

Chapter 7

Linking Land-Change Science and Policy: Current Lessons and Future Integration

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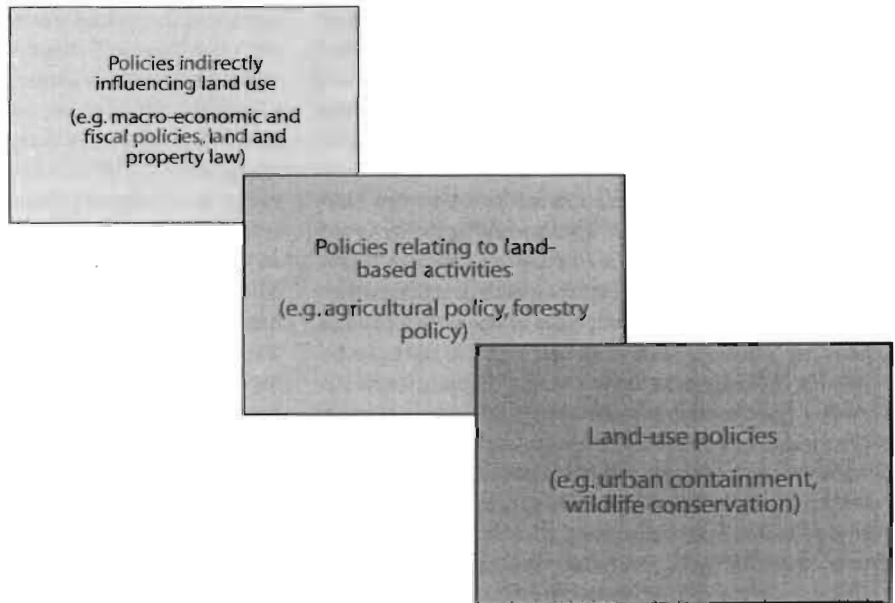
7.1 Introduction

Human use of the land and oceans is at the center of some of the most complicated and pressing problems faced by policy makers around the world today (e.g., DeFries et al. 2004b; Platt 2004; Millennium Ecosystem Assessment 2005). For the terrestrial biosphere, our need to balance current human needs and longer-term environmental sustainability often involves consideration of the way we use ecosystem goods and services produced by the land. Land-use is at the center of these trade-offs because changes in land use often enhance the share of energy, water and nutrients devoted to human needs but decrease the share available for other species and ecosystem functions. Problems as far ranging as improving human health or ensuring adequate food production cannot be solved unless policy makers understand how their policies alter land use and how altered land use affects ecosystem functions. For example, public health policy that adequately accounts for the future spread of mosquitoes that carry *Plasmodium* or malaria in the tropics often requires an understanding of the interplay between land

use and climate (Lines 1995) (see Chap. 4). In China, agricultural policy makers are using a recent assessment of cropland area to create policies that ensure there will be enough land to meet China's rapidly growing demand for food, feedgrains, and raw materials that is driven by rapid economic growth (Welch and Pannell 1982; Yang and Li 2000; Ho and Lin 2004; Lin and Ho 2005), although it is not clear that other ecosystem services will be maintained in this process.

While policy makers must understand land use to address certain pressing policy issues, policy can also cause changes in land use. Some policies, such as those creating protected areas, directly affect land use, while others affect land-based activities like agriculture or forestry. But other policies, not intended to affect land use, can have profound but indirect impacts, particularly by influencing the underlying causes of that change. These include sectoral policies, like agricultural price policies, trade policy, and public investments in infrastructure, and macroeconomic policies, like exchange rates and monetary policy that influence interest rates and credit availability – see Fig. 7.1. For example, in Amazonia, developing road infrastructure within the framework of

Fig. 7.1. Types of policies that affect land use from those directly affecting land use (land-use policies, in front), to those related to land-based activities (middle) and those indirectly affecting land use (back) (Mather 2006c)



large-scale development programs has created a potent avenue for deforestation: 90% of all deforestation in the 1991–1997 period was observed within 100 km of major roads opened during the 1970s (Alves 2002b). Land use on humid forest uplands in Southeast Asia has changed rapidly in response to (or sometimes in spite of) sectoral and land policies regulating resettlement, land tenure and agricultural prices (Tomich et al. 2004c) and regional integration (Krumm and Kharas 2004). In East Africa and Central Asia, implementation of policy that privatizes land ownership in rangelands now causes rapid landscape fragmentation and expansion of cultivation and fencing (Rutten 1992; Williams 1996; Reid et al. 2005). Indeed, in drylands around the world, privatization of common property and public lands, public sector development projects, diffusion of agricultural technologies and chemical inputs, and market liberalization can trigger rapid intensification of land use with concomitant environmental problems in some cases (Beresford et al. 2001; Geist and Lambin 2004). European, U.S., and Japanese production subsidies and trade barriers distort world markets for agricultural products. This affects how farmers in both the former and the latter countries choose to use their land.

It is thus critical that good information about the causes and consequences of land-use change reach policy makers so that they can create more effective policies and understand policy impacts (Goetz et al. 2004). We are beginning to see cases around the world where lessons from land-change science are being used to revise old policies and create new ones. Information as simple as land-use maps can clarify land-management issues in indelible ways. International meetings to discuss global environmental policy matters often start with a presentation by a prominent scientist showing a map or graphic that originated within land-change science. New land-use research sometimes includes policy makers from the outset so that problems they face are the point of departure for the scientific process (Tomich et al. 2004a; Reid et al. 2005). As discussed below, some elegant ways of demonstrating the trade-offs between human needs and environmental sustainability are being used to address local and national policy concerns.

This chapter will examine interactions between land-change science and policy by first describing the key, credible lessons from the science of land-use that can be relevant to policy. We will then explore specific examples where land-change science is already part of the policy process. Finally, we will suggest how we can improve the links between land-change science and policy. Integration of science and policy will first be addressed by describing some of the needs and perceptions of policy makers. We will then describe some ways in which land-use scientists can better address those needs, using a conceptual framework that addresses three key characteristics of the type of science that successfully links with policy makers: science that is credible, salient and legitimate (Cash et al. 2003).

7.2 Key Public Policy Lessons from Land-Change Science

Over the last decade, land-change science has contributed strongly to our understanding of where, when, how fast and why people change their use of the land (see Chap. 2 and 3). We now have a credible and reliable science of land use. Here we discuss the information from that science that we think is most important to improving policy, with a focus on lessons that generally apply across the globe. Many of these lessons, however, are specific to regions, and we thus also present policy interventions suggested by different authors for specific regions. We define policy makers broadly as those land managers and political leaders who affect how land is used from very local levels in communities to national and international-level policy makers. We structure this section around nine straightforward statements about what we have learned; these are key messages to policy makers, meant to promote sustainable land use.

Message 1

Some types of land use are more sustainable than others; this often depends how simple or diverse the land-use activity is.

