Royal Geographical Society with IBG
Advancing geography and geographical learning
AREA

Area (2010) 42.3, 359–368 doi: 10.1111/j.1475-4762.2009.00928.x

Environmental change and adaptation in degraded agro-ecosystems: the case of highland Madagascar

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Revised manuscript received 27 October 2009

While the view that the poorer agricultural populations in developing countries will be at the forefront of negative consequences due to environmental change is widely accepted, this perspective must become considerably more nuanced in order to recognise and take advantage of emerging opportunities for realistic adaptation. This paper presents a case from Madagascar that suggests adaptation opportunities involve more than looking for alternatives to what are presently perceived to be negative socio-ecologic processes. In Madagascar the severe erosion occurring on the deforested central plateau actually appears to create, over time, opportunities for increased food security and environmental management compared with uneroded portions of the same landscape. The paper proposes that while concern and action are needed to attend to the problems that the poor of the developing world will face due to impacts from environmental change, the repercussions of such change on agricultural systems also need to be looked at in ways that involve recognising the local and aggregate potential opportunities that they may present in certain systems, in order to realise the prospects for adaptation.

Key words: *Madagascar, environmental change, adaptation, land degradation, erosion*

Introduction

As the scientific, policy and applied efforts focused on global environmental change and in particular climate change move forward, increasing attention is focused on the ability of societies to adapt. Generally it is thought that among the most vulnerable to such changes will be the rural poor who occupy degraded and marginal environments in the developing world. This is because these populations depend most directly on natural resources for livelihoods, but at the same time do not possess options for planning and management that are open to others occupying more optimal agricultural environments (e.g. Dilley and Boudreau 2001; Kelly and Adger 2000; Downing 2002; Eriksen *et al.* 2005; Beg *et al.* 2002; Reilly and Schimmelpfenning 1999; Eakin and Luers 2006; Mendelsohn and Dinar 1999). Africa is of particular concern in this regard (e.g. Magadza 2000; Smith and Lenhart 1996; Mohamed *et al.* 2002; Toulmin *et al.* 2005; Black 2006). However, such a broad approach to peoples and areas as 'most vulnerable', while enjoying a certain logic, lacks acknowledgement of the many directions that land degradation takes, and how this intersects with local innovation and unexpected forms of adaptation that may significantly decrease livelihood vulnerability. This paper argues that the impacts of environmental change on agricultural systems in the

ISSN 0004-0894

developing world need to be looked at in ways that include recognising the potential opportunities that such impacts may themselves present in certain systems, in order to more comprehensively understand the possibilities for adaptation.

This article makes a preliminary examination of a case from Madagascar, which suggests that adaptation opportunities can include variations that actually take advantage of what are presently perceived to be negative socio-ecologic processes associated with environmental change. This may particularly be the case where such processes have already moved certain agricultural systems into serious land degradation and food insecurity. While additional data-gathering is needed, we present preliminary findings here based on qualitative observations and the literature, and comment on possible lessons learned.

The Malagasy highlands

Madagascar's highlands cover approximately one-fifth of the island and the physiography varies between rolling hills, plains, incised valleys, rolling and volcanic cones and massifs (Kull 1998). The area is occupied by the Merina and Betsileo ethnic groups and is one of the most populated regions of the country, with more than six million people, and a population density of over 200 people per km^2 (Kull 1998). The indices of poverty in the highlands are among the highest in the country (Mistiaen 2002). Historic vegetation comprised mosaics of forest in riparian areas, woodlands, grasslands and heath (Kull 1998). With the onset of human occupation in the 13th century, there was increased burning for agriculture, hunting and pasture, which resulted in significant grassland expansion (Kull 1998; Burney 1997; Dewar and Wright 1993).

Figure 1 The central highlands of Madagascar
Source: Simmon (2004)

Land degradation

Deforested and eroded landscapes are important outcomes of environmental change, and contribute to compromised agricultural systems, food security and livelihoods (e.g. Kakembo and Rowntree 2002; Clay and Lewis 1990; Jarosz 1993; Poesen *et al.* 2003; Mushala 1997; Lal 2001). Deforestation and soil erosion in Madagascar have received significant attention, with numerous studies describing severely degraded highland ecosystems and agriculture (e.g. Gade 1996; Kull 1998; Jarosz 1993; Tricart 1953; Sussman *et al.* 1994). The Malagasy central plateau (Figure 1) has been the site of land degradation since the onset of human occupation of the island, with deforestation resulting in a largely treeless region, pocketed by extreme forms of erosion which are tied to human use of the landscape (e.g. Wells and Andriamihaja 1993; Tricart 1953; Wells *et al.* 1991). Erosion in highland Madagascar frequently manifests itself in very large numbers of deep cuts and collapsed hillsides (*lavaka*), mudflows, slumping and mass flows. The *lavaka* and associated processes are particularly pervasive (Plate 1). These form an initial cut or gap in a hillside, and then widen and lengthen over time to become much longer and broader landscape features (Wells *et al.* 1987). Plates 2–4 illustrate such a progression.

