ANALYSIS

Interrelationships between economic policy and agri-environmental indicators: an investigative framework with examples from South Africa

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Abstract

A number of methodological approaches to understanding and quantifying the potential impacts of changes in macroeconomic and sectoral policies on the natural resource environment have been developed in recent years. However each has its limitations, resulting in policy change still being implemented without due attention to environmental impacts. Two key drawbacks of those methodologies that do attempt to model these impacts are that they are generally static in their approach, thus may not alert the decision maker to the often quite different long-term implications, and that they attempt to generate rather specific sets of indicators, making them difficult to use and/or interpret outside case study applications. In this paper we expound a framework for addressing these limitations in the context of the agriculture sector. In developing countries in particular the dynamic dimension is critical given the twin pressures of population growth and rising incomes associated with economic growth. In light of the second drawback, it is the propensity of policy to impact upon the natural resource environment via its effect on the type of farming practice adopted that forms the focus of the paper. A methodology is first developed to facilitate the tracing of likely impacts of both price and non-price reforms, via both the incentives and constraints to increased food production. By separating out the impacts on environmental indicators associated with extensification and intensification of agriculture, it is possible to determine which of these indicators are most likely to be affected by policy changes, and to what degree in both the short and longer term. The framework is then applied to case study data from the South African agriculture sector to demonstrate how consideration of the risk of natural resource degradation earlier in the policy dialogue process could result in the implementation of more effective complementary measures. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Farming practices; Economic policy; Environmental indicators; South Africa

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1. Introduction

Two central themes of the so-called Global Food Debate, (see, for example, Brown, 1994; McCalla, 1994; Islam, 1995) surrounding the issue of increased agricultural production in poor countries are the influence of the technologies currently deployed and likely to be developed in the future, and the impacts on the natural resource environment as it comes under increasing pressure from attempts to raise the productivity of the resources used in agricultural production. The relationship between the technological choices and the policy environment are well documented, but the link between policy change and the natural resource environment has received much less attention. While the impacts of specific localised changes in the socio-economic context have received substantial focus, for example, those stemming from the implementation of projects where the association between action and impact are both visible and measurable, the links between sectoral and macro-economic policy and the sustainability of the natural resource environment have received much less attention. In analysing the impact of any policy change, policy makers would ideally take into account these environmental costs and benefits as well as the economic outcomes in terms of increased efficiency. Often, however, it is difficult even to determine whether the impacts associated with such policy decisions will be positive or negative, let alone the magnitude of any effects.

The assessment of the impacts of policy decisions on the natural resource environment has been hindered by the absence of a methodology for tracing these impacts (Munasinghe and Cruz, 1994). Even where such relationships are recognised they are rarely incorporated at the policy design stage, as it is difficult to determine the magnitude of environmental effects until they become apparent. In the context of substantive economic policy reform, this implies that these effects are not taken into consideration until after the reform process has been implemented and the response is reactive rather than proactive. The latter point highlights the importance of both the environmental impact assessment and the analysis of the economic costs and benefits of policy decisions being completed at the same point in the policy formulation process, a theme central to the Action Impact Matrix (AIM) methodology (Munasinghe and Cruz, 1994).

One problem facing researchers is that their attempts to incorporate sustainability issues into policy analysis are likely to be static in nature because both technology and population growth rates are considered to be exogenous influences. However, models that attempt to treat these variables endogenously are likely to be of little use to policy makers due to their being both highly complex and intractable, while more simplified models are likely to prove unreliable. This paper attempts to develop a framework that demonstrates that farmers’ supply response to changes in incentives resulting from, for example, changes in population density, is influenced by the existing state of technology and subject to the constraints on innovation imposed by government policy, and that this is likely to result in quite different site-specific outcomes.

In explaining the AIM approach, Munasinghe and Cruz (1994) stress that the eventual impact of policy reform on the incentives faced by farming households is influenced by intervening institutional factors such as those affecting access to and use rights over resources, including land and water. Whilst they suggest that the complexity surrounding these issues implies that country-specific analysis will generally be required, the authors also point out that key reforms have specific identifiable impacts on subgroups of high priority problems. However, the AIM methodology does not appear to distinguish different possible responses to changes in incentives. In the agriculture sector, for example, output can be increased in response to an increase in output price by either extensifying or intensifying production activities, each having different associated impacts. It is therefore crucial to be able to identify the form and propensity to impact. For example, an appreciation in the exchange rate can result in inorganic inputs becoming relatively less expensive. Agricultural producers may respond by intensifying production on their more productive land. By contrast, a depreciation of the currency
may result in greater amount of marginal land being brought into production as relative input prices rise. The impacts on the natural resource environment under each scenario might be quite different.

In this paper we restrict our discussion to the effects on the natural resource environment which occur as a result of policy decisions that affect the agricultural sector. There has been substantive work carried out on the environmental impact of different farming practices, and on the development of technical indicators to describe the direction and magnitude of these impacts, notable among these being the OECD (1997) driving force-state-response framework. The OECD framework proceeds by attempting to determine what causes environmental conditions in agriculture to change, what effect this is having on the state of the environment, and what actions are being taken to respond to the changing state of the environment. The framework, thereby aids the identification of indicators to explain and quantify these links (OECD, 1999).