Sustainable land use refers to the use of land resources to produce goods and services in such a way that, over the long term, the natural resource base is not damaged, and that future human needs can be met. The time horizon of the concept covers several generations. For various reasons, broad trends in agriculture run toward intensification and specialization at the plot level, often (but not inevitably) culminating in “monocultures” associated with land-use activities of much simpler structure and lower biodiversity richness than “polycultures”. Consider a specific comparison: agricultural systems established at the humid forest margins following slash-and-burn range from highly biodiverse systems such as rubber or cacao agroforests in Indonesia and West Africa, respectively, to systems with much lower biodiversity like pastures in the Amazon or cassava plantations in Indonesia. The sustainability of these varied systems was measured and compared through the Alternatives to Slash-and-Burn (ASB) Programme according to three types of criteria: (a) environmental – carbon stocks and above- and belowground biodiversity; (b) agronomic – soil structure and biology, nutrient balances, and pests; and (c) socio-economic – returns to land and labor, implications for household food security, capital constraints arising from levels of investment required and years to positive cash flows, as well as an array of other policy, social and institutional indicators. The studies have revealed the feasi-

bility of a “middle path” of development that delivers an attractive balance between environmental benefits and equitable economic growth. The Sumatran rubber agroforests and their cocoa and fruit counterparts in Cameroon contain about 25–50% of the carbon stocks of the natural forest (Palm et al. 2005). The biodiversity in these forests, though not as high as in natural forest, are far higher than those in monocrop tree plantations, short term fallows, or annual cropping systems (Gillison 2005). It is also interesting to note that there are many types of tree-based systems with similar levels of C storage but drastically different profitability and hence attractiveness to farmers (Gockowski et al. 2001). Agronomic criteria show moderate to high levels of sustainability in agroforests with pests and potentially negative nutrient balances as the main issues of concern, depending on the specific systems assessed (Hairiah et al. 2005). Simple tree crop systems (monoculture plantations) often experience problems of soil structure (compaction), besides problems with crop protection. Crop/fallow systems vary greatly in their effect on agronomic sustainability. The long fallow systems with low cropping intensity in Indonesia and Cameroon (traditional slash-and-burn shifting cultivation systems) are sustainable, but unimproved short fallow systems with intensified cropping have detrimental effects on soil structure, nutrient balance, and crop health; these also produce very low returns to labor. Continuous annual cropping, as with cassava in Indonesia, is often, but not always, problematic in the forest margins of the humid tropics. Pastures, particularly with improved management practices, tend to have a medium level of impact on the natural resource base, though impacts on global environmental issues (biodiversity and greenhouse gas emissions) may be quite large (see Chap. 4). A tool developed for analyzing these trade-offs in the tropical forest margins, the ASB matrix, is discussed under message 8 below.

In African dry forests and savannas, grazing can maintain the diversity of native plants, birds and butterflies more than in croplands (Soderstrom et al. 2003). Under-grazing has even been implicated in loss of plant diversity from grasslands across the world (e.g., Milchunas et al. 1988), as has over-grazing. In Africa and Europe, there are more native species in croplands with more complex features like hedgerows and woodlots (even in large trees) than in less complex landscapes with few of these features (Reid et al. 1997; Wilson et al. 1997; Soderstrom et al. 2001). However, complex, agricultural landscapes do not usually support large-bodied wild animals with large home ranges; farmers exterminate these species earlier in the process of clearing land. The diversity of small species (birds, insects) can be quite high on pastures, prompting European policies to preserve cattle pastures because of their high biodiversity. These examples suggest that agricultural land use can be compatible with biodiversity and other ecosystem services, which contribute to the nexus of agricultural biodiversity, dietary diversity and human health and nutrition, but this

is far from always the case. This is an obvious place for policy to influence conservation of biodiversity, but the ability to influence land use outcomes depends greatly on public finance and administrative capacity. While elaborate land-management schemes can be implemented through land-use planning and incentive schemes in Europe and the United States of America, such approaches are problematic across most of the developing world.

Message 2

Single factor causes are rare, but the range of “syndromes” (combinations of causes) is not infinite; some specific combinations account for a significant share of land-use change.

Although expressed in manifold ways, there are few, important causes of land-use change, that often work together in concert. And these can work in unexpected ways. For example, population growth sometimes causes land-use change and sometimes does not. But when “population” comes in as an explanatory variable, it is less fertility increase than migration, mainly in-migration to a given location or site. This phenomenon shows up in all major meta-analytical studies done under the umbrella of the Land-Use/Cover Change (LUCC) project (see Chap. 3). Moreover, even in the face of land scarcity and human population growth, agriculture and land use can stagnate. In addition, the location of growth is important. For example, farming land contracted and forests expanded in Europe at the same time that human populations were on the rise, because populations grew chiefly in the cities, not the countryside. Massive productivity increases and economic transformation (from agrarian to industrial) allowed support of larger populations with less agricultural land. Sectoral and macro-economic policies (e.g., price policies for agricultural inputs and outputs, infrastructure investments, land tenure and taxation policies, reforestation programs, and natural resources policies regulating exploitation of forests, minerals, and petroleum), are significant causes of land-use change, and thus are a set of levers held by policy makers that can influence either sustainable or unsustainable paths of land use. It is important to realize that while these policies interact to cause change, they also are aimed at a wide range of objectives, of which sustainable land use often is not the primary goal.

Policy makers will be more successful if they understand the underlying causes of land-use change (institutions, policies, population) as well as the proximate causes (logging, cultivation) that presently receive most attention in policy debates. Furthermore, effective policies need to account for the multiple and often interacting causes of land-use change, as highlighted in Chap. 3 – see Fig. 7.2. Lifestyle choices and shifting consumption

patterns of goods and services are affecting land-use choices all over the world. For example, land users in the Yellowstone ecosystem, United States, are shifting from ranching to construction of leisure homes (Hanson et al. 2002), while semi-nomadic herders in Africa and Central Asia are choosing to settle to access schools and better health care (Rutten 1992; Blench 2000). In the most populous countries of the world (United States, India and China), economic integration and globalization, modified by national land policies, also strongly affect how and where people use the land.

In drylands and humid tropical forests, similar broad classes of factors underlie deforestation and desertification including: human population dynamics, market integration, urbanization, technological change (e.g., introduction of technical irrigation or new crop varieties), governance (e.g., corruption), changes in property rights, public attitudes and beliefs, individual household behaviors, and sometimes climate (Geist and Lambin 2002, 2004). While the factors to be considered may be similar, the main causes of change are not the same for humid and arid. For example, links to global markets are much more important for humid forests, while local drivers are more important for arid lands (Geist et al. 2006) – see Tables 7.1 and 7.2. The broad analytical “similarity” here relates to the large bundles of variables, but the scale (global, local) of the driving forces must be understood in context.

Message 3

Underlying causes, originating far from where land is actually changing, often drive local changes in the land.

With economic liberalization and globalization, people increasingly choose how they use the land on the basis of influences originating outside their communities, and this has major implications for transitions to sustainability (Lambin and Geist 2003a; Geist et al. 2006). Actually, agents of change become increasingly disconnected spatially from major stakeholders of these changes. However, the resulting change is almost always in response to a combination of local and global causes, leading to some uncertainty in likely outcomes. For example, even if local communities in East Africa can both reduce poverty and conserve wildlife through local land-use initiatives, these efforts will be unsustainable if they continually collide with inappropriate land-use policies (like subsidies that encourage crop cultivation) at the national level. In this case, local civil society groups that promote pastoral human rights are well aware of this need and act both locally and nationally in a synergistic fashion to agitate for change (Reid et al. 2005). Thus, working locally to sustain local land-use systems will likely succeed more quickly and maintain gains longer if national policies support rather than hinder local efforts – see Fig. 7.2.

