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USING CLIMATE MODELS TO IMPROVE INDONESIAN FOOD SECURITY

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El Niño Southern Oscillation (ENSO) events exert significant influence on Southeast Asian rice output and markets. This paper measures ENSO effects on Indonesia's national and regional rice production and on world rice prices, using the August Niño 3.4 sea surface temperature anomaly (SSTA) to gauge climate variability. It shows that each degree Celsius change in the August SSTA produces a 1,318,000 metric ton effect on output and a $21/metric ton change in the world price for lower quality rice. Of the inter-annual production changes due to SSTA variation, 90% occur within 12 provinces, notably Java and South Sulawesi. New data and models offer opportunities to understand the agricultural effects of ENSO events, to reach early consensus on coming ENSO effects, and to use forecasting to improve agencies' and individuals' capacity to mitigate climate effects on food security. We propose that Indonesia hold an 'ENSO summit' each September to analyse the food-security implications of upcoming climate events.

INTRODUCTION

Food policy in Indonesia has changed substantially since the end of the Soeharto regime in 1998. With these policy changes have come associated alterations in decision-making processes and in the institutions serving food and agriculture. International developments have also affected Indonesia's food system. The world market for rice is larger in volume and more stable with respect to prices than in earlier periods; the Asian financial crisis of the late 1990s is more or less over; and new climate data and models for the Indo-Pacific region have shifted speculation on El Niño Southern Oscillation (ENSO) impacts on agriculture from shamans to computers. Collectively, these changes have enhanced the role of the private sector in Indonesia's rice trade, and have altered the manner in which various actors use available instruments to deal with annual variations in paddy production.[1]

The central concern of this paper is to estimate the magnitude of year-to-year changes in paddy production—nationally and regionally—caused by ENSO variables. Since these estimated magnitudes turn out to be large, our second, more normative, focus is on how improved production forecasts can best be used to improve food security in an evolving rice system—one that is more decentralised and privatised than the system that prevailed during the Soeharto era.

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The Climate Context

The recurring pattern of climate variability in the eastern equatorial Pacific is characterised by anomalies in both sea surface temperature (referred to as El Niño and La Niña for warming and cooling periods, respectively) and sea level pressure (Southern Oscillation). During El Niño events, the prevailing easterly Pacific winds slacken or reverse direction. As a consequence, the warmer ocean water shifts eastward away from Indonesia, causing rain to fall over the central Pacific Ocean and simultaneously causing drought to occur over large parts of the Indonesian archipelago.

Previous research by the authors demonstrated the specific impacts of ENSO events on Indonesian agriculture (Naylor *et al.* 2001, 2002). Although Indonesia has long been known to receive strong ENSO signals, quantitative relationships among sea surface temperature anomalies (SSTAs) in the central Pacific Ocean, rainfall patterns, and rice production were obscured by data and cropping-system complexities. However, when rice production data were retabulated on a crop-year (September–August) rather than on a calendar-year basis, and when focus shifted from yield to area variables, simple econometric models proved remarkably robust in quantifying climate–production linkages.

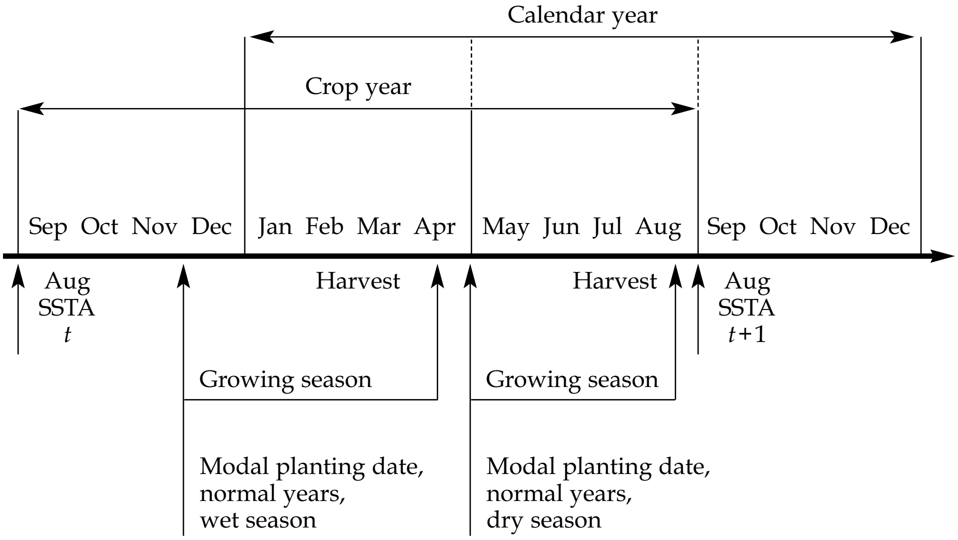
Several conclusions emerged from the earlier research, which in turn provide underpinnings for the extensions explored in this paper. First, August SSTAs (as measured by the Niño 3.4 SSTA index in the Pacific Ocean) are central to an understanding of subsequent rainfall patterns in Indonesia.[2] Second, most of the climate-induced variation in paddy production occurs as a consequence of changes in the area harvested rather than in the yield of paddy per hectare. Third, extreme El Niño events, of the type that occurred in 1982/83 and 1997/98, shift both the timing of plantings and the total amount of paddy produced, though there appears to be some 'catching up' of paddy production later in the crop year. The difference in magnitudes in Indonesian paddy area between the most extreme El Niño and La Niña years (1982/83 and 1975/76, respectively) is about 800 thousand hectares, roughly equivalent to 3,500 thousand metric tons (tmt) or about 7% of annual paddy production (Naylor *et al.* 2002). Climate variability is thus a (and perhaps *the*) primary determinant of year-to-year variation in Indonesian rice production.

The models presented in the second portion of this paper extend our earlier research in three important dimensions. First, we reformulate the basic model using level rather than first-difference forms of the variables, and analyse whether models that best predict variations in national paddy production are also effective and appropriate for use at the provincial level. We subsequently assess the extent and nature of feedbacks to the world rice price caused by climate variability in the Indo-Pacific region. Understanding these price feedbacks is especially important in gauging the food-security implications of our model. The final portion of the article illustrates the forecasting capacity of the model, and shows how such forecasts might be used to promote food security.

ENSO EFFECTS ON PADDY YIELDS, AREA AND PRODUCTION

Estimating ENSO impacts for Indonesia and then conveying the implications of those results would be much easier if climatic episodes corresponded well with

FIGURE 1 *Time-line Used for ENSO Models*



calendar years. However, none of the statistical formulations we have tried on a calendar-year basis has proven successful. We have thus used trimester agricultural data and have retabulated the data into crop years that begin on 1 September of year (t) and end on 31 August of year (t + 1).[3] As it happens, the trimesters themselves are of interest, especially the first trimester of each calendar year, since the January–April period corresponds well with the large (wet-season) harvest of paddy throughout much of Indonesia (figure 1).

Problems with time trends in the various production series further complicate statistical procedures. Our earlier climate–rice production models were based on the years 1983/84–1998/99, the period for which tri-yearly national data were then available. These models were formulated in first-difference form, i.e. changes in paddy production from year (t) to (t + 1) were estimated as a function of changes in the SSTA for August from year (t – 1) to (t).[4] This formulation solved most of the troubling statistical problems associated with serial correlation among the residuals, and the resulting equation was both simple and clear in its demonstration of climatic effects on rice production. It was also easy to explain to policy analysts and practitioners. However, in this statistical formulation, time trends in the production series end up being captured by the constant term in the estimation process. If these time trends are decelerating, as empirically they are, using a first-difference model for actual forecasting purposes becomes increasingly problematic, as the equation tends to underestimate the changes caused by the SSTA variable.