However, there are still a number of limitations to the use of these approaches. Pearce (1999) concludes that although the OECD’s framework is valuable in terms of the development of indicators within a conceptual framework, there has been limited appreciation of the real driving forces such as missing markets and government policy. Pearce suggests that further research is needed to identify the non-market attributes of agriculture, namely, the external benefits and costs, and the relationship between government policy and the agriculture sector.

Similar reservations are held by Doyle (1999) who finds that too many of the recommended OECD indicators are concerned with measuring the state of the environment in terms of physical and biophysical phenomenon. As such the indicators are not able to indicate the propensity of policy change to impact upon the state of the environment. One might conjecture that the reason why biophysical and technical indicators form the focus of attention is the difficulty of constructing indicators that reflect responses to policy change. Similarly, it could be that indicators are selected because of data availability, not any particular relevance to policy reform. Doyle states that ‘clear causal links between policy action and resource impacts need to be identified so that links between interpreting the indicators, developing appropriate policy responses and predicting the environmental and economic impacts can be clearly quantified.’

Thomassin (1999), however, relates that the current trend is the development of models in which policy influences production decisions in terms of crop mix and tillage practice. Results from such models are then used to estimate the environmental impacts with bio-physical models. This approach is taken in, for example, the Policy Evaluation Matrix and the Canadian Regional Agriculture Model.

In line with the observations made in this section, we therefore focus on the ability of policy makers to determine the likely implications of policy reforms on changes in farming practice. In doing so we suggest a framework for considering the likely direction and magnitude of the impact of such changes on the natural resource environment.

2. A framework for determining the direction and magnitude of impacts

Morrison and Pearce (1997) have previously suggested that the conjuncture of socio-economic and natural resource environments together with the policy context largely determines the way in which agricultural activity is conducted. Loosely termed the ‘farming practices’, these activities are shown to form a crucial link in the framework and in any consequent analysis, since they provide a bridge between policy change and changes in the status of the natural resource environment.

The two-stage framework proposed in Morrison and Pearce (1997) provides some insight into how researchers and policy makers might approach the links between economic policy variables and the status of the natural resource environment. Changes in the policy context are hypothesised as impacting on the natural resource environment through their effect on the type of technology practised by farmers. The speed of
evolution of technical change as governed by factors including population pressure and the policy environment determines the likely magnitude and significance of the resulting impacts on the natural resource environment.

Technological change creates the potential for farmers to increase production within ecological constraints by shifting the production function upwards (Bumb, 1995). At the same time, however, the policy context often presents a constraint to the adoption of new technologies. For example, in many countries of sub-Saharan Africa, a combination of exchange rate, trade and agricultural price policies have eroded any incentives to increase agricultural production, such that the mechanisms for transmitting changes in agricultural technology have become severely inadequate (Cleaver and Schreiber, 1994).

If we could assume some standard and static technology, we could hypothesise as to the likely response of the farmer to a policy change in terms of any increase or decrease in input levels (both capital and land), and therefore in changes in the proportion of land under annual crops as opposed to some other use. The nature of production technology at farm level thus plays a pivotal role in determining the way in which policy influences input use (Fox, 1993).

In a more dynamic scenario, the extent to which technological evolution is driven by, for example, population growth and/or constrained by the policy context becomes an important focus: we need to know, therefore, the rate of technical change in order to consider the potential impacts on a range of environmental indicators that are likely to be changed as a result. However, farming practices are varied and are often constrained by the current technology. This impinges not only upon the likely response in terms of changes in farming practice, but also upon the magnitude and significance of any resulting increase or decrease in the status of the environmental indicator.

These impacts are likely to be ambiguous due to the initial starting point of the agriculture sector in terms of the current level of intensification and/or extensification of the production system, and the likely direction of change towards the extensive or intensive margins. These are in turn dynamically related to the policy environment, and provide important points of departure when considering how to mitigate any adverse implications of the policy change, or what complementary measures might be appropriate to implement with the change.

In order to circumvent the ambiguity associated with the impact of policy, it is useful to begin by assuming that policies can be categorised as those that: (a) directly affect relative prices of agricultural inputs and outputs, such as input subsidies and taxes, export subsidies, exchange rate policies; or (b) place ease constraints on resource access such as land reform, credit/interest rate policies, etc.

2.1. Analysing the impacts of price policy

Consider a policy that alters the relative price ratio in favour of annual crops. Under the assumption that the supply elasticity in developing countries is positive, we would expect an aggregate increase in the production of annual crops. However, this type of analysis tells us nothing of the way in which the additional output is produced. Clearly, this depends upon the farming practice that is adopted. For example, there could be increased environmental damage through increased input use resulting in deteriorating water quality; or we could find natural resource degradation in the form of soil erosion or deforestation as a result of the opening up of frontier land for crop production.