Table 7.1. Driving forces of tropical deforestation by scale of influence

	All factors (range in %)	Demographic factors (%) ^a	Economic factors (%)	Technological factors (%)	Policy and institu- tional factors (%)	Cultural or socio- political factors (%)
	N = 152 cases	n = 93	n = 123	n = 107	n = 119	n = 101
Local	2 – 88	88	2	23	4	16
National	1 – 14	1	14	3	2	7
Global	0 – 1	–	1	–	–	–
Several scales: global-local interplays	11 – 94	11	82	74	94	77

^a 6 cases of unspecified population pressure could not be attributed to scales. Source: Geist et al. (2006), p. 64.

Table 7.2. Driving forces of desertification by scale of influence

	All factors (range in %)	Demographic factors (%) ^a	Economic factors (%)	Technological factors (%)	Policy and institu- tional factors (%)	Cultural or socio- political factors (%)	Climatic factors (%) ^b
	N = 132	n = 73	n = 79	n = 91	n = 85	n = 55	n = 174
Local	12 – 29	23	18	29	12	16	–
National	4 – 20	–	13	–	20	4	–
Global	4 – 12	–	4	–	6	–	12
Several scales: national-local interplays	29 – 80	29	66	71	63	80	60

^a 35 demography-driven and 32 climate-driven cases could not be attributed to scales. Source: Geist et al. (2006), p. 65.

Conversely, such local initiatives have little scope for success if adverse national policies and international market forces are ignored.

The liberalization of trade, and the opening up of new areas to national and international markets, can have several effects. One is to expand the scale of production and extent of monoculture of a particular commodity with possible effects on biodiversity. Another is for the production of particular commodities to be concentrated in particular areas, where they enjoy geographical advantages in environmental or other terms. This concentration could, in turn, yield economic benefits from positive spillovers through a concentration of knowledge, service provision, and marketing facilities (e.g., fertilizers, glasshouse heating, etc.). Some local “dis-benefits” might result from the former, and some local benefits from the latter. The significance both of distant causes and of national responses can be long-lasting. In the latter part of the 19th century, an episode of globalization involving the opening up of the American Prairies and the export of cheap grain from there had a major effect on European farming. Some countries, such as France, provided protection for their farmers, in the form of import tariffs. Others, such as Denmark and the Netherlands, encouraged diversification into the production of commodities in which there was less competition. Others again, such as Britain, took a *laissez-faire* approach, and left farmers fully exposed to competition. The effects of this episode, and especially of the differing responses, are still evident a century later.

Message 4

A finite set of pathways can be used to develop policy-relevant land-use scenarios that are relevant to different regions of the world.

A pathway is a particular set of events that together describe how land use changes in particular area, which is different from but related to the actual cause of the change described in message 2 (see Chap. 3). One obvious pathway is the opening up of a forest “frontier” by constructing a road, that results in conversion of native vegetation to cropland or pastures. To develop information on pathways that will be useful for policy development and land management in particular places, we must account for historical land-use patterns, climatic, economic and ecological constraints on land use, what causes change, how different causes act together (synergies), and how resulting land-use activities feed back to affect these causes. Once we have a basic functional understanding of these pathways, it will be clearer what policy interventions will and will not promote sustainable land use in specific cases. Understanding these pathways can also help land managers and policy makers anticipate changes and cope with uncertainty (see Chap. 6).

Message 5

Drivers can work together to create rapid land-cover change and unexpected land degradation; policy-oriented research should focus on these “hot spots” of rapid change and degradation.

Land cover changes faster in some locations than others around the globe (see Chap. 2). For example, deforestation mostly takes place at the edge of large forest areas and in conjunction with major investments in transportation networks and other infrastructure (e.g., the “arc of deforestation” in the Amazon Basin; Pacheco 2006c). At the national level, land use is changing more rapidly in transitional economies in post-socialist countries like China and Russia (Hill 1994; Kondrashov 2001) because of a rapid shift in property rights, decollectivization, decentralization and a collapse of employment opportunities in the non-agricultural sectors (Sturgeon and Sikor 2004).

Migration, education and land-tenure changes can together cause rapid changes in land use. In China and Kenya, for example, strong migration has expanded settlement and land use around and inside protected areas with surprising rapidity in the last 30 years (Liu et al. 2001, 2003a; Lamprey and Reid 2004). But additional social changes, through education and changes in land tenure, caused large cohesive families to split into smaller single family units at the same time. Migration and social change working together caused an explosion of household growth and settlement, with strong consequences for wildlife habitat in both cases. Careful analysis of these situations needs to be made quickly, and policy needs to focus on weakening synergistic causes that degrade the land. This could be done, in the Kenyan example, through new land use and access policy that allow secure land ownership but also supports the mobility of livestock herds and wildlife, particularly in times of stress during droughts.

Several parts of the world are not adequately represented in the available data sets (see Chap. 2), so it is possible that rapid change is occurring in locations where data are poor. Data on changes in drylands and mountains are the most incomplete of all types of change, because satellite imagery of these regions is difficult to interpret and we are largely unable to distinguish human-induced trends from large, climate-driven interannual variability in vegetation cover. Rapid land-cover changes that are still poorly documented at the global scale include, for example, changes in the (sub)tropical dry forests (e.g., miombo forests in southern Africa and chaco forests in South America); forest-cover changes caused by fires and insect damage; drainage or other changes in wetlands; soil degradation in croplands and changes in the extent and productive capacity of pastoral lands (Lambin et al. 2003). It is also possible that ecological impacts of change are large even in places where land-use change is slow, as in the case of depletion of wild mammals through hunt-

ing for bushmeat. These exceptions and gaps in our knowledge suggest that researchers should not focus solely on areas of readily-detected change in land cover.

Message 6

Mobility and flexibility often are critical to sustainable land use.

Long-fallow, rotational shifting cultivation (“swidden agriculture”) is one well-documented example of how mobility and flexibility underpin the sustainability of extensive smallholder systems; if these attributes are lost, such systems may collapse. Similarly, policies that support mobile lifestyles and flexible livelihood strategies can allow pastures to “rest” seasonally and thus curb overgrazing. Pastoral land use, all over the world, is shrinking as farmers push further into marginal lands and herders settle more often around infrastructure for water, health and education (Ellis and Swift 1988; Niamir-Fuller 1999). Access to large and diverse landscapes is critical to maintaining productivity of livestock in pastoral systems and reducing vulnerability of pastoral families, particularly

during drought. For example, in a traditional system of transhumance, Sahel herders migrate large distances, following seasonally varying rainfall, to find greener pastures and full water holes. Recent privatization and sale of pieces of pastoral rangelands by pastoral peoples has been aptly termed “selling wealth to buy poverty” (Rutten 1992). In other agricultural systems, shifting cultivators and mountain farmers use mobility as a strategy to access resources over time. Policies need to provide mobile services to mobile communities to allow them good health care and educational opportunities while they, for example, move livestock to seasonal pastures.

Message 7

Specific “entry points” exist where revised or new policies can improve land-use practices; it is possible to restore lands degraded by inappropriate land use, but sometimes the line between degradation and sustainability is fine.

Some policies support sustainable land use, while others do not. We will focus on the latter first. Policy can intervene to weaken some of the underlying causes of this unsustainable land-use change by revising perverse policies or generating new policy – see Fig. 7.2. In humid forests, much deforestation is caused by poor governance and perverse subsidies (like tax-breaks and low-interest loans) that encourage farmers to settle in forests (see Chap. 3). Some of these policy instruments are easier for policy makers to manipulate than others (such as trade or macro-economic policies), and thus can be the first places for policy action.