A review of the prototypical erosional process in the central highlands posits a range of anthropogenic and

ISSN 0004-0894

Plate 1 Land degradation on Madagascar's central highlands
Photo: WildMadagascar.org

Plate 2a Fresh *lavaka* cut, eroded into hillside
Photo: Team Lavaka Image Collection, R Cox

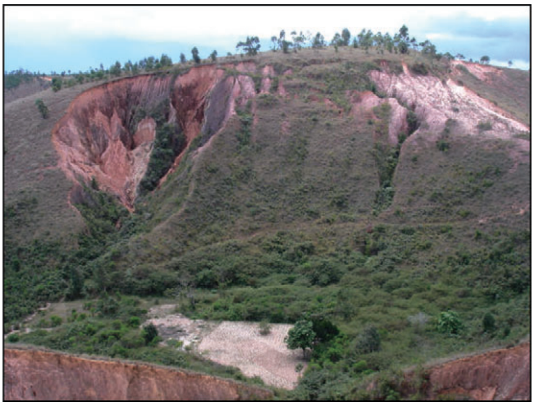

Plate 2b Relatively new *lavaka*, with manioc field on outflow
Photo: Team Lavaka Image Collection, R Cox

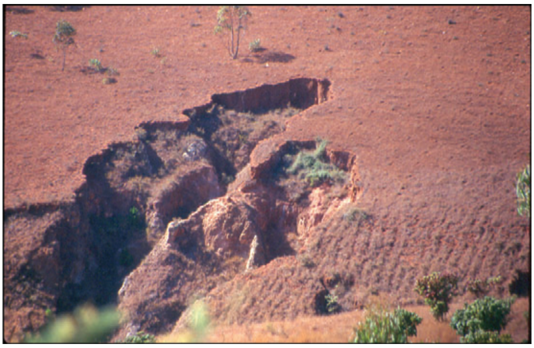

Plate 2c Newly forming *lavaka*
Photo: J. Unruh

natural causes over time (Wells *et al.* 1987 and Wells and Andriamihaja 1993 and the references cited therein; Harvey *et al.* 1985). The human factors include historic creation of fortifications on hilltops, the formation of tracks and trails by humans and livestock, overgrazing, deforestation, the construction of canals and rice paddies, the placement of agricultural fields on denuded hills, use of fire to promote pasture prior to the onset of the rainy season, and the deliberate initiation of *lavaka* in order to purposefully alluviate valley floors so as to create large, flattened areas for rice cultivation (Gade 1996; Kull 1998; Jolly 1987; Wells and Andriamihaja 1993; Paulian 1984; Gallegos 1997). Natural processes include an interaction of progressive drying in the late Holocene (MacPhee 1986), rainfall and runoff together with bare surfaces, large-scale mass movements of soil, small-scale earth falls, soil slips, the presence of subsurface water and localised groundwater outflow (Wells and Andriamihaja 1993). Climate change due to human activities is also thought to be a significant factor, with Wells and Andriamihaja noting that

> [t]emperature, and/or rainfall shifts, changes in storminess, timing of rains, changes in seasonal wetting and drying cycles, and the like could easily affect vegetation and erosion in many ways. (1993, 31)

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Plate 2d Recently burned, older *lavaka*
Photo: J. Unruh

Plate 3a Cultivation in outfall area of vegetated, lightly active *lavaka*
Photo: Team Lavaka Image Collection, M Jungers

Plate 3b Bananas and fields in outfall area of largely inactive, vegetated *lavaka*
Photo: Team Lavaka Image Collection, R Cox

Plate 3c Trees colonising active *lavaka*
Photo: Team Lavaka Image Collection, R Cox

The interaction of human and natural influences has resulted in an enormous increase in the occurrence of erosional features on the highland landscape over time, as population increase, problematic land tenure, a variety of land-use practices and biophysical processes operate together (Gallegos 1997; Wells and Andriamihaja 1993).