How, therefore, can farming practices be depicted in a manner that will allow us to determine which indicators are likely to be affected and, more importantly, to what degree? An appropriate way forward is to classify responses in terms of an extensification or intensification of farming practices. In referring to farming practice we imply the particular set of activities for which land is used, in combination with the technical parameters describing production methods. The centrality of the concept is illustrated in Fig. 1. The diagram juxtaposes different technical systems onto land use patterns as described by the ratio of crop production to pasture. Thus, the southwest
quadrant, e.g. point A, describes a land use system characterised by a small proportion of cropping, and extensive use of the land devoted to pasture or forest, typically mixed farming systems with a long crop rotation or fallow. Analogously, the north-west quadrant, exemplified by point B, describes arable systems which could be described as low-capital or ‘traditional’, while the southeast and northeast quadrants represent more intensive production systems.

The vertical axis can be viewed as representing a movement from production patterns characterised by a low proportion of arable to, at the extreme, continuous mono-cropping. Movement along the horizontal axis describes an intensification of production through increasing land productivity, although not necessarily rising total factor productivity.

The southwest quadrant represents the type of farming practice likely to be the most benign with regard to the natural resource environment. However, the circumstances in which a farming system characterised by such practices is sustainable are not widespread, since such practices are generally static in terms of output per unit of resource and, when subject to the exogenous pressures such as population expansion and/or income growth, both of which increase the demand for agricultural output, shift in one of the directions indicated by the arrows. Within certain constraints agricultural policy will have a substantial influence on the speed of movement in any direction, and on the direction itself.

![Fig. 1. Hypothetical scatter plot of farm practices.](image)

2.2. The relationship between farming practice and environmental indicators

The diagram can be extended to capture the relationship between changes in farming practice and changes in the natural resource status, under the contention that there is at best a propensity for natural resource degradation, rather than an inevitability. Developing the distinction between extensification and intensification, two broad forms of environmental degradation can be considered:

1. any form of cropping exposes the land to the risk of soil erosion through a combination of wind and water. Within certain limits it is probably true to say that the more intensive these cropping practices become, the greater the risk of erosion, with consequent on-site and off-site costs.

2. the more intensive the land use activities, the greater the risk of environmental degradation from a number of other causes, including salinisation, chemical pollution and soil compaction.

Fig. 2 shows the implications in terms of potential environmental cost of a change in farming practices in a given direction. The shapes of the two cost functions\(^1\) \(C_1\) and \(C_2\) will vary with the particular context, especially with the patterns of temperature, rainfall and soil structure. The shape could also vary with the type of crop, since any variation in cultivation technique attributable, for example, to a change in the types or varieties of crop produced may change the magnitude of the environmental impact. Nevertheless, it can be expected that they will be broadly of the shape depicted here, with costs increasing more than proportionately with increases in cropping or land use intensity.

Separating the two functions, therefore, facilitates the separate consideration of the two underlying features of agricultural change: extending the extensive margin of cultivation (ploughing of virgin pasture, shortening of fallows, etc.) and extending the intensive margin of cultivation (typ-

\(^{1}\) Note that the total cost function, \(C_t\), cannot be represented graphically in two dimensional space.
Fig. 2. Farming practices and environmental implications.

Historically, a frequently observed pattern of change would be illustrated by movement from point A to point B, i.e. by an extension of the cultivated area followed by movement towards point D, as the available cultivable land is used up and more capital-intensive methods are adopted. A direct movement to point C may also occur in some farming systems as, for example, stocking rates increase owing to restrictions on the movement of livestock, or where the land is unsuitable for cultivation.

Continuous cereal production is more likely, in most circumstances, to lead to land degradation than adopting a balanced cropping mix which facilitates more general ground cover and nutrient balance. The availability of artificial fertilisers can restore soil nutrients up to a point, but if the retention capacity of the soil is being undermined by lack of cover and/or crusting, then heavy use of fertilisers can lead to both acidification and the contamination of groundwater supplies. This key characteristic is described by the two cost functions where costs increase more than proportionately with the degree of extensification or intensification, indicating increasing marginal damaging both the higher the ratio of crop to other land use and the greater the level of land intensity.

Because the environmental costs associated with an expansion of cropped area will vary with the cropping pattern adopted, policy interventions will influence these costs through their influence on the incentive structure and through this on the type and range of crops produced. An intervention, which changes relative output prices, will also influence the relative profitability of individual crops. This would be manifested in Fig. 2 in a change in the slope of the cost function $C_1$.

Similarly, the intensification of production can involve a variety of different paths or factor combinations. Most importantly, in many developing country contexts it can involve a choice between more intensive use of labour or capital per unit of land area. The choice will depend, to a significant extent, on relative factor prices. The capacity of government to influence these, particularly through interventions affecting the price of working and fixed capital goods, is substantial. Frequently the choice will have consequences in
terms of environmental cost for example; the overuse of machinery leading to soil compaction, or the excessive use of chemical inputs leading to the contamination of water supplies. Analogously to the case of cropping activity, the influence of policy would be manifest in the shape of the $C_2$ curve, which could change in response to policy initiatives. The effect of policy and the overall influence of agricultural activity on the natural resource environment is depicted by shifts in the two cost functions $C_1$ and $C_2$. The total cost function demonstrates that a policy change can reverse, exacerbate or leave unchanged previous trends in natural resource degradation.