Policy can be targeted to weaken the positive feedbacks that accelerate unsustainable changes in land use and strengthen negative feedbacks that slow change (Lambin and Geist 2003b) – see Fig. 7.2. For example, good communication of the location and speed of land-use changes to policy makers can allow them to react in a timely manner to particularly fast or unexpected changes, or to start a protracted policy discussion in anticipation of future changes. In Brazil, for example, deforestation over the entire Amazon is monitored each year, so that changes can be detected and acted upon when there is the political will (INPE 2000; Alves 2001a). In Kenya, scientists have collected information on changes in land use and wildlife populations for over 40 years that highlight hot spots of change and other areas where coexistence of livestock and wildlife is sustainable (Said 2003). The key here is communication of information in a way that is useful to policy makers and engagement of policy makers often and early in the scientific analysis process. But, of course, while better information often is a necessary ingredient to improved policy, it is by no means sufficient. Typically, there are conflicts among the interests of particular groups within society regarding land-use priorities and between

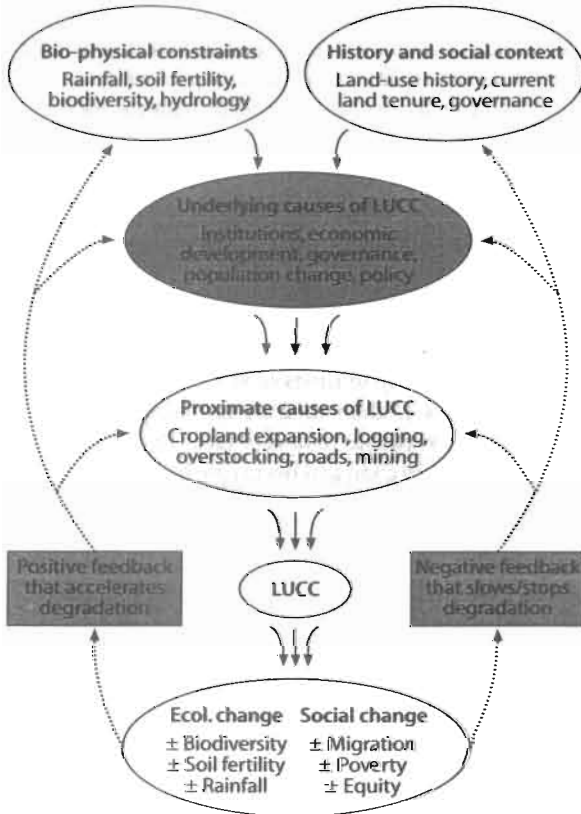


Fig. 7.2. Conceptual model showing where, during the processes of land-use change, national-level policy is likely to have the most impacts on land use (in red) or where intervention will be more difficult (yellow). Local policy will more easily impact the proximate causes of change; however, unless the underlying causes are addressed at the same time, local action may not be sustainable

the broader public interest and narrow private interests in land-use outcomes. To be effective, land-use science and policy studies must also consider these contending interests and the balance of political power.

Good land management and appropriate policies can help farmers and herders avoid land degradation or restore degraded ecosystems. From all over the world, there are examples of farmers who use sustainable land-use practices, even in the face of growing human population density, when the institutions are appropriate, social networks are strong, access to markets and technologies is good and they have strategies to reduce risk (Schweik et al. 1997; Gray and Kevane 2001; Turner and Williams 2002; Dietz et al. 2003; Gibson et al. 2003; Tiffen 2003; Laney 2002). This has led some to suggest, for example, that “more people means less erosion” (Tiffen et al. 1994a), but “more people” can also lead to more erosion and less water conservation (Kates and Haarman 1991, 1992). Or even “more people and more forest” but “less livelihood security and poor environmental services” if the institutions, policies, markets and livelihood options are not in place. In one case study in Yunnan, southwest China, for example, forest cover increased at the expense of decreasing farmland and farmers’ access to forest resources. However, monoculture reforestation with pine has caused both biophysical and socio-economic consequences, including negative effects on rural livelihoods (Xu et al. 2005a).

There can be a delicate tip point between trajectories ensuring innovation/restoration and those that cause degradation/deforestation, as demonstrated at a very local scale for the southern Yucatán (Klepeis and Turner 2001; Bray et al. 2004; Turner et al. 2004). This implies that scientists need to help policy makers monitor the effects of policy instruments, so that unexpected effects can be countered before degradation starts, or to model the probable effects of different policy instruments before they are deployed.

Message 8

Land use that combines poverty reduction and nature conservation is rare, but new efforts exist to evaluate these often opposing goals more clearly, and monitor progress towards them.

Certainly there are examples where misguided policy, poor governance, and outright corruption undermine both conservation and development objectives; tropical forests are a well-documented case in point (e.g., Repetto and Gillis 1988). In these “lose-lose” cases, there may be opportunities to make incremental gains for people and nature through policy reform and better governance (Panayotou 1993). Unfortunately, though, there are few cases where a single type of land use achieves development without some sacrifice of conservation values of natural systems (where it is commercially viable, ecotourism is one such “win-win”).

However, as already suggested, much depends on the point of reference and the trajectory of change. In the humid tropics, no forest-derived land use can match the global environmental values of natural forest – see Table 7.3 for the case of Sumatra. On the other hand, restoration of “degraded” tropical landscapes may provide a rare win-win opportunity, where restoration of ecological function and environmental services also could create livelihood opportunities if poor people are involved appropriately (Tomich et al. 2005). More common are situations where farmers can expand land use and improve their incomes (a win situation), while losing only part of the ecological services provided by a landscape (a small loss situation; DeFries et al. 2004b). The ASB matrix (Tomich et al. 2005; Palm et al. 2005) provides an approach to assessing the trade-offs and complementarities between losses of certain ecological services of global importance such as carbon stocks, which affect central functions of the climate system, and gains in the production of food, fiber and feeds to support local communities and national economic development. Tools like this allow identification of innovative policies and institutions needed to balance both sets of goals. The matrix also provides a basis for policy makers and stakeholders to assess trade-offs comparing among different land-use systems (and choices) regarding environmental and development goals (see Sect. 4.8). There is a new effort, supported by many land-change scientists and institutions, to develop a first-ever Climate, Community and Biodiversity (CCB) standards for different land-use practices. These standards are a public/private partnership seeking to recognize land users if they sequester carbon, conserve biodiversity and reduce poverty at the same time.

Empirical evidence shows that labor-intensive technological progress like new irrigation techniques often facilitates intensification on existing agricultural areas and, at the same time, has the potential to increase rural incomes. The increase in productivity on existing land leads labor-constrained households to allocate less time to land clearing and land expansion into upland areas and, in that way, has the potential to conserve forest cover on more marginal land; see, for example, Müller and Zeller (2002) in Vietnam, Pender et al. (2001) in Honduras, Pender et al. (2004) in Shively and Martinez et al. (2001) in the Philippines. In these cases, the key aspects underlying the win-win outcome are first that the technology is suited only to existing agricultural land (so it does not create incentives for conversion of wild lands) and second that it is labor-intensive as well as profitable (thereby inducing households to shift labor out of deforestation activities).

