



Framing the application of adaptation pathways for rural livelihoods and global change in eastern Indonesian islands



J.R.A. Butler^{a,*}, W. Suadnya^b, K. Puspadi^c, Y. Sutaryono^d, R.M. Wise^e, T.D. Skewes^f, D. Kirono^g, E.L. Bohensky^h, T. Handayani^b, P. Habibi^b, M. Kisman^b, I. Suhartoⁱ, Hanartani^b, S. Supartarningsih^b, A. Ripaldi^j, A. Fachry^k, Y. Yanuartati^b, G. Abbas^l, K. Duggan^m, A. Ash^a

^a CSIRO Ecosystem Sciences, EcoSciences Precinct, GPO Box 2583, Brisbane, QLD 4001, Australia

^b Faculty of Agriculture, University of Mataram, Jl. Majapahit 62, Mataram 83127, Nusa Tenggara Barat Province, Indonesia

^c Assessment Institute for Agricultural Technology, Lombok, Nusa Tenggara Barat Province, Indonesia

^d Faculty of Livestock Science, University of Mataram, Jl. Majapahit 62, Mataram 83125, Nusa Tenggara Barat Province, Indonesia

^e CSIRO Ecosystem Sciences, Black Mountain, Canberra, ACT 2911, Australia

^f CSIRO Marine and Atmospheric Research, GPO Box 2583, Brisbane, QLD 4001, Australia

^g CSIRO Marine and Atmospheric Research, Centre for Australian Weather and Climate Research, Private Bag No 1, Aspendale, VIC 3195, Australia

^h CSIRO Ecosystem Sciences, Australian Tropical Science Precinct, Private Mail Bag, Aitkenvale, QLD 4814, Australia

ⁱ VECO Indonesia, Denpasar, Indonesia

^j Indonesia Meteorology Climatology and Geophysics Agency, Jl. TGH. Ibrahim Khalidy, Kediri, Lobar, Mataram, Nusa Tenggara Barat Province, Indonesia

^k Faculty of Economics, University of Mataram, Jl. Majapahit 62, Mataram 83127, Nusa Tenggara Barat Province, Indonesia

^l NTB Environmental and Research Agency, Jalan Majapahit 56, Mataram, Nusa Tenggara Barat Province, Indonesia

^m Griffin NRM, PO Box XYZ, Canberra, ACT, Australia

ARTICLE INFO

Article history:

Received 10 April 2013

Received in revised form 17 November 2013

Accepted 2 December 2013

Available online 30 December 2013

Keywords:

Adaptive co-management

Climate change

Drivers of change

Innovation niches

Livelihoods

Millennium Development Goals

ABSTRACT

In developing countries adaptation responses to climate and global change should be integrated with human development to generate no regrets, co-benefit strategies for the rural poor, but there are few examples of how to achieve this. The adaptation pathways approach provides a potentially useful decision-making framework because it aims to steer societies towards sustainable futures by accounting for complex systems, uncertainty and contested multi-stakeholder arenas, and by maintaining adaptation options. Using Nusa Tenggara Barat Province, Indonesia, as an example we consider whether generic justifications for adaptation pathways are tenable in the local context of climate and global change, rural poverty and development. Interviews and focus groups held with a cross-section of provincial leaders showed that the causes of community vulnerability are indeed highly complex and dynamic, influenced by 20 interacting drivers, of which climate variability and change are only two. Climate change interacts with population growth and ecosystem degradation to reduce land, water and food availability. Although poverty is resilient due to corruption, traditional institutions and fatalism, there is also considerable system flux due to decentralisation, modernisation and erosion of traditional culture. Together with several thresholds in drivers, potential shocks and paradoxes, these characteristics result in unpredictable system trajectories. Decision-making is also contested due to tensions around formal and informal leadership, corruption, community participation in planning and female empowerment. Based on this context we propose an adaptation pathways approach which can address the proximate and systemic causes of vulnerability and contested decision-making. Appropriate participatory processes and governance structures are suggested, including integrated livelihoods and multi-scale systems analysis, scenario planning, adaptive co-management and 'livelihood innovation niches'. We briefly discuss how this framing of adaptation pathways would differ from one in the developed context of neighbouring Australia, including the influence of the province's island geography on the heterogeneity of livelihoods and climate change, the pre-eminence and rapid change of social drivers, and the necessity to 'leap-frog' the Millennium Development Goals by mid-century to build adaptive capacity for imminent climate change impacts.

Crown Copyright © 2013 Published by Elsevier Ltd. All rights reserved.

* Corresponding author. Tel.: +61 2 6776 1358; fax: +61 2 6776 1333.

E-mail addresses: james.butler@csiro.au (J.R.A. Butler), iwsuadnya@hotmail.com (W. Suadnya), ketutpuspadi@yahoo.com (K. Puspadi), ysf_25@yahoo.com (Y. Sutaryono), russell.wise@csiro.au (R.M. Wise), tim.skewes@csiro.au (T.D. Skewes), dewi.kirono@csiro.au (D. Kirono), erin.bohensky@csiro.au (E.L. Bohensky), ims_dd@yahoo.com (I. Suharto), rivalntb@yahoo.com (A. Ripaldi), afachry@gmail.com (A. Fachry), gulbas.zulfikar@gmail.com (G. Abbas), kduggan@griffin-nrm.com.au (K. Duggan).