It is apparent that the movement from A to B can engender a variety of very different environmental impacts. Economic policy, for the reasons described above, can not only influence the way in which increased agricultural activity occurs, but also the way in which a given volume of output is produced, demonstrated by a variety of outcomes at, for example, point B. If we assume that the starting point for a typical or homogenous farm is A, and that policy changes imply that the typical farmer is presented with an incentive to increase crop production, the question arises as to whether an increase in crop production will be achieved by a move to B, where intensity remains constant but land in annual cropping increases, or C, where land under crops remains constant, but input use increases. The response will be determined by the technology or production system currently employed, which in turn will depend upon the relative prices of land to capital as characterised by land availability.

In circumstances where land is plentiful, the relative price of land will be low compared to that of capital inputs. Farmers are therefore unlikely to have the incentive to intensify unless there are tenurial constraints on their access to land. If there are no land constraints, it makes sense to extend the use of land and minimise the use of other inputs, i.e. capital and labour (Cleaver and Schreiber, 1994). Thus a movement towards B is likely to be the preferred response. In this case we could hypothesise, for example, that there would be an increase in the risk of natural resource degradation from soil erosion rather than an increase in pollution or acidification.

In some countries, however, for example, Bangladesh, there is no alternative but to continue to intensify agricultural production (Pagiola, 1995). At the same time, it should be noted that natural resource degradation is not an inevitable consequence of intensification; some modern technologies such as high yielding varieties, which require less pesticide application, can have the reverse effect. In these circumstances, the correct policy intervention might be to invest more in farmer education rather than on modifying policies affecting prices or resource access.

2.3. Incorporating the existing state of technology

In Fig. 3, hypothetical technology ‘zones’ have been mapped in the northeast quadrant of the diagram. It is assumed that farming practices characterised by so-called ‘traditional’ technologies, typically with low levels of capital and labour input per unit of land, will be located in zone I. At point a, agricultural activity is also characterised by a relatively small proportion of annual crop production: i.e. there has been little pressure on either the extensive or intensive margins of cultivation. Points b and e represent farming practices where the response to population pressure or increased incomes has led to an expansion of area under annual crops. Zone II depicts a zone of limited technical change characteristic of many developing country situations where there is limited use of chemical inputs and where labour inputs per hectare may be high compared to zone I. Zone III is more typical of so-called ‘modern’ agriculture, where both the intensive and extensive margins of cultivation (point g) have been extended as far as modern technology will allow. Point f is typical of some developing country agricultural activities where there is a dual system of ownership with a highly skewed form of land ownership which has resulted in an intensively operated but highly land-constrained subsector.

It is apparent that the significance of the starting point lies in the fact that the marginal unit of environmental cost (in terms of, for example, soil loss or nitrate pollution) associated with any shift from that starting point, is greater the more ex-
tensive or intensive is the existing system as alluded to previously. Of course, local contexts will vary considerably in these respects, and ideally the cost functions for each such context would be calculated. However, this would be an extremely data-intensive exercise, and in most cases, the more practical solution would be to use the ‘typical’ farm context and generalise from this.

The key point here, however, is that agricultural policy which brings about changes in farming practice will have different implications for the natural resource environment, depending on the point of departure. This implies that the type of environmental cost typically experienced at the margin in developed countries is often different to that experienced in developing countries. If farming practices are located in zone I, then the environmental costs associated with increased production are likely to be minimal, as suggested by a shift from a to c in Fig. 3, and the concomitant movements along the two cost functions. Similarly, a shift from d towards c would imply some increase in external costs, but proportionately less than for farmers using practices located in zone III. For example, the significance of an $x\%$ increase in the magnitude of an environmental indicator (such as water quality) is likely to be less in an extensively farmed region than in one that is already intensively operated. The relative significance is depicted in the cost functions, which illustrate increasing marginal external cost. In theory at least, the monetary valuation of the external costs associated with intensification or extensification would allow more informed trade-offs between the two to be made.\footnote{In practice the valuation of changes in all indicators is impractical and thus the framework developed in this paper can be used to determine the types of indicators that are likely to be most worthy of attention.} Given that most farmers in developing countries are likely to be operating close to point b in zone I or point c in zone II, agricultural policies designed to raise food production, for example, could therefore be used to encourage a higher uptake of fertiliser and pesticide use without having a major effect on environmental costs.
2.4. Implications of non-price policies

Policies such as land reform, infrastructure improvement and targeted credit schemes will also potentially lead to increased output. We can use the same descriptive framework to describe this process. In Fig. 4, the northeast quadrant of Fig. 3 has been reproduced and constraint lines introduced to demonstrate how barriers to resource access may result, in the context of population growth and/or rising incomes, in the diversion of farming practices towards more costly solutions in terms of natural resource degradation than would otherwise be the case.