Another win-win example involves the edible mushroom, matsutake or pine mushroom (*Tricholoma* spp.), prized in Japan since ancient times. Recent dramatic increases in price and demand for these mushrooms have encouraged Tibetan collectors to shift from logging to collecting mushrooms for income generation, reviving cus-

Table 7.3. ASB matrix of trade-offs at the agriculture/forest margin in Sumatra

Land use	Global environment			Agronomic sustainability	National policymakers' concerns		Smallholders		Smallholders' concerns
	Carbon sequestration	Biodiversity	Aboveground, time-averaged (Mt ha ⁻¹)		Potential profitability at social prices	Employment	Adoptability by smallholders	Production incentives at private prices	
					Returns to land (US\$ ha ⁻¹)	Average labor input (days ha ⁻¹ yr ⁻¹)	Returns to labor (US\$ day ⁻¹)	Entitlement paths	
Natural forest	306	120		1	0	0	0	NA	
Community-based forest management	120	100		1	5	0.2 - 0.4	4.77	Food and income	
Commercial logging	94	90		0.5	1080	31	0.78	Income	
Rubber agroforest	66-79	90		0.5	0.7-878	111 - 150	1.67-2.25	Income	
Oil palm monoculture	62	25		0.5	114	108	4.74	Income	
Upland rice/bush fallow rotation	37	45		0.5	-62	15 - 25	1.47	Food	
Continuous cassava degrading to <i>Imperata</i>	2	15		0	60	98 - 104	1.78	Food and income	

Source: Geist et al. (2006), p. 66.

tomary institutions which manage forest habitats (alpine oak and pine forest) and regulate access to mushroom harvest in a particular place. This is a multi-million dollar trade for local people (Yeh 2000; Xu and Salas 2003). The key to the apparent case of a “win-win” possibility here would seem to be that the market for these mushrooms has dramatically increased the value of maintaining natural forests and diverted labor that would have gone into clearing forests.

Message 9

Thorough understanding of key actors and local situations is important for the design of appropriate and successful policy interventions.

The importance of recognizing and understanding different actors has been widely recognized (see Chap. 5), for example, in the rapidly changing Brazilian Amazon (Alves 2001a; Mahar 2002; Walker 2004). The recognition of the different actors and social groups in this very large and diverse region is crucial for land-use policies because these need to recognize large regional differences in land use, demography and economics (Alves 2001a), and also because different groups have distinct social behaviors, land-use practices, and (often competing) interests. This is particularly important for two of the most important land-use policies for the Brazilian Amazon – Forest Code and Ecological-Economic Zoning – where, in some cases, the failure to identify the different actors and social groups has already affected policy formulation and its effectiveness (Alves 2001a; Mahar 2002).

There also is a need to understand the political ideology of the policy makers and politicians as well as the policy-making process. For example, large-scale rubber planting manifested state power during the socialist collective period in China. Rubber monocultures were introduced in marginal climatic zones. These large-scale settlement projects were viewed as part of the state’s strategy to supply industrial raw materials in the national interest for political security through self-sufficiency during China’s collective period. The outcomes, however, were inefficient (both technically and economically) as well as damaging to the environment (Xu et al. 2005b).

Using a framework developed within the Land-Use/Cover Change (LUCC) project, Geist and colleagues explored the type of actors involved in different regions of the world and at different scales in drylands and humid forests (Geist et al. 2006). They found that we need to discover and apply locally adapted methods and solutions and these need to be revised continually to maintain sustainable land uses. For example, for desertification problems, it is much more effective to identify and focus on individual problem areas or hot spots of desertification than to raise a general alarm since it is unlikely comprehensive evidence will be available (see Chap. 2).

There is increasing recognition of the critical role that community involvement can play in managing land-cover change. For example, the “tragedy of the commons” holds that open access to communal land causes overgrazing and land degradation (Dietz et al. 2003; Gibson et al. 2003). A synthesis of case studies throughout the world’s drylands revealed that a more appropriate notion may be the “tragedy of enclosure” (Geist 1999a), which describes, for example, the loss of land for herders when other land uses encroach on grazing lands (Geist 2005). Case studies across the world have now clearly demonstrated that no single type of ownership, whether private, community or government, is by itself an automatic guarantee of effective management. When community management boundaries are well defined, legitimate, and effectively enforced, the social capital generated through community involvement can be very effective in promoting sustainable development and conservation over the long term, especially at local or regional scales (Nagendra 2006).

7.3 Influence of Land-Change Science on Policy: Some Successes and Failures

Clearly, several of these messages from land-change science may be broadly useful for policy research and analysis. However, producing credible scientific results is only one pre-requisite for establishing strong links between science and policy. Successful links always require scientists to listen to what policy makers need, to understand some of the processes and constraints to how policy actually is “made”, to create new scientific designs and data needed to address these needs, and actively engage stakeholders with different points of view. Here, we ask: are there examples where credible land-change science is already salient and legitimate, and thus already part of the policy process? By *salient*, we mean information that is immediately relevant and useful to policy makers; *legitimate* information is unbiased in its creation and both fair and reasonably comprehensive in its treatment of opposing views and interests (Cash et al. 2003).

The different worldviews of researchers and policy makers create a cultural gap preventing adequate use of research (Neilson 2001) and adequate understanding of the needs of policy makers. These two groups have contrasting values and expectations and are rewarded for different behaviors. Scientists produce knowledge and often are rewarded for the number and profile of their technical publications; any activity that takes them away from these tasks may limit their chance of career advancement. Scientists are also rewarded for training students, but rarely for working with land managers and policy makers, except for those working in “boundary” organizations whose goals are to link research and policy (Cash et al. 2003). Ideally, in the arena of land-use issues, suc-

cess for a policy maker lies in using policy instruments to maintain or improve land-management practices (Crewe and Young 2002), by responding to the needs of those who appoint them or their constituents. (In reality, policy makers will be responding to a range of interests and influences.)

An understanding of the policy development process provides scientists with an appreciation of places where they may engage and influence the process. The rational actor model, pioneered by Lasswell in the 1950s, portrayed the policy making process as a linear, non-iterative process, where policy makers rationally consider information on alternative options and then decide how to move forward. Few policies are actually created this way (Allison 1971); rather policy making is a complex interplay among political interests and competing discourses by multiple actors (Crewe and Young 2002). The key point is that scientists need to understand how organizational processes, bureaucratic politics, and other real-world phenomena (for example, corruption, bureaucracy, local politics) both open and foreclose opportunities for science to influence policy and its outcomes.

Scientists and policy makers also create and use different types of knowledge. Scientists (and local communities) tend to create and use process-based knowledge even including indigenous knowledge (Xu et al. 2005c), while policy makers use “rules of thumb” (M. van Noordwijk, personal observation). In addition, scientists often choose their areas of interest based on a subjective selection of “interesting cases” that may be of limited interest to politicians. Scientists also often focus too much on the creation of policy rather than on the implementation of policy, where local politics influence outcomes decisively (Grindle 1980).