From erosion to agriculture

While the biophysical formation of *lavaka* has been well elaborated by Wells *et al.* (1991), Wells and Andriamihaja (1993) and Gade (1996), what has not been examined is how local inhabitants are able to take advantage of the widespread presence of these erosional features once they have become pervasive across highland landscapes, to further their development so as to improve food security and livelihood resilience. Of interest in an adaptation context is this development over time. Wells *et al.* (1991) outline the various stages of *lavaka* maturation, from an initial sharp incision, to much larger more worn features. As the walls of *lavaka* erode, retreat and become more rounded, they grow much wider and longer. They can expand to reach the valley floor, and can eventually end up as significant side-valleys (Wells *et al.* 1991). The more mature *lavaka* are then the focus of intensive agricultural activity by local inhabitants (Plates 4a–c). This occurs in part because rains, runoff and continued erosion deposit soil (and associated nutrients) into concentrated locations within these cuts and at the outflows, providing favourable localised conditions in which to plant annual and perennial crops, pursue terracing activities, and control how further erosion and deposition occurs. With continued modification

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Plate 3d Agriculturally occupied *lavaka* outflow
Photo: Team Lavaka Image Collection, M Jungers

Plate 4b Mature *lavaka* with crops and trees
Photo: J. Unruh

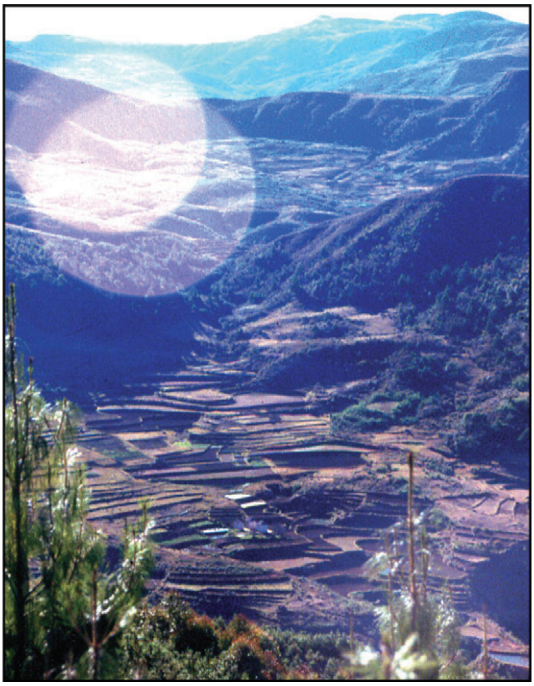

Plate 4a Mature *lavaka* as a side valley with intensive agriculture
Photo: J. Unruh

Plate 4c Mature *lavaka* with terracing and homestead buildings (lower centre)
Photo: J. Unruh

by local inhabitants, the rugged nature of the cut changes over time to become an intensively managed tree–crop association.

Plates 2–4 illustrate the progression of *lavaka* for the purpose of agricultural adaptation to the opportunities such features provide, or can be managed to provide. Plates 2a–d show young *lavaka* as raw cuts in hillsides. Plates 3a, b and d show a series of more mature *lavaka* with some initial agricultural management including cultivated fields and agroforestry on the outflow at the foot of the *lavaka*. Plate 3c is a photograph of natural tree colonisation inside of a *lavaka*. Plates 4a–c illustrate developed crop agriculture in still more mature *lavaka* which have grown to become small side valleys. Evident in Plate 4 is the intensive management of agriculture, particularly with regard to terracing. Plates 5a and b illustrate the prevalence of *lavaka* on the landscape from air photos, and the overall presence of vegetation (especially woody vegetation) which reside primarily within or associated with these erosional features. For all photos note that there is almost no agriculture and very little tree presence

ISSN 0004-0894

Plate 5a Air photo of numerous *lavaka*
Photo: J. Unruh

Plate 5b *Lavaka* colonised by tree regrowth
Photo: J. Unruh

outside of the *lavaka*. This is particularly evident when aerial views are examined (Plates 5a, b).