If the starting point was at point d, for example, and land distribution was highly skewed, the bulk of farmers would be forced, in response to rising population and incomes, to adopt practices typical of point f rather than point c. From the perspective of the natural resource environment, this is the higher cost solution. A redistributive land reform in this context could produce environmental benefits.

An analogous case can be made with regard to non-price policies which improve the access of farmers to capital inputs. In many developing countries, so-called ‘modern’ inputs are simply not available to large numbers of farmers, for example, as a consequence of poor physical infrastructure, inadequate marketing infrastructures or lack of purchasing power during crucial time periods. If the starting point is at point b, this can ‘force’ the adoption of practices more typical of point e rather than the lower cost (in terms of natural resource degradation) point c. Policies to improve access, such as investment in physical and marketing infrastructures, and the provision of low cost credit can overcome this constraint and achieve environmental benefits.

From the discussion above it is apparent that the static, or shortterm, response to a policy change will depend upon the technology currently employed by farmers. In addition, the dynamic or longer-term response will depend upon how conducive the policy context is to the adoption of technologies, which impart lower overall costs on the natural resource environment.

3. An application to South African agriculture

The issue of natural resource degradation is a very topical one in a democratic South Africa, currently embarking on a significant land reform. Agriculture has in the past been dominated by the white commercial farming sub-sector. At the same time, there is widespread concern that agricultural activity, especially that practised by commercial farmers, has proved severely detrimental to the natural resource environment. This concern is centred particularly on the issue of soil erosion, which is perceived as a long-standing problem, and more recently on soil degradation through acidification and compaction. The rate at which water supplies are either being ‘mined’ by irrigated agriculture and forestry or reduced in quality through contamination from a variety of sources has also given rise to some anxiety.

Agricultural policy in South Africa has been characterised by a number of discrete stages, although for much of this century it has moved along a persistent path designed to first create, and then sustain, large-scale commercial farms owned and operated by white farmers. The policy environment that characterised the ‘apartheid era’ has been adequately documented elsewhere (see for example, van Rooyen et al., 1994; World Bank, 1994). Among the many policy characteristics of this infamous period, it is relevant to stress here: the post-war accent on self-sufficiency which resulted from the increasing isolation of the

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Fig. 4. Effects of barriers to resource access.
regime, and its consequences in terms of increasing levels of support and a high degree of border protection. Both the economic and environmental costs of this approach became increasingly evident, however, and the emergence of a more ‘liberal’ approach during the late 1980s, has coincided in recent years with political liberalisation and the end of apartheid (LAPC, 1993).

From an extensive review by McKenzie (1994), it is apparent that the principal problems affecting the natural resource environment which stem from agricultural activity in South Africa are the high rate of soil loss through erosion, by both wind and water, and soil degradation through compaction and acidification. These impacts can be considered as resulting from the extensification and/or intensification of agriculture. A series of potential links between agricultural activity and the natural resource environment are suggested:

- The extension of the arable area onto soils and slopes unsuited to cultivation has greatly increased the rate of soil erosion. This has been due to the encroachment of cereal, particularly maize, cultivation on soils unsuited to arable cropping; and the extension of agricultural activity, particularly sugar-cane and possibly timber production onto inappropriate gradients.
- Overstocking of livestock has contributed both to soil erosion and soil compaction.
- High levels of soil acidity have been exacerbated by over-use of (particularly) nitrogenous fertilisers and too little application of lime.
- Investment subsidies have led to inappropriate capital/labour ratios in agriculture, and excessive use of heavy machinery has contributed to problems of soil compaction.

The discussion in the preceding part of this paper highlighted the different implications of relative prices on the one hand, and constraints on resource access on the other. Given the data limitations, however, it is not feasible to review the South African example using the same dichotomy. Instead, the following analysis concentrates on those factors leading to an extension in the margin of cultivation, and those leading to intensification.

### 3.1. Extending the margin of cultivation

The increase in the proportion of farmland under cultivation, or the decline in the area under permanent natural pasture, has been one of the factors contributing to the level of soil erosion. There are no time series data available for natural resource degradation to match with the changes in land use, but circumstantial evidence suggests that the breaking up of permanent pastures in areas of low and variable rainfall, and where soils have a low clay content, has contributed substantially to the current degree of soil degradation.