In an effort to solve this problem, we reformulated the base equation using levels for SSTA, production, area harvested and yields, rather than first differences. We also extended the data series through 2001/02. The SSTA variable exhibited no trend through time; however, we found it necessary to include time and time-

TABLE 1 *Effects of ENSO Events on Paddy Area Harvested, Yield and Production (1983/84–2001/02 Crop Years)*[a]

	Intercept	August SSTA	Time	Time^2	Adj. R^2	RMSE[b]	D.W.[b]
Area harvested ('000 ha)	9,359 (49.13)	–261 (–4.00)	200 (4.52)	–4.0 (–1.84)	0.90	246	2.04
Production (tmt)	35,311 (40.44)	–1,318 (–4.40)	1,675 (8.26)	–45.0 (–4.57)	0.94	1,132	2.00
Yield (mt/ha)	3.80 (65.59)	–0.02 (–0.98)	0.08 (6.16)	–0.003 (–4.42)	0.82	0.08	0.94

[a] t-statistics in parentheses.

[b] RMSE = root mean square error; D.W. = Durbin–Watson statistic; tmt = '000 metric tons.

squared variables to accommodate trends in production—thereby ensuring that the resulting residuals were stationary.[5] Accounting for trends in this manner ensured that both the production and SSTA variables were balanced.[6]

Equation (1) represents the new formulation for Indonesia's paddy production on a crop-year basis. It shows a production effect of –1,318 tmt per degree Celsius rise in the SSTA. That coefficient is virtually identical to the –1,400 tmt per degree Celsius change predicted by first-difference methods. However, equation (1) provides for considerably more flexibility in estimating technology effects. In particular, the squared time term allows for the possibility of an acceleration or deceleration of productivity increases in paddy production.

$$\text{Paddy production} = 35{,}311 - 1{,}318\ \text{AugSSTA} + 1{,}675\ \text{time} - 45.0\ \text{time}^2 \qquad (1)$$

t-statistic values (40.44) (–4.40) (8.26) (–4.57)
Adj. $R^2 = 0.94$ Durbin–Watson = 2.00
Time is measured in years, where 1 = 1983/84

ENSO Effects at the National Level

National Crop-Year Models. Table 1, which for completeness contains equation (1), presents an array of national results for the crop year. For each of the area, yield and production equations, intercept and slope coefficients are followed by their respective t-statistics in succeeding rows. Adjusted R^2, root mean square error, and Durbin–Watson statistics are also provided.

A number of important conclusions emerge from these results. First and foremost, SSTAs are important determinants of both area harvested and production of paddy. Each degree Celsius increase in the SSTA results in an area effect of –261 thousand hectares and a production effect of –1,318 tmt. (These results are symmetric—a decline of one-degree Celsius in the SSTA results in an increase of 261 thousand hectares and of 1,318 tmt of production.) The root mean square error for the production equation is 1,132 tmt, or roughly 2% of current yearly paddy pro-

TABLE 2 *Effects of ENSO Events on Paddy Area Harvested, Yield and Production (1983/84–2001/02, September–December)*[a]

	Intercept	August SSTA	Time	Time^2	Adj. R^2	RMSE[b]	D.W.[b]
Area harvested ('000 ha)	1,619 (15.15)	–142 (–3.88)	48 (1.94)	–0.59 (–0.49)	0.75	138	2.24
Production (tmt)	6,200 (14.45)	–556 (–3.78)	280 (2.81)	–4.24 (–0.87)	0.83	556	2.25
Yield (mt/ha)	3.85 (74.26)	0.02 (1.13)	0.05 (4.10)	–0.001 (–2.23)	0.80	0.07	1.36

[a] t-statistics in parentheses.

[b] As for table 1.

duction. Moreover, both the production and area-harvested equations are stable, with no serious outlier observations. To test the latter proposition, we dropped one observation sequentially, re-estimated the equation each time, and then used the new equation to 'forecast' the observation that was omitted. The correlations between the actual dependent variables and their forecast values using this procedure were 0.95 and 0.91 for production and area harvested, respectively.[7]

We also tested the model's stability by calculating it using a subset of observations and verifying its ability to predict production and area harvested for the omitted, 'out-of-sample' observations. The model performed well out of sample for both the production and area-harvested variables. Decreases in both variables were correctly predicted for the 1987/88 El Niño event when the first six years were omitted from the model calculation. Similarly, the model predicted decreased production and area harvested in the 1997/98 El Niño event when the last six years were forecast out of sample. The correlation coefficients between out-of-sample predicted production and actual production were 0.93 and 0.75 when the first six observations and last six observations were left out of the model, respectively. Out-of-sample calculations with the area harvested variable yielded similar results.

The effect of SSTAs on the yield component was of the expected sign, but was statistically insignificant. Nonetheless, all three equations—area harvested, production and yield—have adjusted R^{2}s that are very high. In addition, the Durbin–Watson tests are reassuring for the key production and area harvested equations. Finally, the significance of the time variable in the yield equation (which then carries over as a determinant for the production equation) underscores the importance of technology and infrastructure improvements in the 1980s and 1990s, though the highly significant t-statistic on the time-squared term also emphasises the slowdown of productivity increases in recent years.

National Models for the September–December Trimester. The estimates in table 2 for the September–December period show a qualitative pattern very similar to

TABLE 3 *Effects of ENSO Events on Paddy Area Harvested, Yield and Production (1983/84–2001/02, January–April)*[a]

	Intercept	August SSTA	Time	Time^2	Adj. R^2	RMSE[b]	D.W.[b]
Area harvested ('000 ha)	4,503 (30.70)	–188 (–3.74)	179 (5.26)	–6.49 (–3.90)	0.78	190	1.84
Production (tmt)	16,552 (22.54)	–938 (–3.72)	1,210 (7.09)	–43.26 (–5.20)	0.86	952	1.85
Yield (mt/ha)	3.73 (70.88)	–0.03 (–1.46)	0.09 (7.29)	–0.003 (–5.27)	0.86	0.07	1.06

[a] t-statistics in parentheses.

[b] RMSE = root mean square error; D.W. = Durbin–Watson statistic; tmt = '000 metric tons.

that for the total crop year. Perhaps most surprising is the magnitude of the ENSO effects. A one-degree Celsius change in the SSTA from the previous crop year alters area harvested by 142 thousand hectares (more than half of the total 261 thousand hectares for the entire crop year), and production by some 556 tmt. The climate effect on paddy yield was again insignificant for the trimester. In short, the August SSTA is a key indicator of paddy production in the subsequent four months, September–December, which constitute the beginning phase of the crop year.

National Models for the January–April Trimester. Table 3 is of particular interest because of its correspondence with the wet-season harvest for most parts of the country. The production-related ENSO effect is large (some 938 tmt per degree Celsius change in the SSTA), owing mainly to the very significant area effect. Overall, more than 70% of the climate-induced changes in both area harvested and production for the entire crop year occur during the January–April trimester. The yield coefficient of 30 kg per degree change is significant at only the 85% level of confidence, yet at the margin it also adds to the significance of the production equation relative to the area equation.

