0.85%	7,136	0.49%	7,495	1.09%	41.55%	
UPLAND RAINFED												
Ladang Area (ha)	2,680	2,670	-0.07%	-0.15%	2,650	-0.11%	2,620	-0.09%	2,598	-0.10%	-3.08%	
Crop Intensity (times/yr)	0.46	0.55	3.63%	3.06%	0.64	1.20%	0.72	1.02%	0.79	1.73%	73.25%	
Harvested Area (ha)	1,228	1,463	3.56%	2.91%	1,688	1.08%	1,880	0.93%	2,062	1.63%	67.92%	
Yield (kg/ha)	1.95	2.10	1.56%	1.73%	2.29	0.94%	2.52	0.58%	2.67	0.99%	36.96%	-27.0%
Production (unmilled)	2,392	3,078	5.17%	4.69%	3,870	2.03%	4,733	1.52%	5,502	2.64%	129.98%	
SAWAH/LADANG AREA	9,250	9,000	-0.55%	-0.18%	8,920	-0.85%	8,192	-0.72%	7,619	-0.60%	-17.63%	
CROPPING INTENSITY	1.01	1.08	1.47%	1.47%	1.17	0.34%	1.21	0.43%	1.26	0.70%	24.91%	
HARVESTED AREA	9,322	9,757	0.92%	1.29%	10,404	-0.52%	9,880	-0.30%	9,590	0.09%	2.88%	
YIELD (t/ha)	4.32	4.56	1.06%	1.60%	4.93	1.87%	5.94	1.82%	7.11	1.56%	64.34%	-39.2%
TOTAL UNMILLED RICE	40,312	44,485	1.99%	2.91%	51,342	1.34%	58,659	1.51%	68,159	1.65%	69.08%	
TOTAL MILLED RICE	**27,412**	**30,250**			**34,913**		**39,888**		**46,348**			
Population (est.)	178,894	199,700	2.79%	1.59%	216,100	1.31%	246,100	1.04%	273,000	1.21%	52.60%	
Consumption (t/cap/yr)	0.153	0.151	-0.23%	0.65%	0.162	0.03%	0.162	0.46%	0.170	0.29%	10.79%	

Note: Conversion to milled rice (gabah to beras) is 0.68. Growth rates in italics are modifications and additions to growth rates implicit in the World Bank scenario.

TOTAL UNMILLED RICE is the sum of production from LOWLAND IRRIGATED, LOWLAND RAINFED AND UPLAND RAINFED.