Examination of the data in Table 1 shows that while the cultivated area grew during the 1960s and into the 1970s, cultivation of cereals, particularly maize and wheat, grew at a faster rate. That

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Table 1
Changes in land use (thousand hectares) and in livestock numbers

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivated area</td>
<td>7589</td>
<td>8453</td>
<td>8446</td>
<td>7702</td>
</tr>
<tr>
<td>Total cereals</td>
<td>6634</td>
<td>7285</td>
<td>6765</td>
<td>5676</td>
</tr>
<tr>
<td>Maize</td>
<td>4230</td>
<td>4399</td>
<td>4263</td>
<td>3399</td>
</tr>
<tr>
<td>Wheat</td>
<td>1345</td>
<td>1986</td>
<td>1795</td>
<td>1242</td>
</tr>
<tr>
<td>Sugar</td>
<td>258</td>
<td>326</td>
<td>385</td>
<td>375</td>
</tr>
<tr>
<td>Forest</td>
<td>1044</td>
<td>1101</td>
<td>1148</td>
<td>1815</td>
</tr>
<tr>
<td>Natural pasture</td>
<td>82 476</td>
<td>71 089</td>
<td>70 137</td>
<td>67 934</td>
</tr>
<tr>
<td>Cattle (million)</td>
<td>11.04</td>
<td>7.78</td>
<td>8.47</td>
<td>8.63</td>
</tr>
<tr>
<td>Sheep (million)</td>
<td>34.84</td>
<td>32.81</td>
<td>30.90</td>
<td>29.41</td>
</tr>
<tr>
<td>Pasture/LS unit (ha.)</td>
<td>5.15</td>
<td>4.96</td>
<td>4.79</td>
<td>4.68</td>
</tr>
</tbody>
</table>

*Note: a livestock unit is calculated by dividing sheep numbers by seven and adding to cattle numbers. Source: derived from Gander and Forster (1994), Roth et al. (1992), RSA (1995).*
Table 2
Linking land use and agricultural policy

<table>
<thead>
<tr>
<th>Year</th>
<th>$X$</th>
<th>$Y$</th>
<th>$R^2$</th>
<th>Significant at 95%</th>
<th>Significant at 99%</th>
<th>df</th>
<th>$t$-stat</th>
<th>$F$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961–1993</td>
<td>Maize input/output price ratio</td>
<td>% Age maize in total cropped area</td>
<td>0.55</td>
<td>✓</td>
<td>✓</td>
<td>31</td>
<td>6.07</td>
<td>36.88</td>
</tr>
<tr>
<td>1981–1990</td>
<td>Maize/wool price ratio</td>
<td>Maize area</td>
<td>0.24</td>
<td>✓</td>
<td>✓</td>
<td>10</td>
<td>1.59</td>
<td>2.53</td>
</tr>
<tr>
<td>1960–1980</td>
<td>Maize/cotton price ratio</td>
<td>Maize area</td>
<td>0.33</td>
<td>✓</td>
<td>✓</td>
<td>19</td>
<td>−2.95</td>
<td>8.72</td>
</tr>
<tr>
<td>1961–1993</td>
<td>Maize/wool price ratio</td>
<td>Maize area</td>
<td>0.28</td>
<td>✓</td>
<td>✓</td>
<td>19</td>
<td>−3.41</td>
<td>11.60</td>
</tr>
<tr>
<td>1961–1993</td>
<td>Maize comm. ToT</td>
<td>Sugar prices</td>
<td>0.71</td>
<td>✓</td>
<td>✓</td>
<td>31</td>
<td>8.48</td>
<td>71.83</td>
</tr>
<tr>
<td>1960–1981</td>
<td>Sugar prices</td>
<td>Forest area</td>
<td>0.40</td>
<td>✓</td>
<td>✓</td>
<td>22</td>
<td>3.64</td>
<td>13.22</td>
</tr>
<tr>
<td>1981–1993</td>
<td>Sugar prices</td>
<td>Forest area</td>
<td>0.80</td>
<td>✓</td>
<td>✓</td>
<td>12</td>
<td>−6.69</td>
<td>44.77</td>
</tr>
</tbody>
</table>

*Source: authors’ calculations.*

these trends have since been partially reversed does not detract from the likelihood that the period including the 1960s, and possibly starting earlier, witnessed a sharp upturn in the extent of arable cultivation in marginal areas, and concomitant increase in soil erosion. Not only is the expansion of cropped area driven by the growth in cereal production but, since the latter grows at a faster rate than the former, there may also have been an increase in the degree of continuous cereal production. The latter exacerbates the loss of groundcover and the possibility of soil erosion. Thus, there is some empirical evidence to corroborate the premise that there has been an encroachment of cereal production onto marginal lands, and that this may also have been accompanied by rotational changes in farming systems. The question remains, however, as to the extent to which these developments can be linked to agricultural policy. Possible links can be developed through an examination of commodity price policy because the latter has been the Lynch pin of government support to agricultural production, particularly with respect to cereals.

Analysis of the commodity terms of trade and relative crop price ratios reveals some evidence, albeit limited, to suggest that agricultural price policy may have been an important factor in engendering the expansion in the cultivated area. The values in Table 2 demonstrate (through correlation coefficients) the strength of relationships between the policy variable ($X$) and the consequences for farming practice ($Y$ variable).