National Models for the May–August Trimester. In some fundamental sense, table 4 is qualitatively different from tables 1–3. By May of year (t + 1), the effects of the previous August SSTA are diminishing, as reflected by the lower adjusted R^{2}s. The May–August period is also the 'catch-up' season. In El Niño years, rains are both late and limited, which in turn shifts more of the cropping schedule into the May–August trimester. (The cropping schedule for West Java, a representative province, is shown in figure 2.) In contrast with the two other subperiods, the key SSTA slope coefficients for production and area harvested are positive rather than negative, although the production coefficient is significant at only about the 75% level of confidence. Table 4 thus helps to underscore an important timing point relevant for policy making and policy makers.[8] Crop prospects in El Niño years appear bleakest in about February. It is at that point that the crop is furthest behind. By July, at least some of the shortfall has been recovered. This point, while important, is obviously less than completely consoling to poor families who must deal with a prolonged hungry season (*paceklek*) due to the delayed wet-season harvest.

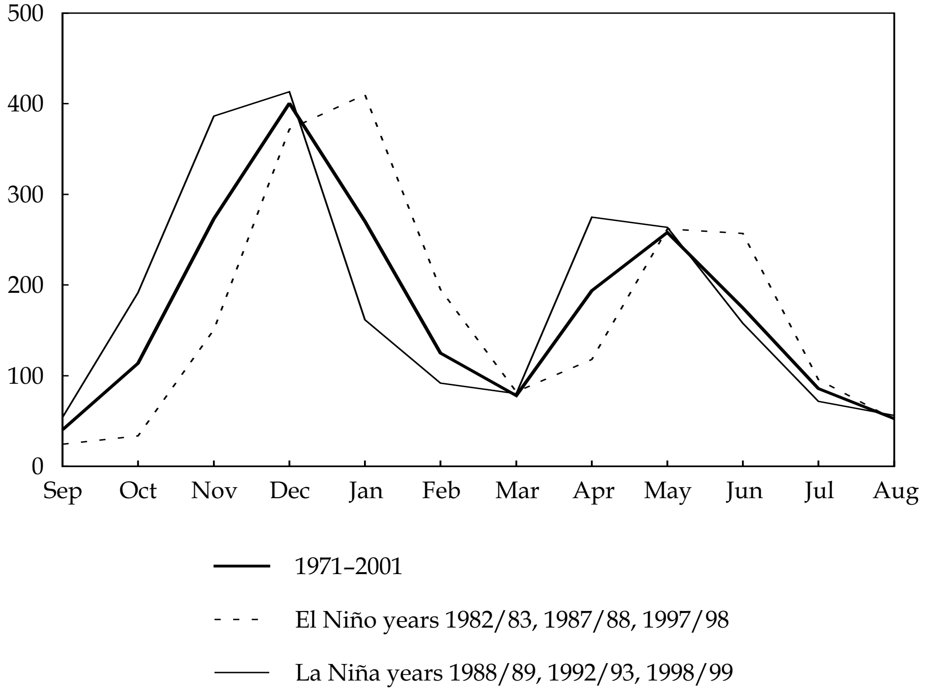
TABLE 4 *Effects of ENSO Events on Paddy Area Harvested, Yield and Production (1983/84–2001/02, May–August)*[a]

	Intercept	August SSTA	Time	Time^2	Adj. R^2	RMSE[b]	D.W.[b]
Area harvested ('000 ha)	3,237 (32.82)	69 (2.05)	–27 (–1.19)	3.11 (2.78)	0.73	128	2.50
Production (tmt)	12,558 (27.81)	176 (1.14)	185 (1.76)	2.33 (0.46)	0.83	586	2.13
Yield (mt/ha)	3.87 (45.23)	–0.04 (–1.24)	0.1 (4.86)	–0.004 (–0.37)	0.68	0.11	1.10

[a] t-statistics in parentheses.

[b] As for table 3.

FIGURE 2 *Average Monthly Plantings, West Java, 1971–2001 ('000 hectares)*



National Summary. The overall message from tables 1–4 is both clear and powerful. Climate patterns in the Central Pacific as measured by the August SSTA are key determinants of year-to-year variation in Indonesian paddy production. They show up with remarkable consistency in a series of econometric formulations, and they provide crop forecasts with considerable lead times. In early September, following publication by the National Oceanic and Atmospheric Administration (NOAA) of its August SSTA, there now exists a powerful (although not perfect) statistical basis for forecasting Indonesian paddy production for the crop year that follows. Within the past 20 years the August SSTA has varied by as much as 3.4 degrees Celsius in successive years. A 1,318 tmt effect on paddy production per degree change thus has very large potential consequences for Indonesian paddy production. Knowing the likely magnitude of climate-induced production variation early in the crop year thus provides an important window of opportunity for enlightened food-security measures.

ENSO Effects at the Provincial Level

The effects of ENSO events on paddy production, area harvested and yield were also derived for each of 24 provinces. These estimates are provided in appendix A. It is beyond the scope of this paper to describe and analyse each equation for each province. However, it is helpful to summarise how well the base model worked at the provincial level, where it worked, and where it seemed to have little predictive power.

Four features of the provincial tables appear noteworthy: the adjusted R^2s, the significance and magnitudes of the SSTA coefficients, and the relative contributions of area versus yield. Although our principal interest in this paper is in the specific effects of ENSO events on production, it is useful to begin the provincial discussion with an assessment of the overall estimating power of the base equation. In 17 of the 24 provinces, adjusted R^2s for the base equation equalled 0.75 or higher for production and/or area harvested for the crop year. In six of the 17 'significant' provinces, the high adjusted R^2s are due primarily to time trends. However, having simple climate equations for a dozen key rice provinces should be very helpful to regional and national authorities and to private traders serving these areas.

An intriguing regional story of specific climate effects is also told in the provincial tables. Our concern is with both the magnitude of the SSTA coefficients and their statistical significance as measured by t-statistics. The 12 provinces with significant SSTA coefficients are shown in table 5. For paddy production for the entire crop year, 10 provinces show t-statistics that are significant at the 95% level, and two additional provinces have t-values on the SSTA coefficient that are significant at the 85% level. Since these dozen provinces produced an average of 81% of Indonesia's paddy between 1997/98 and 2001/02, there can be no doubt that ENSO events are having widespread geographic effects.