What determines if policy makers use credible science in decision making? Scientific information that attains a balance of credibility, salience and legitimacy is most likely to effectively influence policy (Cash et al. 2003). Perhaps first and foremost, this information must address issues of sufficient importance (i.e., salience) to capture the attention of policy makers at the appropriate level (Tomich et al. 2004a). Salient research assesses the benefits and costs of different policy options or provides a solution to the problem. Participatory approaches and pilot demonstrations of solutions are particularly effective, and increase legitimacy (Court and Young 2003). Similarly, non-participatory approaches can be quite ineffective (Mahar 2002). Also crucial are strong communication links through informal and formal networks between researchers and policy makers that promote trust, openness, and legitimacy (Court and Young 2003). It is important for both researchers and policy makers to recognize each other's constraints in producing and using information (Crewe and Young 2002). Policy makers must realize that scientific knowledge is influenced by the values and beliefs of the scientists themselves, how-

ever strenuously they try to be objective. Scientists must realize that power relations within politics will likely affect the ability of policy makers to use the information they provide.

Researchers most often influence policy when they work with individuals or organizations who focus on the task of crossing the boundary of communication between researchers and policy makers (Cash et al. 2003), thereby improving saliency and legitimacy. These individuals or organizations promote active, interactive and inclusive communication between scientists and policy makers, translate information so the two groups understand each other, and mediate any misunderstandings between them (Cash et al. 2003). Civil society can often fill this role. Individual scientists, trusted by communities and policy makers alike, sometimes communicate among different actors in the policy process. These boundary-crossing activities – communication, translation and mediation – require real investments of time and energy by scientists (Guston 2001). This requires additional resources and is not a natural component of scientific inquiry.

But what is the evidence that some of the products of land-change science have influenced the policy dialogue at the international level? Similarly, are land-use scientists responding to the needs of policy makers? No formal assessment of this two-way translation exists, but it is easy to see some of the principles articulated above at work. The climate change assessments by the IPCC (Intergovernmental Panel for Climate Change), which included input from land-use scientists, were highly credible because they included an unprecedented range of scientific research. They were also salient and relevant for policy makers because the assessments appeared when the issue of climate change became a global public concern. Governmental involvement and the UN Framework on Climate Change (UNFCCC) provided links between the scientists in the IPCC and policy makers. The Millennium Ecosystem Assessment involves many land-change scientists and has been designed to respond to the articulated need for policy advice at the global level for the future management of ecosystems worldwide (Millennium Ecosystem Assessment 2003, 2005), and thus includes land-use issues. These initiatives (and institutions like IGBP, IHDP and LUCC) are helping scientists to listen better to policy needs and to get their science directly to policy makers in appropriate forms. It also appears that land-change science is having an impact through individuals who act as “translators”, bringing credible science into the public policy arena. The quantitative evidence of impact at all of these levels is weak, but qualitative evidence is abundant.

Qualitative impacts of land-change science on policy also abound at the local or national levels. In Brazil, research linking roads and deforestation (Reis et al. 2001; Alves 2002b; Soares-Filho et al. 2004) had significant impacts, along with other information, on the formulation of policies to curb or contain forest clearing in the

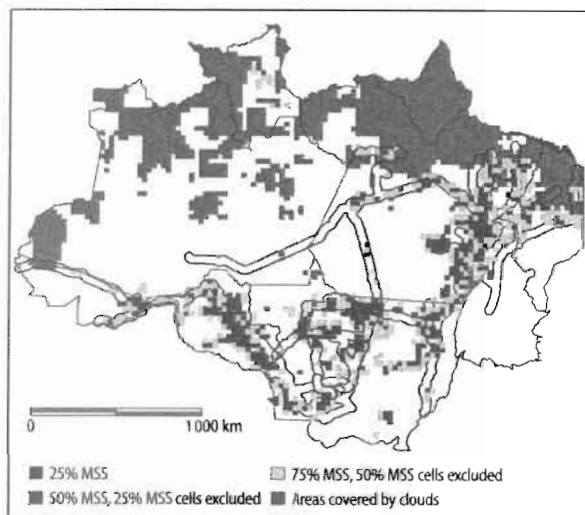


Fig. 7.3. Distribution of deforestation along road corridors in the Brazilian Amazon, showing areas with 25%, 50% and 75% deforestation (colors) and the areas within 25 km from the nearest road (gray line). Cells covered by a minimum of 50% of clouds also shown in gray (Alves 2002a). Information like this was used by scientists to show policy makers that road construction is linked to deforestation (see Chap. 3, Box 3.5)

Brazilian Amazon – see Fig. 7.3. This knowledge has led development banks and agencies to change their lending policies for road development projects in the Amazon (Redwood III 2002). It also motivated the Brazilian Federal government to establish public panels to discuss the paving of an important road link between Central Brazil and a major port on the Amazon River under the so called “Avança Brasil” development program.

In Nigeria, land-change research on urbanization has raised the profile of important issues of land-use change by providing credible information on the proximate causes, rates and locations of urbanization. In some ways, this research increased the saliency of the issue of urbanization by popularizing and disseminating research results to the public. Land-change science, because of its connection to high profile climate change research, has high political visibility in the government and NGO sectors, and has helped re-invigorate institutional support for urban planning.

Another example from East Africa uses the principles of establishing trust, strengthening researcher-policy networks, initiating research with a strong communication strategy, and establishing a network of research policy “translators” (Reid et al. 2005). This research team evaluates the trade-offs and complementarities inherent in different land-use practices in promoting pastoral welfare and conserving wildlife, goals often addressed by entirely different sectors of the government and donor communities. One key to this approach is identification (and re-identification over time) of the salient, policy-relevant issues for research with local community members and leaders and also with national-level research and management institutions. Legitimacy was

established by including and addressing the wide-ranging concerns of different actors (individuals, institutions) that focus on agricultural development, land-use planning, water resources and wildlife conservation. The centerpiece of the communication strategy revolved around a group of researcher-community members, whose role was to establish legitimacy and guarantee saliency of the research, and to develop and strengthen researcher – policy maker links at the local and national levels. Another effective strategy was for the core research – communication team to act as a convenor and catalyst for other national and international researchers working in the same ecosystems to communicate with local and national policy makers. Specific activities to strengthen these links include feedback workshops with researcher and community members, meetings with policy makers to revise policy acts on wildlife and pastoral development, grants to international students to report their PhD results back to communities and discuss policy and management options, and meetings for researcher-policy maker discussions of salient issues. However, like most projects of this kind, no formal evaluation of the impacts of research on policy has been attempted.

The Krui people in Lampung Province, Indonesia, and their scientific colleagues on the ASB team together successfully reformed government policy that was set to violate their land tenure and appropriate their land for logging and conversion to an oil palm estate. They achieved this first by creating a credible and legitimate assessment of the social, ecological and economic benefits of their traditional agroforestry practices, so that government planners no longer classified their lands as “empty”. Local groups were able to speak with conviction about the value of the way they used the land when policy makers visited their land, persuading policy makers to recognize the value of their lifeways. Six months after these visits and a report to the Ministry of Forestry, the Indonesian government reversed their appropriation policy (Tomich and Lewis 2001).

In China, political discourse (Brown 1995), technology advance (Welch and Pannell 1982), as well as a national land-use survey (Smil 1995) have aroused the Chinese state’s concern about land use and food security. As a result, the state has implemented a very strict policy to maintain enough agricultural land to feed the population, a total of arable land area of no less than 1.28 million km² in China. The government is reclaiming land in northern China to compensate farmers for the loss of agricultural land mainly along the coast and in southern China due to urbanization and infrastructure development in the last two decades (Yang and Li 2000) which, in turn, paradoxically causes further land degradation and desertification in some cases.