The crucial period of expansion is that from 1960 to the mid-to-late 1970s, and it is during this period that the relative price of maize favoured the cereal expansion that occurred. Thus, it seems likely that relative prices were important in shaping cropping patterns and rotations. The expansion of cereal cultivation, however, in so far as it took place in marginal areas, encroached on rangeland or natural pasture. In this respect the most common competitive output would be from sheep. Wool production is one of the principal outputs from natural pasture, and the conclusion that agricultural price policy was at least partly responsible for the encroachment of arable cultivation onto marginal lands is reinforced by the observation that the maize/wool price ratio has risen consistently for much of the period of expansion in maize area. The price ratio fell back subsequently, again partially explaining the fall back in the area of maize cultivated.

Expansion of the cultivated area often occurs as a result of the cultivation of inappropriate terrain. Most concern has been expressed regarding this issue with respect to the cultivation of sugarcane in the KwaZulu–Natal Region. It is here that the
Table 3
Linking agricultural policy and intensification of farming practices

<table>
<thead>
<tr>
<th>Y</th>
<th>X</th>
<th>Year</th>
<th>$R^2$</th>
<th>Significant at 95%</th>
<th>Significant at 99%</th>
<th>df</th>
<th>t-stat</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fert. exp. per ha.</td>
<td>Value of fert. subsidy</td>
<td>1960–1970</td>
<td>0.75</td>
<td>✓</td>
<td>✓</td>
<td>11</td>
<td>5.14</td>
<td>26.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1970–1980</td>
<td>0.81</td>
<td>✓</td>
<td>✓</td>
<td>10</td>
<td>−6.32</td>
<td>39.91</td>
</tr>
<tr>
<td></td>
<td>Fert. exp. per ha.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stocking density</td>
<td>Maize/wool price ratio</td>
<td>1960–1980</td>
<td>0.28</td>
<td>✓</td>
<td></td>
<td>19</td>
<td>2.66</td>
<td>7.05</td>
</tr>
<tr>
<td>Stocking density</td>
<td>Maize/stock price ratio</td>
<td>1960–1980</td>
<td>0.30</td>
<td>✓</td>
<td></td>
<td>19</td>
<td>−2.77</td>
<td>7.68</td>
</tr>
</tbody>
</table>

*Source: authors’ calculations.*

bulk of the sugar cane is produced, and where there is competition for land between timber and sugar cane production. Production of these crops has expanded considerably in recent years, with the area devoted to each growing significantly and, in the case of sugar cane, yields also increasing. There is no direct evidence to quantify the extent to which the expansion of either of these activities has led to cultivation of hitherto uncultivated slopes, but there is substantial anecdotal evidence. From the perspective of soil erosion, timber production can be a preferred alternative to sugar cane, but this has its own problems since forests can be heavier users of scarce water resources.

The link to agricultural policy is tenuous, but not altogether without substance (Table 3). In spite of falling real sugar prices during the 1980s, changes in policy with regard to sugar production facilitated an expansion in small-scale sugar production, which exacerbated the trend towards hillside cultivation. The negative correlation between sugar-cane prices and area under timber production suggests that the expansion in sugar-cane production would have been more pronounced with more severe consequences had it not been for the relative rise in returns to timber production.

3.2. The intensive margin of cultivation

Not only the proportion of cultivated land to the total, but also the management of cultivated land is important in determining the sustainability of agricultural practices, and it is apparent that intensification of production methods has also been a factor in the degradation of the natural resource base. For example, livestock numbers have not fallen in line with the area of rangeland available for grazing, suggesting more intensive grazing and (conjectural) overstocking, especially because the traditional rangeland animals are sheep rather than cattle.

The data also show that there was an increase in stocking density after 1970, although it is probable that it was falling prior to this date. Certainly the index of livestock numbers fell during the 1960s, reflecting a fall in both sheep and cattle numbers, and numbers have not since recovered to the levels of the late 1950s. The fall in stocking intensity is due to the decline in the area under natural pasture, rather than to any increase in numbers. Agricultural policy may have influenced these trends in two ways: (a) by influencing activities in the livestock sub-sector directly; and (b) through the impact on the relative profitability of crop and livestock production. In addition, growth in the use of chemical inputs as well as anecdotal evidence suggesting a growth in monocropping point to the potential creation of environmental problems through intensification of production.

The environmental concerns of soil acidification and soil compaction were investigated with respect to policy regarding agricultural inputs. Acidification can be linked, a priori, to the non-optimality of total fertiliser use, the latter acting as a proxy for nitrogenous fertilisers. Application of fertilisers in terms of the real value applied per
hectare expanded substantially during the 1960s and 1970s, before declining and then levelling off in the 1980s. In the absence of appropriate data any association between changes in fertiliser use and in the level of soil acidity is only conjecture; nevertheless, the fact that quantities applied followed the observed pattern suggests that application exceeded the optimal, particularly during the early 1970s. The partial correlation between fertiliser subsidies and use per hectare does suggest that the policy of input subsidisation played a role in this.