Further inspection of table 5 provides several generalisations—and a few surprises. The key rice provinces of Java and South Sulawesi all show significant results. The province of West Nusa Tenggara (Nusa Tenggara Barat, NTB) also has a significant SSTA t-statistic, as do North Sulawesi, East Kalimantan, Riau and West Sumatra. By contrast, several important rice-producing provinces in south-central Sumatra (e.g. South Sumatra and Lampung) do not show tight

TABLE 5 *Significant Provincial Production Effects Caused by a 1°C Increase in the August SSTA*

Province	Crop-Year Production Effect (September–August) (tmt)	Percentage of National Effect	Significance of Production Effect (t-statistic)	Ratio of Production Effect to Average Yearly Production 1997/98–2001/02
West Java	–380	28.83	–3.01	–0.037
Central Java	–238	18.06	–3.67	–0.026
East Java	–232	17.60	–4.06	–0.026
South Sulawesi	–102	7.74	–2.02	–0.033
North Sumatra	–54	4.10	–1.57	–0.016
West Sumatra	–46	3.49	–2.18	–0.026
East Kalimantan	*–41*	*3.11*	*–2.60*	*–0.118*
North Sulawesi	*–38*	*2.88*	*–3.31*	*–0.104*
West Nusa Tenggara	–30	2.28	–2.63	–0.021
Riau	–17	1.29	–2.14	–0.041
Southeast Sulawesi	–10	0.76	–1.68	–0.033
Bali	–3	0.23	–2.82	–0.003
Subtotal	–1,191	90.36		
Coefficient for all-Indonesia (table 1)	–1,318	100.00		

SSTA connections (appendix table A-1). The answer almost surely lies with particular wind movements, and perhaps with the physical locations of these provinces *vis-à-vis* peninsular Malaysia and Kalimantan. Based on the work of Fox (2000), we had also expected to see an SSTA association with paddy production in East Nusa Tenggara (Nusa Tenggara Timur, NTT). However, Fox also indicates that in NTT (and in several other eastern provinces) SSTA effects play out more importantly for crops other than paddy, such as corn.

For the crop year as a whole, the largest production effects from a one-degree Celsius change in the SSTA take place on Java. Indeed, the impact in West Java is by far the greatest of any province. Table 5 shows that when the coefficients for these 12 provinces are summed (1,191 tmt), they account for 90% of the national impact (1,318 tmt).

Table 5 also illustrates one other regional point of importance. Although the largest adjustments take place on Java, the percentage effect of a one-degree Celsius change relative to provincial production is substantially higher in the off-Java provinces of East Kalimantan and North Sulawesi. Since those provinces have rice systems that are less well integrated than the Java provinces into both the national and international rice markets, advance warnings of production variations may be particularly helpful to them from a regional food-security perspective.

Finally, the provincial results in appendix A demonstrate that almost all of the ENSO impacts are via changes in area harvested. In only one province is the yield–SSTA linkage statistically significant: in South Sumatra, yields are affected by about 60 kg/ha per degree Celsius change in the SSTA. We are puzzled by this result, especially because the SSTA variable does not significantly affect area harvested or production in South Sumatra.

The provincial ENSO story is remarkably consistent and straightforward. Most of the large effects on paddy production arising from changes in the SSTA are in four provinces, even though a total of 12 provinces are significantly affected. Moreover, even on a provincial basis, virtually all of the ENSO production effects are via the amount and timing of areas harvested and almost none are via yields.

Climate and Price Linkages

The significant effect of ENSO on rice production begs the question of what role prices play in the dynamics of the system. We examined the role of prices, first as a causal variable influencing Indonesian rice supply along with climate, and second as a dependent variable being affected by changes in climate. In attempting to build farm prices into the foregoing paddy production models, we used numerous price alternatives, including deflated paddy prices, the ratio of paddy prices to corn prices, and the ratio of government-announced floor prices to the price of urea. In the end, none of the price variables proved statistically significant on a consistent basis.

Better measures of expected prices might solve some of the estimation problems in the Indonesia rice-supply equations. However, such measures are unlikely to overcome the fundamental econometric problem for the period under review. Stabilising the real price of rice was a cornerstone of food policy in the 1980s and most of the 1990s, and there is insufficient variation in the relevant price variables to permit the successful econometric estimations of supply response that could supplement the equations of tables 1–4. Obviously prices are important to farmers, and our finding does not suggest otherwise. Paddy has generally been the most profitable of the major crops for farmers to grow (Heytens 1991; Pearson, Bahri and Gotsch 2003), and paddy prices have thus been a key determinant of farm income, even if their variation has been insufficiently large to induce significant changes in cropping patterns.

The combination of policy decisions in Indonesia and climatic variability in the Indo-Pacific region has had important effects on world prices. After a period of self-sufficiency on a trend basis (and even substantial exports in the crop year 1984/85), Indonesia has become a consistent importer of rice. In addition, the variation in Indonesian imports has been very large. In the decade of the 1990s, for example, the range of rice import tonnages went from a low of 24 tmt in 1993 to a high of 4,748 tmt in 1999 (FAOSTAT 2003).[9] Import quantities depended on domestic stocks of rice, domestic prices, world prices, exchange rates and a series of other policy variables. However, there can be no doubt that the ENSO effects described in previous sections play a big role in determining the amount of rice imported. Dawe (2002) has had some success in isolating specific country effects on world prices. Our intention here is to link SSTAs directly to the world price of rice. While the logic of this procedure is clear enough, the data constraints are formidable.

The world rice market is very different from the markets for wheat and corn. The latter have active futures markets, and virtually all international contracts are written with reference to Chicago or one of the other organised markets. Rice, by contrast, has no comparable market.[10] The reasons have much to do with the political nature of rice, especially in Asia, and the high percentage of international trade that was historically completed via government-to-government (G-to-G) transactions. Partly as cause and partly as consequence of these arrangements, international rice trade has been a small percentage of total output (usually less than 4%). The private trade that has existed internationally has tended to be among friends and families, in no small measure because this facilitated contract enforcement. However, with the liberalisation of rice policy in the 1990s in countries like India and Vietnam, both of which went on to become substantial exporters, the world rice market roughly doubled in size and became much less variable with respect to prices. Increasingly, private trade has replaced G-to-G sales. In short, a real international market for rice has begun to develop (Dawe 2002).

One historical by-product of the marketing arrangements has been the lack of reliable international price data. Over the years, the 'government-posted price' of rice in Bangkok has been the predominant indicator price, but increasingly there have been complaints that these posted prices were 'desired outcomes' rather than actual transaction prices. Notwithstanding difficulties with official Bangkok prices, the data show a clear and surprisingly strong link between ENSO events and world rice prices. Equation (2) below is representative. It shows the change in export prices of A1 Special (A1S) rice (a lower-quality *indica* rice) from the fourth quarter of one year to the fourth quarter of the next as a function of the previous year's change in the August SSTA.

$$\Delta\text{A1S price } (4Q_t - 4Q_{t+1}) = -2.40 + 21.08\ \Delta\text{AugSSTA } [(t-1) \text{ to } (t)] \qquad (2)$$

t-statistic values (–0.29) (3.72)

Adjusted $R^2 = 0.46$ Durbin–Watson = 2.02

This simple first-difference formulation indicates that a one-degree Celsius change in the SSTA has resulted in an increase of about $21 per metric ton in the price of rice more than a year later, and the equation explains nearly half of the variation in year-to-year changes in nominal world prices for the period January 1986 to December 2003.[11] A1 Special rice traded between 1986 and 2003 at an average price of $180 per metric ton f.o.b. Bangkok, and thus in this case the ENSO feedback on the low-quality rice market is very significant. By contrast, change in the SSTA variable is not a good predictor of changes in the price of high-quality rice; the adjusted R^2 of a similar first-difference formulation for Thai 5% brokens, a representative high-quality variety, is only 0.003.