Another very clear example of land-use scientists working to directly influence land policy involves panda conservation in Wolong Nature Reserve in China. Loss

of high-quality panda habitat was faster after the reserve was set up (1974–1997) than before the reserve's establishment (1965–1974; Liu et al. 2001). This was due to a rapid increase in human population and an even faster jump in the number of households (Liu et al. 2003a), thus greatly expanding human settlement and other human activities (e.g., fuelwood collection and agriculture). This type of information helped the government develop and implement a set of new initiatives. The initiatives include: (a) establishment of an eco-hydropower plant to reduce fuelwood cutting, (b) direct payments (approximately \$100–150 per household per year, or approximately 20% of average household income) to local communities to monitor natural forests and prevent illegal harvesting of trees, and (c) a grain-to-green program where farmers are given tree seedlings to plant in their fields and are paid (in the forms of grain and cash) for the amount of land they convert back to forest (Feng et al. 2006). Although the second and third programs are nation-wide in response to the 1998 major floods in China, their implementation in Wolong is mainly for panda habitat restoration and financial support for adjacent areas outside Wolong has been much less than that inside Wolong. Many suggestions based on the Wolong study (Liu et al. 2003b) are also being seriously considered for improving the entire nature reserve system in China because many of the reserves (almost 2 000 in total) are faced with similar challenges as Wolong. There are at least three reasons for this success: (a) the issue that the scientists tackled was high-profile or salient both within China and on the world stage, (b) the scientific team worked closely with policy makers, and (c) governance structures in China allow policy makers to enact policy quickly.

In Europe, policy makers initiated or funded several applications of land-use models to answer specific questions. For example, the EURURALIS project aims to develop an interactive, user-friendly meta-model to catalyze a balanced discussion about the future of the rural areas in 25 European countries from the perspective of sustainable land use in the coming decades – see Box 5.6. The project team interacts closely with the policy advisory group of the Dutch Ministry of Agriculture, Nature management and Food Quality (ANF), and the results will be discussed by the 25 nations. This work raised the profile and attention given by policy makers to land-use issues, but it is unclear if the results will be used to revise policy (Verburg et al. 2006b).

In Costa Rica, a team of scientists worked with policy-makers to develop models that allow them to assess the environmental and socio-economic impacts of land-use/cover change, commissioned by the World Bank (Kok and Veldkamp 2001; Kok and Winograd 2002). Translation and communication of results between scientists and policy makers was one of the big challenges of this integrated team. Scientists presented land-cover change maps, showing hot spots of change, but policy makers

wanted piecharts and graphics of appropriate and inappropriate land uses. From the scientists' perspectives, this means the crucial information of the specific locations and rates of land-use change is lost in this translation. However, good progress is being made because policy makers now pay a good deal of attention to land-use change issues and they recognize the value of making future projections of land use.

7.4 How Can Land-Change Science Be More Useful in the Policy Process?

Despite these successes, why doesn't land-change science have more impact on policy now? How can science have more influence on land-use policy in the future? There are some clues from the research of those who have worked in this area and attempted to understand how research influences policy outside of land-change science (Garrett 1998; Sutton 1999; Court and Young 2003). All assessments admit that our understanding of these impacts is "thin" and better, more formal assessments need to be made. Despite this, there are some clear ways that land-change science could be more useful to policy makers. In thinking about this, scientists must understand that there is little chance for science to control policy outcomes. Rather, the key is for scientists to link their work to social/political processes and use this linkage to set more "salient" research priorities that will have a better chance of affecting those processes (van Noordwijk et al. 2001).

First, scientists need to listen to understand policy makers care the most about. Understanding needs and beliefs will allow scientists to design their research so that it is truly relevant and salient to policy makers. In this discussion of science and policy, we focus on scientists and policy makers, but it is particularly critical to include the viewpoints of the land users themselves throughout the process. One way to do this is to transform the current, relatively *ad hoc* information collection by land-use scientists, that may (or may not) have policy implications, into more purposeful land-change policy research that aims to be useful to policy makers (Tomich 1999; Tomich et al. 2004a) and land users. Policy research starts with a clear definition of a policy research problem, including assessment of policy objectives and the impact of existing policies, identification of relevant policy instruments, and establishing working relationships with policy makers who have influence over those policy instruments. One of the first steps for researchers seeking to embark on policy-relevant research is to listen to the questions that policy makers ask (Tomich et al. 2004a):

- Who cares? Who loses? Does anybody win? Are the negative (or positive) effects big enough to capture the attention of local people or of policy makers?

- So what? Is it a policy problem? Would action serve one or more public policy objectives?
- What can be done? Do we know enough to act? Will it work? What are the risks? What will it cost?

Once scientists listen to questions posed by policy makers and land users, they will be able to frame salient, appropriate and useful policy research questions. They will then be able to design their research to collect the most effective data to address the policy problem, which will depend, in part, on where the problem is in the policy issue cycle (Tomich et al. 2004a) – see Fig. 7.4. With a new issue, scientists need to focus on establishing if the issue is a problem, using process-based research that establishes cause and effect. This is where much of global land-change science has focused in the last decade, since much of our understanding of connections between land use and the environment, for example, is relatively new. Some of the land-change science at the local and national levels now focuses further along the cycle, on how big the problem is, what to do about it (mitigation or adaptation options) and how to monitor progress on addressing the problem. Towards the end of the issue cycle, after stakeholders have a broad understanding of the problem and have reached consensus on the need and way to act, then research is likely to have the most impact if it develops cheap, replicable and credible indicators (that will stand up under legal scrutiny, for example) for use in monitoring and enforcement.

In most cases, however, it simply is naïve to expect that better information alone will lead to better public policy and land use. Typically, the most that can be hoped for is that policy research can support the efforts of cer-

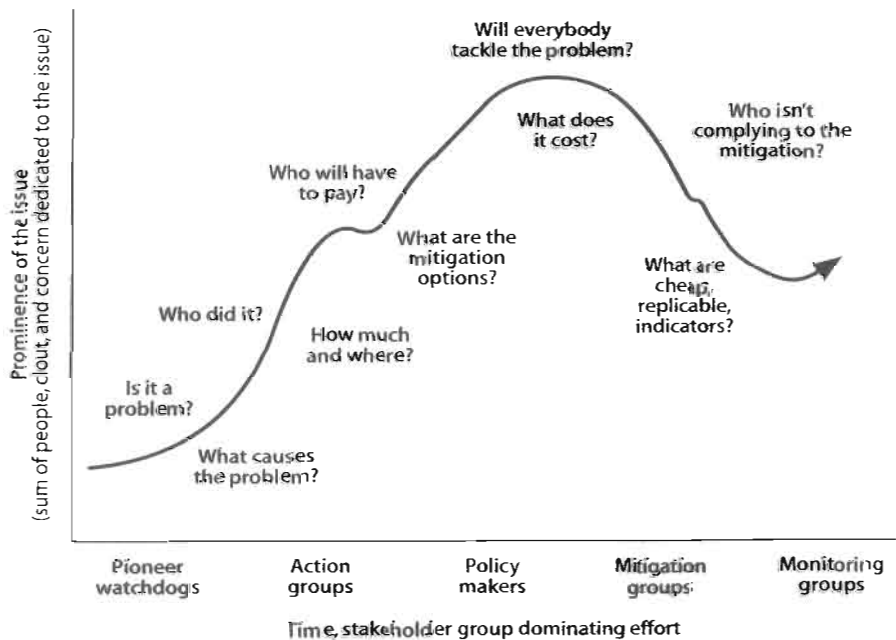
tain policy makers, politicians and others who share a commitment to core long-term land-use policy objectives such as reducing deforestation or combating desertification. Without links to influential individuals, prospects for constructive impact of policy research are severely limited. This also means that, if there are beneficial policy changes, these influential individuals – not researchers – deserve the credit (Tomich 1999).