The length of time it takes for *lavaka* to become productive is an important, albeit complicated, question. While this study did not examine this specifically, and it goes unreported in the literature, a number of variables are important in the time required for a *lavaka* to attain some form of productivity. Presumably if a farmer were to initiate the creation of a *lavaka* this would perhaps indicate the prospect of at least a medium-term return in terms of productivity in some form. In addition, certain parts of *lavaka* will be productive earlier than others. Outflows at the foot of *lavaka* for example will likely be productive more quickly, especially for annual crop production, than the more interior components which can still be undergoing relatively early stages of erosion at the same time. Certain locations within *lavaka*, such as places of significant soil and water deposition may be selected earlier for planting economic trees, while other parts of a *lavaka* will be developed at a later time. Also the level of attention given to the development of *lavaka* by farmers will be variable. The amount of time in a given month or year that a farmer is able to devote to the productive development of a *lavaka* will have a significant influence on the time needed for a *lavaka* to attain productivity. As well, any given farmer may have a few *lavaka* that are intensively invested in, developed and used, while other *lavaka* the same farmer owns receives less attention and so will take longer to develop into a particular stage of productivity. Tenure security will also likely play a role. The link between tenure security and investment by small-scale agriculturalists is well established, such that if farmers believe they do not have security of tenure, then they will be less likely to invest (particularly with regard to investments such as terraces and tree crops). Then there is the definition of 'productivity' from the perspective of the farmer. Utility and value from *lavaka* can be realised from a variety of different kinds of useful *lavaka*. Even *lavaka* with only naturally occurring trees can still be 'productive' and useful for the minor forest products they produce. At the other end of the continuum of course are very intensively developed *lavaka* with stands of economic trees, terraces and residences.

The Madagascar case provides an example where severe land degradation – one of the repercussions of environmental change – may provide unexpected opportunities for adaptation. This occurs as landscapes become 'loaded' with numerous features of degradation (Plates 5a, b) that are more pronounced (erosion) than the initial form of degradation (deforestation). In this case the more acute form of degradation is what is managed, and what presents the opportunity for adaptation. The frequency of agriculturally occupied erosional features in the highlands, together with the frequency of those that contain primarily woody biomass from which minor forest products are collected, in aggregate, present the possibility for greater livelihood resilience and food security at the local to

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landscape scale than if such features did not occur on the denuded highlands.[1]

Lessons learned

The prospects for 'lessons learned' for this type of adaptation exist at three levels:

1. local, customary approaches for management of individual *lavaka* or sets of *lavaka* and their immediate surroundings
2. the national development approaches for planning and management of agricultural and conservation projects, and
3. the more global treatment of options for adaptation to environmental change and the prospects for mitigation of such change.

At the local level, communities in highland Madagascar are certainly aware of the opportunities that *lavaka* present, hence their interest in encouraging their formation and their ability to develop them. For such communities, adaptation involves both considering where on the landscape initiating the hillside collapses that subsequently turn in to useful *lavaka* might be employed, and where and how to utilise naturally occurring *lavaka*. The existence of intensive agriculture within mature *lavaka* (Plates 4a-c) attests to the existence of fairly well-developed strategies on the part of local households and communities. Purposeful management strategies at this level appear to focus on localised needs for agricultural production within cultivated *lavaka*, and fuelwood and other minor forest products available from nearby *lavaka* containing stands of woody vegetation growth (Plate 3c). Thus in agricultural *lavaka,* management focuses on planting annual and perennial crops in and along crevices (especially in younger *lavaka*; Plates 3a, b and d), and the construction of terraces and their agricultural management in the more mature *lavaka* (Plate 4a–c). In both younger and older *lavaka*, agricultural management of outflows at the bottom for both annual and perennial crops is evident (e.g. Plates 3a, b, d).

At the national level the lessons allowing recognition and use of local adaptations that may develop in unexpected or counterintuitive directions would need to begin with a departure from the conservationist paradigm which holds there to be a set desired directional response to land degradation – essentially reversing degradation. As this case shows, forms of degradation themselves (e.g. erosion in this example) can, under certain circumstances, be useful to forms of adaptation. In this context the specific lesson would be the need to look beyond what appear to be detrimental components of smallholder responses to environmental change (erosion and hillside collapse in this case) to a more comprehensive planning process that allows for such components to be viewed as having possibilities other than increased degradation and the resulting increase in population vulnerability only. And while degradation processes, features and local responses will certainly not always contain the prospect of positive adaptation, when they do, their potential can be missed if there is not the strategic awareness of this possibility.

In this regard top-down planning and management approaches are problematic in that they can assume there are no valuable counterintuitive environmental management approaches that could emerge from the local level, and as a result these can remain unrealised. For national-level development planning, it can be productive to first examine what local populations are already doing and the possible directions it may take them. One of the more general themes that this case illustrates about the process of adaptation is that for people who continue to live in degraded and very degraded environments an important question is what are they currently doing to (a) continue to be able to live in such an environment and (b) to try to move agricultural and resource exploitation possibilities in new directions.