Two conclusions emerge from the analysis. The first is that the strong relationship between ENSO events and world rice prices only holds for the lower qualities, namely 35% brokens and A1 Special. This result is entirely logical—Indonesia is consistently one of the largest importers of rice on the world market, and it imports primarily the lower qualities. Thus it would appear likely that the

SSTA mechanism operates principally through Indonesia, although preliminary work by Dawe (2003) and Mastrandrea (2003) suggests that similar but smaller SSTA effects also operate via the Philippines and Vietnam, respectively. Second, El Niño episodes alter the relative prices of various grades of rice. Markets for lower-quality and higher-quality rice generally tend to move somewhat independently—the correlation coefficient between changes in the price of A1 Special and the price of Thai 5% brokens, for example, is only about 0.64—and in post El Niño situations the price of lower-quality rice tends to rise relative to higher-quality rice prices. In 'normal' years, the price ratio of A1 Special to Thai 5% brokens is about 0.68, whereas in El Niño years it is about 0.80. In other words, El Niño events cause the price difference between the high- and low-quality varieties to shrink by around $25/metric ton.

USING CLIMATE DATA TO IMPROVE PLANNING

The power of our model rests on four attributes: the large percentage of variation that it explains, which is indicated by the high values of the adjusted R^2s; its additive nature, which permits disaggregation by season and province; its long lead time, which provides quantitative forecasts in sufficient time for decision makers to engage in discussion and take meaningful action; and its logical simplicity, which makes it easily understood by policy makers. In the following section, we discuss how the equations outlined in the preceding sections can be employed to improve public and private sector activities in Indonesia.

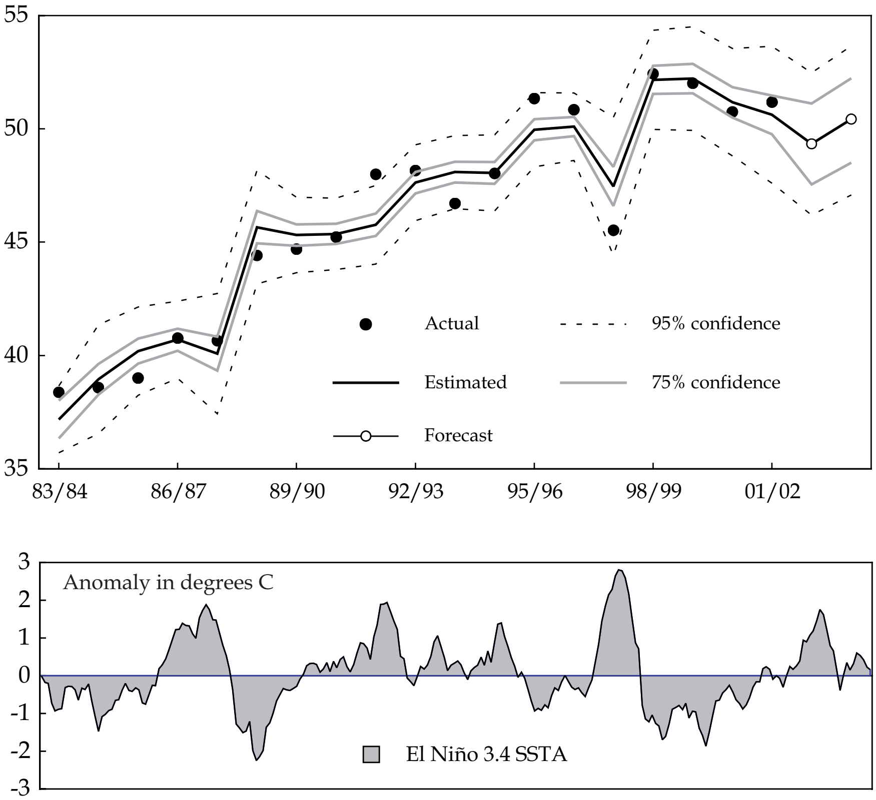
Even if the utmost care is taken, there are some inherent uncertainties associated with production forecasts based on ENSO data. The fact that the estimates are probabilistic and therefore rarely perfectly accurate might be seen by some as a reason to limit their transparent use. That would be a great mistake, for the advantage of using formalised models such as the one presented here lies precisely in their ability to reduce uncertainty.

There is also a tendency among some analysts within Indonesia to disregard more aggregated models that use time as a proxy for a number of variables. They argue instead for models that are more complex and that add variables such as fertiliser usage, irrigation volumes, areas damaged by pests, and factor and product prices. However, these models are typically cumbersome to build, they tend to be specific to one or two regions, and they are difficult to update on a time-relevant basis because of data constraints. As a consequence, their usefulness turns out to be limited across time and space. Our primary concern, by contrast, is with forecasts that clearly delineate the effects of climate and that can be updated consistently on an annual basis.

The Mechanics of Forecasting

All of the equations in tables 1–4 are similar in structure. For any particular trimester or crop year, they depend on the year's sequence number (e.g. 1983/84 = 1; 2001/02 = 19) and the August SSTA datum of the Niño 3.4 series compiled by NOAA. During the two decades covered by the equations, the August SSTA ranged from a high of 2.14 degrees Celsius above the long-run average to a low of –1.46 degrees Celsius below average.[12] By about 10 September of each year, NOAA posts the August value. At that time, all of the equations in this paper can

FIGURE 3 *Crop-year Production, Actual vs Predicted (million metric tons)*



be used to forecast the upcoming crop year or a particular trimester, either for Indonesia as a whole or for a specific province. In September 2002, for example, we estimated that, as a consequence of the moderate El Niño indicated by the August 2002 SSTA, the paddy crop in 2002/03 would be down by about 1,300 tmt (about 850 tmt of rice) from our forecast of the preceding crop year. In October 2003, we forecast that total paddy production for 2003/04 would be 50,430 tmt, or up about 1,040 tmt over 2002/03.

Figure 3 displays estimated versus actual paddy production plotted by crop year, with prediction confidence intervals provided for the in-sample predictions (1982/83–2001/02) and forecasting confidence intervals provided for the out-of-sample, ‘future’ predictions (2002/03 and 2003/04). A plot of monthly SSTA measurements shares the time axis so that the powerful effect of SSTA on production can be observed. Figure 3 also emphasises that the model is robust but inherently probabilistic, and thus its forecasting ability cannot be expected to be exact.

Crop Year versus Calendar Year

We noted earlier that climatic episodes do not correspond well with calendar years. This limitation is unfortunate analytically, because of the way historical data have been recorded and preserved. Although we cannot provide calendar-year forecasts, we are able, after the fact, to reconstruct estimates on a calendar-year basis for the post-1983 era. The process is somewhat tedious but very straightforward. In the case of national paddy production, for example, tables 2–4 can be used to estimate every trimester in the series, beginning with September 1983. After those forecasts have been estimated by trimester, it is then possible to retabulate the estimates on a calendar-year basis. For any given calendar year, SSTA data from two years are required to form the composite estimate.

Figure 4 plots actual production against production estimates calculated for both the crop year and the calendar year. The figure shows that both methods arrive at a similar result. If the estimates were perfect for all years, a plot of actual versus estimated paddy production would lie exactly along the 45-degree line. As it stands, the fits for both are extraordinarily good, and the plot in figure 4 simply reaffirms visually the very high adjusted R^2s of the national estimating equations.