4. The implications for policy

The discussion in this paper has assumed that agricultural policy can impact on the natural resource environment through farming practice. At the same time, many of the undesirable consequences of agricultural activity in this respect can be mitigated through the simultaneous adoption of conservation measures. The extent to which such measures are adopted will depend not only on the private (as opposed to social) costs and benefits, but also on the effectiveness of the extension service and on environmental policy.

The previous discussion concluded that there were some grounds for believing that agricultural policy had influenced agricultural activity in South Africa in a way which may have been harmful to the natural resource environment. The most apparent ways in which this may have been the case are with respect to: (a) the relative incentives provided to cereal production compared to livestock production (particularly wool), leading in the 1960s to a rapid expansion of the area under cereal cultivation; (b) the probability that fertiliser use was greater than optimal; and (c) the high levels of protection afforded the sugar-cane sector and the consequent expansion of cultivation onto inappropriate terrain.

The assumption that agricultural policy could influence the extent to which the natural resource base is degraded or eroded may be a tenable one, but there is no agreement concerning either the direction or extent of influence. Successful environmental policy requires a combination of three principal components: knowledge of environmental status and the ability to monitor it at the local level; the legislative framework or set of laws and codes of practice governing farmers' activities (environmental policy per se); and the will and ability to implement the policy.

In many cases none of these are present, and it is probably rare that all three combine in an effective manner. In South Africa the Soil Conservation Act was designed to institute preventative action through the establishment of Soil Conservation Committees in 1946, which were committees constituted and run by the local farming community. They were designed to place responsibility for the implementation of environmental policy in the hands of farmers themselves, exercised through the committees invested with the necessary powers to monitor and prosecute farmers for failing to take appropriate soil conservation measures. Other legislative efforts included a drought insurance scheme for stock farmers, a veld reclamation scheme and a stock reduction scheme.3

It is estimated that R130 million was spent by the Government of South Africa on financial aid for soil conservation between 1948 and 1983, prior to the Conservation of Agricultural Resources Act. The Soil Conservation Scheme was established under the latter Act and implemented by the Soil Conservation Committees. The Scheme provides subsidies or low-interest loans for soil conservation works such as the construction of weirs, storm water furrows, contour banks and cover cropping; drainage; veld utilisation programmes such as fencing and watering systems; and drought relief activities such as fodder storage facilities and feed paddocks. Between 1988 and 1993, subsidies to the value of some R37 million were paid for soil conservation efforts through the scheme, and around R13 million provided through low interest loans.

While payments under the Act were substantial, the enforcement of conservation policy was weak. There were very few successful prosecutions (Barlow, 1995). It appears that the policy of allowing

3 The following review of soil conservation policy in South Africa is largely based on Barlow (1995).
farmers to police their own activity through the Soil Conservation Committees did not prove successful. The necessary legislative framework may be in place, but the means and will to implement it are perhaps absent.

If the options for changing land use are limited, the onus shifts to environmental (or conservation) policy to protect the natural resource environment. ‘Free’ markets for agricultural produce, at least as far as the major staple commodities are concerned, do not exist anywhere and are unlikely to exist in the future, although there is a trend towards less intervention and more transparency, at least in developing countries. Governments, including the South African Government, will continue to intervene in some respect. The question then arises as to whether such intervention (in the form of agricultural policy) should take account of any prospective environmental consequences, or whether conservation is the exclusive domain of environmental policy.

There is no straightforward answer to this question, but knowledge of the consequences of policy action is a necessary starting point. At the same time, it is most probably fair to conclude that the greater the number of targets attributed to any single policy intervention, the less it is likely to achieve any.

5. Concluding remarks

It is important for policy makers to realise that a specific policy change can have a wide array of potential impacts upon the natural resource environment, depending upon the wider policy context and the type of technology currently employed. As demonstrated with the South African application, it should be possible in a limited information scenario, to trace the likely response of farmers with regard to the practices used in agricultural activity, in order to achieve an a priori indication regarding which natural resource indicators should be monitored, and what complementary measures are likely to be necessary in order to offset any unacceptable environmental costs.

Definitive conclusions in a study of this kind are hard to draw. The use of aggregate data often masks as much as it reveals. In addition, although South Africa is better placed than many countries, particularly other developing countries, with regard to the documented knowledge of environmental degradation, the lack of local (or even regional) estimates, and of time series data, makes correlation with specific agricultural policies little more than conjectural. The evidence suggests that such links can be made if routed through variables associated with farming practice, but the argument remains for the present largely circumstantial. It should be stressed, however, that the approach outlined in this paper is merely designed to preface more detailed research prior to policy implementation. In particular, more empirical investigation would be required to: (1) classify farming practices in terms of (a) the technology employed and (b) how close existing systems are to the margin; (2) determine the extent and trajectory of the environmental costs as represented by the shape of the cost curves.

It is also apparent that in the analysis we have not attempted to incorporate the effects of conservation measures and the effects that extension and other environmental policy interventions might have in terms of the adoption of more sustainable farming practices. An extension of the above to incorporate such interventions into the analysis in a similar manner to that describing alternative economic policies would, however, be relatively straightforward.

References