At the international policy level, two potential lessons are important: the prospect for applying the approach elsewhere and the aggregate, large-scale implications and repercussions of population-wide forms of adaptation or conservation, such as forms of carbon sequestration in woody biomass and improving food security. With regard to the former, Wells *et al.* (1991) note that Malagasy *lavaka* are similar to features described in Brazil and New Zealand, such that a very similar approach may be applicable in other countries. At the aggregate scale, policy priorities can suffer from a variety of international to local top-down problems, including

1. favouring (and hence supporting) what is perceived to benefit aggregate (e.g. international) scale goals
2. a non-appreciation of locally derived approaches to adaptation that have local benefits, and
3. the design and implementation of on-the-ground projects which presume that a set of benefits will accrue to local populations, when in reality their adoption can be difficult.

ISSN 0004-0894

The problematic nature of 'benefits' with regard to internationally recognised adaptation directions and projects has received little attention in the adaptation literature but is relevant to the Madagascar case. The primary problem is that predicted benefits to communities as a result of top-down adaptation approaches are not compared with benefits already in existence at the local level which would be changed or lost with the implementation of such adaptation schemes. How the two sets of benefits compare in quantity, quality, type, functionality and in particular who within communities will gain and lose with a change from one set to the other is fundamental to the realisation of benefits associated with adapting to new situations and hence the adoption of new approaches. Unfortunately the literature regarding benefits associated with adaptation does not engage such a comparison. Instead what is described are generalised ideas of 'benefits' for local communities, along with the assumption that such benefits will entice adoption of changed practices (e.g. May *et al.* 2003; Jindal *et al.* 2008; Brown *et al.* 2001; Pagiola *et al.* 2002; Toulmin *et al.* 2005; Smith 2002; Bloomfield and Pearson 2000; Klooster and Masera 2000; Saunders *et al.* 2002).

At the final plenary of a recent conference on Food Security and Environmental Change (Global Environmental Change and Food Systems 2008), a number of points were highlighted as primary policy-relevant conference outcomes. Among these, four are strongly supported by the Madagascar case presented here:

1 that indigenous knowledge and 'high science' should come together to gain insight into the prospects for adaptation
2 the importance of communities' role in innovative approaches to adaptation, and in integrating these into broader adaptive systems, as opposed to considering the broader food system as the first priority and then working down to the community level
3 the need to look at what works where and why, and the value of forming typologies of what works in specific localities and how to aggregate up from these experiences, and
4 the need to guard against dictating forms of adaptation from the top down (Global Environmental Change and Food Systems 2008).

Conclusion

This very preliminary consideration of the potential utility of *lavaka* does not assess the quantity of food derived or the number of people involved. Instead the intent here is to provide an initial awareness of the potential adaptive response. While more detailed description and analysis is needed, what is already clear, particularly given the intensive agricultural use of *lavaka* (Plate 4), is that as policies and development initiatives increasingly prioritise adaptation to environmental change, they need to consider becoming more nuanced and innovative (including considering the counterintuitive) with regard to approaches to agricultural and natural resource planning, management and conservation in order to support the local derivation of forms of adaptation.

Presently our understanding of the operative mechanisms and the nature of local capacity regarding different types of adaptation among the poor occupying degraded or problematic landscapes of the developing world is weak. What this case illustrates about the process of adaptation is that such capacity is not defined and does not operate in only one way (i.e. the ability to engage in conservation of a current or earlier set of resources). Indeed a couple of authors have begun to examine considerable variation in adaptive responses (Scherr 2000; Mortimore and Adams 2001; Sendzimir and Flacher 2007). We do not have sufficient knowledge of the many ways that adaptation could work or could emerge.

While the reality that the poorer agricultural populations in developing countries will be at the forefront of negative consequences due to environmental change and particularly climate change is widely accepted, this perspective must become considerably more elaborated in order to recognise and take advantage of unexpected opportunities for adaptation. As Madagascar illustrates, some forms of degradation can themselves become opportunities for adaptation. The notion that 'the poor are most vulnerable', while perhaps useful in an aggregate sense, begins to lose utility as research on adaptation progresses, and local adaptations emerge on their own with very different operative understandings with regard to the constraints and opportunities that result from environmental change.

Note

1 Use of erosional processes to expand food security opportunities are also known elsewhere. In Sonora, Mexico, erosional deposition in desert landscapes is controlled with the construction of fencerows to slow and spread out flow from annual rains, depositing sediment over an area larger than what would have occurred naturally. Such areas are then planted, and over time these expand into significant cultivated areas (Nabhan and Sheridan 1977).

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