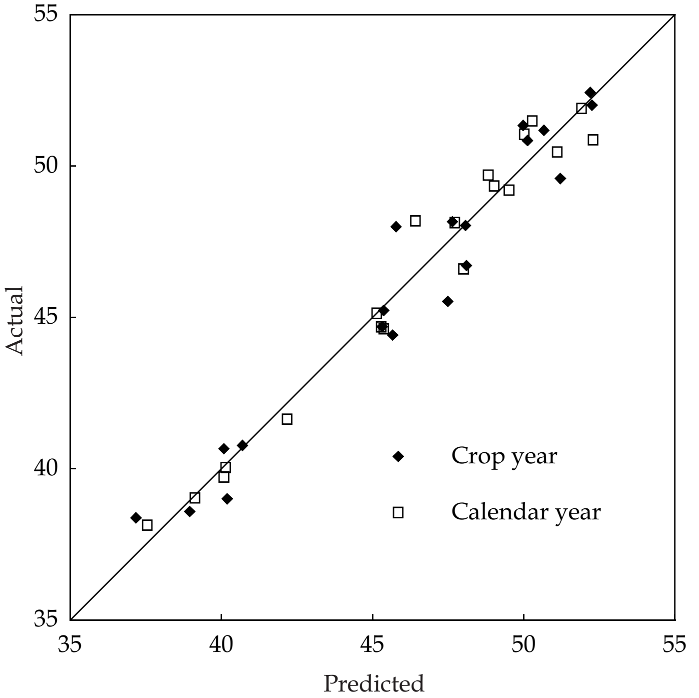
The main problem with the calendar-year model lies not in its forecasting skill but rather in its timing. Full calendar-year tabulations cannot generally be constructed in sufficient time to permit decision makers to be very proactive with policy decisions. On the other hand, there are some occasions in September (and even later in the year) when it would be quite useful to have an independent forecast of paddy production for the calendar year in progress. Such an estimate is easily available using the procedure outlined above. For example, our all-Indonesia forecast for paddy production for calendar year 2003 was 50,014 tmt, down some 270 tmt from our estimate for 2002. Since final official data for calendar 2003 would not have been released until June 2004, even an estimate in September 2003 would have had some potential usefulness for policy purposes and for preparation of the budget.

The Future of Forecasting

The foregoing analysis begs an obvious question: what if ENSO events were themselves predictable? As it stands now, the model presented in this paper is useful only after the August SSTA value has been announced. If, however, the August SSTA were itself predictable with pinpoint accuracy, forecasters could conceivably provide crop-year and calendar-year production forecasts much earlier than is currently possible.

Existing ENSO models provide reasonable forecasts of El Niño events up to six months in advance. However, forecasts provided as early as April or May have relatively large error bars that, when combined with the error on the production forecasts, result in more uncertainty than most policy makers can accept. Recent work by Chen *et al.* (2004) appears to demonstrate that ENSO events are much more predictable than was previously imagined, and suggests that larger events could be anticipated up to two years in advance. It should be re-emphasised, though, that coupling the model presented here with SSTA predictions necessarily makes the forecasting process more probabilistic and less accurate, and would be likely to complicate the policy advice given below. Currently, the state of the science is such that predictions of SSTA cannot easily—or perhaps desirably—be included in crop forecasting models. But as the ability to predict ENSO events improves, forecasters in Indonesia and elsewhere will be given increasingly valuable tools that can both strengthen and lengthen their forecasting abilities.

FIGURE 4 *Crop-year and Calendar-year Paddy Rice Production, 1983–2002 (million metric tons)*



Institutional Ownership

The possibility of greatly improved forecasts prompts the equity-related questions of which agency should construct and disseminate the estimates, to whom the estimates should be sent, and in what form (Pfaff, Broad and Glantz 1999). These questions arise in part because of a widespread reluctance in Indonesia, as elsewhere, to circulate data among public sector agencies and between public and private groups. Indonesia's welfare as a country would be improved with widespread institutional cooperation and sharing of climate data. Yet the sense that knowledge is power—and therefore not to be shared—is a difficult mindset to overcome, especially on a topic as important as rice.

A second problem of information generation and dissemination arises because of the sheer number of groups with food-security interests who feel that they have a legitimate need for forecasts based on ENSO data. For example, in most years since independence in 1945, Indonesia's presidents have spoken about the likelihood and consequences of ENSO events. The scientific underpinning for these comments, however, has never been very clear. With firmer forecasts, such statements now have the potential for creating widespread interest and action about forthcoming climate events.

The Ministry of Agriculture also has important responsibilities to farmers about the ENSO-related outlook. If forecasts are sufficiently clear, the ministry should be in a position to provide information about special cropping patterns in anticipation of an approaching drought, or to suggest revised recommendations on such inputs as fertiliser. The ministry is well aware of its responsibilities and has already begun to use formal methods of ENSO estimation as a regular part of its planning and informational processes.

In an earlier era, the food logistics agency, Bulog, would have been the primary user of ENSO-based forecasts. During much of the 1980s and 1990s, Bulog had responsibility for supporting paddy prices to farmers, for ensuring that consumer prices did not exceed a policy-determined band, and for rice imports, over which it held a monopoly (Bappenas *et al.* 2002). The more decentralised and privatised system now in place has appropriately diminished Bulog's role in the rice economy. Yet Bulog still has responsibility for procuring domestic paddy (within budget-constrained limits) and for distributing rice both to the military and selected segments of the civil service, and to poor households. The latter is a particularly important responsibility, especially in El Niño years, when the hungry season is prolonged and rice prices increase. In such years, the number of destitute households expands proportionately even more than paddy production declines (Molyneaux 2003). Food security deteriorates as a result of delayed income, depleted rice stocks, greater reliance of households on markets, and a greater than normal rise in seasonal prices for the staple food commodity.

Because our model is in the public domain, any of a number of groups could in principle use it to provide updated estimates. Nevertheless, it seems to us as a practical matter that some semi-formal mechanism is needed now within Indonesia to improve the connections among this network of concerned agencies and individuals.

A PROPOSAL

New data and models now combine to provide Indonesia with opportunities for *understanding* the effects of ENSO events on rice production, for *forming a timely consensus* on likely ENSO effects for the coming year, and for *using forecasts* in ways that permit agencies and individuals to do a more credible job in mitigating negative climate effects. We suggest, therefore, that an 'ENSO Summit' be held each year, as close as possible to 15 September, to discuss the food-security implications of forecasts based on newly released ENSO data. This meeting could also be used as a vehicle for outlining the types of forecasts that are most useful for different user groups.

Modelling efforts now show clearly that the August 3.4 SSTA value is important for understanding annual rainfall and climate scenarios in Indonesia. SSTA data before August do not provide the precision required by decision makers in either the public or the private sector. Data after August help to refine the model, but at a serious cost in terms of the loss in lead times for the results. We believe, therefore, that the optimal time for a workshop is shortly after the August SSTA has been posted by NOAA, and hence our call for a September summit.

There is a further corollary on timing. The results of the modelling efforts to date indicate that much more can be said about likely ENSO effects on rice production after 15 September even relative to what can be said two months earlier. The power of good forecasts will be sharply diminished if there is idle speculation before 15 September about likely El Niños, or if there is a wide range of guesses presented as fact or analysis. The scientific basis for forecasting El Niños is improving significantly, but we nonetheless urge various Indonesian spokespersons to limit their El Niño conjectures until after the August SSTA datum is available.