Policy makers – especially in democratic societies – often want to maximize votes and agreement in short election cycles. Where opportunities exist, scientists and policy-makers alike need to put additional emphasis on win-win situations that deliver both short-term benefits for politicians and long-term conservation of natural resources. Of course, this political calculus applies even in non-democratic societies.

Another issue is that land-use problems often occur at landscape and regional scales. This creates a problem in policy, because, particularly in developing countries, there are few institutions that naturally operate at this scale: many function locally and internationally, but not in the “missing middle” (Tomich et al. 2004a). In general, collective action is more difficult when more people or institutions are involved, they are in different locations, and they speak different languages: they are substantially heterogeneous. Thus, in the missing middle, action is problematic and institutions are weaker, making policy action doubly difficult.

Scientists, land users and policy makers may find that it is useful to work directly with boundary or “translator” organizations whose goals are to bring the best of scientific information into policy (Cash et al. 2003; Soberon 2004). These organizations (or individuals) can mediate when scientists and policy makers (and other stakehold-

Fig. 7.4. The “issue cycle” in a democracy showing, over time, the groups who focus on an environmental problem (x-axis), how prominent the problem is in public discourse (y-axis), the appropriate policy questions (blue, above line) and scientific questions (green text, below line; adapted from Tomich et al. 2004b)



ers) have different constraints and goals, and when they differ on what kind of information is credible and useful. They can ensure that communication is active, iterative and inclusive, thus strengthening the legitimacy of these interactions. They can also help scientists understand what policy makers and land users need and how the policy process works. It is helpful if key individuals in these boundary organizations are accountable to the scientists, land users and policy makers.

Land-use scientists need to work closely with policy makers and land users to identify – and in many cases develop, test, and validate – workable policy levers that effectively influence the rate and patterns of land-use change (Tomich et al. 2004c). There are, of course, policy instruments that are relatively easy to manipulate (at least technocratically, if not politically) and that have powerful effects on land use and land-use change. Examples include exchange rates and interest rates; price, trade, and marketing policies; and public expenditures for infrastructure (Tomich et al. 2004a). While it is important to recognize that finance ministries are far more powerful than others concerned with land use (e.g., agriculture, environment), they also have much broader economic goals to satisfy. So, while this group of macroeconomic policy instruments is too important for land-use scientists and policy analysts to ignore, it is unlikely (and probably even undesirable) that they would be “targeted” to achieve specific land-use objectives. Public expenditures on research and extension and laws and regulations affecting access to and transfer of land and other assets are much more tightly linked to land-use issues and comprise an important set of topics for engagement between researchers and policy makers and other stakeholders. Direct mechanisms to address the “market failures” that underpin many of the environmental problems linked to land-use and land-cover change probably are the most challenging among land-policy research issues because few (if any) workable methods have been developed. However, despite this challenge, as a general rule the “closer” an intervention is linked to the problem it seeks to influence, the better the chances for success without also producing offsetting distortions. A specific example here would be mechanisms to reward poor people for managing landscapes to produce environmental services as well as conventional commodities. The approach to research required for success in developing such policy instruments depends on, but also is very different from, research strategies that are effective in identifying and quantifying basic cause and effect relationships. A further complication is that, for situations in which there are multiple, interacting policy problems (as typically is the case in land-use policy analysis), it is unlikely that any single intervention can address all problems. Moreover, a piecemeal approach easily can make the overall situation worse. An important example here would be deregulation of markets to reduce trade distortions for

forest products without also addressing property rights over forest resources. So, a comprehensive approach to policy analysis and implementation is necessary. Given message 3 above, policies need to reconnect agents and stakeholders of change.

Compared with some other issues, land-use issues may not have high priorities in political agendas. This makes it all the more important that land-use scientists explain the land-use implications of policy options.

7.5 Conclusions

In the last decade, land-change science came into its own. Because of this, we can write this chapter and suggest some messages for policy makers. We also can learn from the scholarship in other areas to suggest a process to improve the links between scientists and policy makers. We now know much more about the rates, causes, pathways and consequences of land-use/cover change, and these are usually specific to different parts of the world (see Chap. 2, 3 and 4). We think that understanding patterns of forces driving rapid land-use change and associated effects (or feedbacks) on the environment and human societies can help policy makers develop more effective strategies and identify specific opportunities for policy intervention. We need to build on the few win-wins, where the goals of sustainability and development are aligned, but also on situations where we make big wins and lose only a little. And policy makers must account for the actions of different actors when crafting new policy.

This chapter argues that land-change science has made some major advances in producing information, which builds on and integrates a long tradition of studying land-systems change in various parts of science. This information is often relevant to land policy. For example, we have learned that human population growth is closely associated with land-use change. However, population growth is not as influential as previously thought, particularly if that growth is in urban rather than rural areas (Mather and Needle 2000). Instead, policy-related and other factors often play more important roles. Further, there are many causes of land-use/cover change, but this complexity is not infinite. Some causes are more important than others and similar forces cause land-cover change in systems as dissimilar as humid forests and drylands. Despite this, we still cannot explain fully what affects the speed and magnitude of land-use/cover change (see Chap. 5). We also know that there are some relatively predictable pathways of land-use/cover change and that these allow some generalization about driving forces and development of scenarios of future change (see Chap. 6). And we know how and why single interventions can change the way people use the land. For example, the introduction of new agricultural technologies can sometimes encourage farmers to rapidly clear

tropical forest, but in other places, with differing economic and social contexts, the introduction of a similar technology may discourage farmers from expanding their agricultural land at the expense of the forest. The latter obtains only under quite restrictive conditions and, in reality, the former is much more important. The key insight here, however, is that the outcomes depend as much or more on market access, institutions, and the policy environment – i.e., interacting or mediating factors – than on the specific technology (Angelsen and Kaimowitz 2001b).

But better understanding is just the beginning. The chapters in this collection show how land use involves decisions taken by individuals (e.g., farmers, pastoralists, forest dwellers), but these decisions also are shaped by policy and political economy. The various actors have different knowledge systems, power relations, and interests, which calls for better communication among scientists, policy makers, and society. Effective links between

policy makers, local communities and scientists will reduce the risk of unexpected changes in unexpected places, and strengthen the entire process of land management (Lebel 2004).

Influencing policy clearly is not a trivial task. However, land-use problems touch some of the most daunting problems of our times. To rise to this challenge, land-use scientists can develop better and more reliable ways to provide input into decision making, if they take steps to become properly engaged and make the commitment to follow through. Some scientific leaders call not only for increased engagement with policy makers by scientists, but also for the creation of a radical new approach, creating new professions and strong accountability (Lubchenco 1998). Unfortunately, from experience worldwide so far, it is clear that developing, implementing and evaluating effective science-policy links takes time, perhaps a decade or more (Cash et al. 2003). With no time to lose, the best time to start is now.