Participation in the proposed two-day workshop should be broadly based, with strong representation from both the public and the private sector. The discussion should be focused and rigorous. Not all of the interested groups will need to be on the program, even though all will have something useful to learn from the workshop. The list of speakers might well include climate scientists from outside the country, e.g. from Singapore, Australia and the US, and it is also possible that one or more of the larger multinational grain firms might be willing to share insights based on their considerable climate and weather expertise. In our view, this workshop should focus on climate-based rice production forecasts and their possible food-security implications. It should not be used as an occasion for fighting jurisdictional battles or debating other food and agricultural issues such as tariff and subsidy levels, which may be important, but are not central to the climate issues at hand. Given such a food-security focus, and given also the Ministry of Agriculture's ongoing activities in forecasting ENSO effects, the ministry seems well positioned to take the leadership in establishing the annual workshop. It might make sense for other bodies such as the Central Statistics Agency (BPS) or the Bureau of Meteorology to co-host the event.

The primary goal of the workshop should be to forge a high-level consensus estimate of likely climate impacts, which could then serve as a useful guide for the dissemination of information and for follow-up activities by various agencies and groups. At least initially the program should probably deal only with paddy. With additional experience and research, further crops could be added in subsequent years.

Even though some degree of uncertainty will remain, farmers, poor households, traders and agency managers will be much better off than they presently are if the best forecasting skills in the world can be brought to bear on the topic. Indonesia now stands poised to make much better forecasts than in the past. New science provides an opportunity for improved action, an opportunity whose loss—either by inattention or by jurisdictional fights among competing organisations—would be regrettable.

NOTES

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1 In this essay, 'paddy' (*gabah*) refers to unhusked rice, and 'rice' refers to milled white rice (*beras*). Typical milling ratios result in about 66 kg of milled rice from 100 kg of paddy.

2 The Niño 3.4 SSTA index is one of the leading measures of Central Pacific sea surface temperatures used in climate models. It is composed of temperature measurements from 170 degrees West to 120 degrees West and from 5 degrees North to 5 degrees South. The Niño 3.4 data are maintained by the National Oceanic and Atmospheric Administration (NOAA) and are updated on a weekly basis (NOAA 2003). All future references to SSTA in this article refer to the August value of the Niño 3.4 data series, unless specifically noted otherwise.

3 All yield, area, production and area damaged data used in this article come from Badan Pusat Statistik (various years), *Produksi Tanaman Padi dan Palawija di Indonesia* [Production of Paddy and Secondary Crops in Indonesia], Jakarta. Unless otherwise noted, all area data are for harvested area.

4 The most interesting crop-year equation from the earlier research is:

$$\Delta\text{Paddy production} = 839 - 1{,}400\ \Delta\text{AugSSTA (in tmt for all of Indonesia)}$$

t-values (1.91) (–4.79)
Adj. $R^2 = 0.61$ Durbin–Watson = 2.09

5 Both time and time-squared are used in all equations. Use of the same regressors across equations permits the sum of the trimester coefficients to equal those for the entire crop year. By the same logic, only three of the four equations, i.e. the three trimesters and the total, contain 'real' statistical information, since any one of the equations could be obtained by knowing the other three. In the sets of equations that follow, however, we present all four in tables 1–4 for ease of interpretation.

6 The Dickey–Fuller statistic was used to test whether the errors from the regression of production on t and t-squared were stationary or non-stationary. The test statistic, $Z(t)$, was –5.38, which allowed us to reject the null hypothesis of non-stationarity at a 99% confidence level. The deviations from the t and t-squared equation would also have been an appropriate dependent variable to regress against the August SSTA. We ran these regressions, and the results were virtually identical with those for equation (1). The latter, however, is easier to manipulate econometrically and also easier to explain to policy makers.

7 This approach is sometimes referred to as a 'jackknife' procedure to evaluate skill (Kleinbaum, Kupper and Muller 1988).

8 We have intentionally kept the regressors the same across tables 1–4 to permit addition across trimesters. For the May–August trimester, however, there is one other effect that should be noted. This trimester is also being affected by the 'new' ENSO conditions that are developing. If the SSTA variable for both the previous and current year are included in the estimating equation for area harvested, both coefficients are statistically

significant; they are almost identical in magnitude; they are of different signs; and the adjusted R^2 is unaffected.

$$\begin{array}{lllllll}
\text{Area harvested (May–Aug)} = & 3{,}460 & + 82\ \text{AugSSTA}_{t-1} & - 83\ \text{AugSSTA}_t & - 68\ \text{time} & + 4\ \text{time}^2 \\
\quad \text{t-values} & (35.56) & (2.44) & (-2.49) & (-3.20) & (4.56) \\
\quad \text{Adjusted } R^2 = 0.74 & \text{Durbin–Watson} = 2.04 & & & &
\end{array}$$

While the 'current' August SSTA obviously provides limited lead time for forecasting purposes, including this variable in table 4 after the fact may provide additional explanations of how climate affects paddy area. These explanations may be particularly useful given that official estimates are available only in June of the following year.

9 Private sources indicate that Indonesian rice imports peaked in 1998 rather than 1999, at a volume of slightly more than 6,000 tmt (Slayton 2002).

10 A tiny futures market for rough rice (paddy) currently exists at Chicago's Board of Trade. It is used primarily for domestic marketing in the US. This market's history has been disjointed, and it has never been a significant feature in contracts for rice being traded internationally.

11 Official Bangkok price data are from USDA (2003).

12 The mean and standard deviations of the August 3.4 SSTA over that time period are 0.04 and 0.91, respectively.

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APPENDIX A

Appendix table A-1 (below) shows SSTA effects on paddy production, area harvested and yields for the September–August crop year. Estimates are provided for each of 24 provinces for the period 1983/84 to 2001/02. Readers should be warned that the province of West Java includes provincial paddy data from Jakarta and, since 2001, also data from the new province of Banten, which had formerly been a part of West Java. Similarly, Central Java contains the data for Yogyakarta. In addition, data since 2001 for the new province of Gorantolo have been re-added into North Sulawesi and for Bangka Belitung into South Sumatra. No estimates are provided for East Timor, and for the early years of the series, paddy data for East Timor have been removed from the national totals so as to maintain a consistent data set for the entire period.

TABLE A-1 *Effects of ENSO Events on Regional Paddy Area Harvested, Yield and Production (1983/84–2001/02, Crop Year)*[a]

Province	Measurement	Intercept	t (Int)	Aug. SSTA	t (SSTA)	Time	t (time)	Time^2	t (time^2)	Adj. R^2	D.W.
Aceh	Area harvested	240	14.99	–5	–0.85	13	3.39	0	–2.29	0.60	1.39
	Production	767	11.86	–25	–1.14	81	5.37	–3	–3.69	0.83	1.15
	Yield	3.31	67.08	–0.02	–1.23	0.11	9.59	0.00	–6.83	0.92	1.98
North Sumatra	Area harvested	503	24.98	–8	–1.23	35	7.57	–1	–4.36	0.93	1.70
	Production	1,634	16.39	–54	–1.57	179	7.73	–5	–4.18	0.94	1.56
	Yield	3.33	71.00	–0.03	–1.57	0.08	7.06	0.00	–3.84	0.92	1.96
West Sumatra	Area harvested	316	23.60	–9	–2.07	9	2.83	0	–1.26	0.74	1.89
	Production	1,179	83.46	–46	–2.18	83	5.87	–3	–3.98	0.86	1.83
	Yield	3.85	96.37	–0.01	–0.74	0.12	13.31	–0.01	–11.66	0.92	0.83
Riau	Area harvested	126	16.63	–5	–1.99	5	2.60	0	–2.62	0.26	1.55
	Production	271	11.56	–17	–2.14	27	4.99	–1	–3.97	0.69	1.46
	Yield	2.23	33.65	–0.02	–0.68	0.10	6.22	0.00	–3.52	0.90	0.81
Jambi	Area harvested	146	21.54	–2	–0.95	8	5.38	0	–5.15	0.59	1.97
	Production	386	17.52	–8	–1.09	32	6.29	–1	–5.26	0.74	1.89
	Yield	2.69	45.29	–0.01	–0.41	0.04	2.82	0.00	–1.04	0.76	2.19
South Sumatra	Area harvested	393	18.59	4	0.55	4	0.88	0	1.11	0.79	1.72
	Production	1,044	18.06	–17	–0.84	41	3.07	0	0.27	0.92	1.55
	Yield	2.66	54.27	–0.06	–3.35	0.07	6.40	0.00	–3.72	0.90	2.27
Bengkulu	Area harvested	71	9.53	–2	–0.83	5	2.83	0	–1.80	0.55	1.77
	Production	200	9.15	–6	–0.77	18	3.48	0	–1.67	0.78	1.71
	Yield	2.86	42.67	0.01	0.37	0.03	1.96	0.00	0.34	0.84	1.37
Lampung	Area harvested	294	12.46	2	0.19	17	3.07	0	–1.09	0.80	1.49
	Production	837	11.65	1	0.05	97	5.83	–2	–2.30	0.93	1.70
	Yield	2.95	38.22	–0.01	–0.34	0.11	6.19	0.00	–3.53	0.89	0.63
West Java	Area harvested	2,031	29.48	–74	–3.13	14	0.85	0	–0.55	0.34	2.27
	Production	8,199	22.31	–380	–3.01	384	4.49	–15	–3.62	0.66	1.65
	Yield	4.04	33.68	–0.02	–0.42	0.16	5.57	–0.01	–4.66	0.68	1.04
Central Java	Area harvested	1,605	43.12	–45	–3.50	9	1.06	0	0.26	0.71	2.28
	Production	7,107	37.54	–238	–3.67	225	5.12	–7	–3.06	0.85	2.13
	Yield	4.44	76.23	–0.01	–0.55	0.11	8.03	0.00	–6.51	0.84	1.13
East Java	Area harvested	1,569	49.03	–38	–3.46	1	0.11	0	1.12	0.69	1.79
	Production	7,333	43.93	–232	–4.06	148	3.81	–4	–1.86	0.83	1.93
	Yield	4.68	72.57	–0.02	–1.08	0.09	6.05	0.00	–4.84	0.75	1.56
Bali	Area harvested	175	61.17	–3	–3.00	–2	–2.56	0	0.66	0.80	2.59
	Production	754	44.75	–16	–2.82	14	3.68	–1	–3.36	0.49	2.15
	Yield	4.30	145.09	–0.01	–0.68	0.13	19.44	0.00	–12.60	0.98	1.30

TABLE A-1 (cont.) *Effects of ENSO Events on Regional Paddy Area Harvested, Yield and Production (1983/84–2001/02, Crop Year)*[a]

Province	Measurement	Intercept	t (Int)	Aug. SSTA	t (SSTA)	Time	t (time)	Time^2	t (time^2)	Adj. R^2	D.W.
West Nusa Tenggara	Area harvested	251	28.23	–7	–2.15	0	0.23	0	2.06	0.85	1.91
	Production	901	27.16	–30	–2.63	28	3.66	0	0.17	0.94	1.88
	Yield	3.60	47.25	–0.01	–0.23	0.11	5.93	0.00	–3.99	0.83	1.77
East Nusa Tenggara	Area harvested	97	15.25	–1	–0.62	7	4.56	0	–1.92	0.88	1.48
	Production	198	11.80	–5	–0.94	24	6.22	–1	–2.73	0.93	1.88
	Yield	2.12	53.37	–0.01	–0.76	0.06	6.92	0.00	–3.98	0.91	2.11
West Kalimantan	Area harvested	267	30.41	0	0.12	6	2.84	0	–0.30	0.87	1.76
	Production	566	37.63	–6	–1.10	14	4.09	0	2.11	0.97	2.51
	Yield	2.11	40.91	–0.02	–1.12	0.01	0.90	0.00	1.48	0.85	0.85
Central Kalimantan	Area harvested	90	6.63	8	–1.66	11	3.55	0	–2.27	0.62	1.74
	Production	165	4.94	–15	–1.35	22	2.78	–1	–1.52	0.64	1.64
	Yield	1.87	23.97	0.00	0.08	0.00	0.05	0.00	1.69	0.74	1.02
South Kalimantan	Area harvested	299	13.85	–8	–1.14	10	2.06	0	–0.62	0.68	2.50
	Production	776	10.92	–25	–1.05	30	1.80	0	0.27	0.81	2.34
	Yield	2.58	28.05	0.00	–0.09	0.02	0.71	0.00	0.93	0.72	0.89
East Kalimantan	Area harvested	63	3.55	–14	–2.36	9	2.07	0	–1.29	0.48	2.09
	Production	114	2.48	–41	–2.60	20	1.91	0	–0.57	0.69	2.16
	Yield	1.88	41.46	–0.02	–1.06	0.03	3.02	0.00	2.56	0.97	1.85
North Sulawesi	Area harvested	70	8.65	–9	–3.30	5	2.45	0	–2.20	0.42	1.72
	Production	257	7.74	–38	–3.31	19	2.46	–1	–1.80	0.52	1.85
	Yield	3.70	33.95	0.00	–0.08	0.00	0.18	0.00	1.29	0.67	1.68
Central Sulawesi	Area harvested	101	9.34	–1	–0.34	3	1.14	0	1.08	0.83	1.77
	Production	251	6.43	–5	–0.41	14	1.53	1	1.29	0.89	1.58
	Yield	2.45	24.86	–0.01	–0.21	0.09	3.75	0.00	–1.30	0.86	1.95
South Sulawesi	Area harvested	620	28.99	–22	–3.07	23	4.56	–1	–2.38	0.85	2.00
	Production	2,297	15.61	–102	–2.02	148	4.33	–4	–2.12	0.85	1.61
	Yield	3.76	35.74	–0.01	–0.25	0.08	3.13	0.00	–1.54	0.73	1.56
Southeast Sulawesi	Area harvested	26	3.96	–2	–0.98	6	4.06	0	–2.07	0.81	1.18
	Production	51	3.08	–10	–1.68	20	5.13	0	–1.45	0.94	1.50
	Yield	2.26	22.00	–0.03	–0.87	0.08	3.24	0.00	–0.02	0.91	0.77
Maluku	Area harvested	11	3.58	0	–0.15	0	0.08	0	0.00	0.00	1.66
	Production	9	1.28	–1	–0.21	3	1.86	0	–1.28	0.23	0.07
	Yield	1.02	8.90	0.03	0.70	0.19	7.19	–0.01	–4.44	0.90	1.96
Irian Jaya	Area harvested	–1	–0.58	–1	–0.92	2	3.85	0	–0.59	0.92	1.45
	Production	–1	–0.25	–2	–1.24	3	2.74	0	0.97	0.93	1.74
	Yield	1.98	16.39	–0.01	–0.34	0.05	1.83	0.00	0.03	0.76	0.74

[a] Area harvested and production in thousands of hectares and metric tons respectively; yields in metric tons per hectare.