1. Introduction

The rural poor in developing countries are the most vulnerable to the impacts of climate and global change. Such communities and households are highly dependent on climate-sensitive natural resources and the ecosystem goods and services that these provide, and they have limited adaptive capacity in terms of the assets which they can mobilise in response (Adger et al., 2003; Adger, 2006). Furthermore, the effects of mal-adaptive decisions (i.e. actions that impact adversely on or increase the vulnerability of other systems, sectors or social groups, Barnett and O'Neill, 2010) are likely to be felt disproportionately by these communities, exacerbating their vulnerability (Ensor, 2011). The Rural Poverty Report 2011 (International for Agricultural Development, 2010) concluded that globally 1.4 billion people continue to live in extreme poverty, and that two-thirds of these reside in rural areas of the developing world. Redressing the 'adaptation deficit' amongst these communities has become a priority for development agencies and practitioners (Brooks et al., 2011; Ranger and Garbett-Shiels, 2011).

However, responses to climate change must also be mainstreamed into initiatives focused on the achievement of human development goals, rather than being considered separately and risking potentially negative outcomes for one or other dimensions (Perch et al., 2010; Ensor, 2011; Eriksen et al., 2011; Ranger and Garbett-Shiels, 2011). This task is substantial given that the existing challenge of alleviating poverty through enhanced income, health, food security, gender equality, self-determination, biodiversity and ecosystem services, as enshrined by the Millennium Development Goals, is in itself formidable (United Nations, 2012). Hence there is a need to develop policy and research processes which can identify interventions that achieve co-benefits for poverty alleviation, climate adaptation and greenhouse gas mitigation but avoid mal-adaptation (Perch, 2011; Smith and Vivekananda, 2011) (Fig. 1), and are therefore 'no regrets' because they yield benefits under any future conditions of change (Hallegatte, 2009).

The construct of 'adaptation pathways' as an iterative decision-making process which aims to steer societies towards sustainable futures while maintaining adaptation options (Wise et al., in this volume) provides a potential solution. Because it deliberately goes beyond focussing on climate impacts and responses in isolation, and instead includes other forces of global to local change which may interact unpredictably with climate change, the approach broadens the focus to complex and dynamic multi-scale social-ecological systems rather than their individual components. It also proposes that the values and interests of multiple stakeholders are likely to be contested and will evolve within systems, necessitating adaptive governance frameworks which can foster conflict resolution, integrate knowledge cultures and catalyse collective action. In this way an adaptation pathway accounts for climate and other change within the broader objective of achieving equitable and sustainable growth and improved human well-being, and recognises the roles and agency of multiple stakeholders.

So far the concept as presented by Wise et al. (in this volume) remains untested and generic, and its' framing and application in different cultural or socio-economic contexts has not been fully explored. Further, the modalities of addressing poverty alleviation through an adaptation pathways approach have not been considered. Consequently there is a need to examine whether the adaptation pathways construct is appropriate for bridging the adaptation deficit in developing countries, and if so, how to operationalise it.

We assess this issue by examining one of Indonesia's poorest regions, Nusa Tenggara Barat Province, as a case study. We present

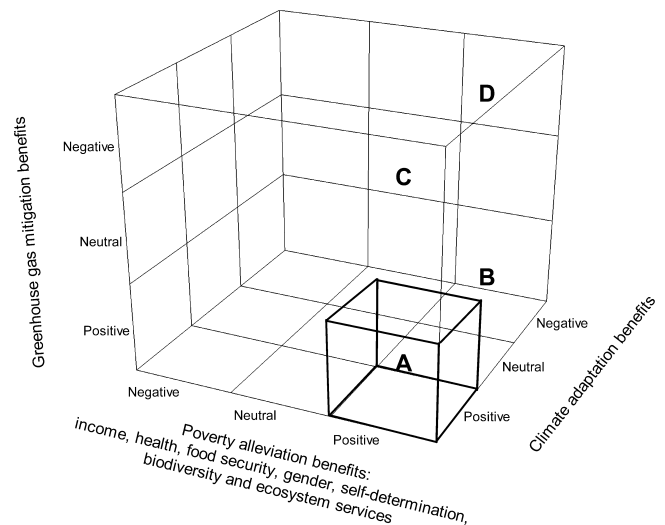


Fig. 1. To redress the adaptation deficit, interventions in developing countries should aim to achieve co-benefits for poverty alleviation, climate adaptation and greenhouse gas mitigation (A), while avoiding those that are mal-adaptive (B), increase greenhouse gas emissions (C), or both (D).

our findings in four sections. First we review Wise et al.'s five justifications for the adaptation pathways construct. Second, we present the context of climate and global change, rural poverty and development in Nusa Tenggara Barat, including the perceptions of a cross-section of decision-makers. Third, using this information we consider whether the justifications are tenable for Nusa Tenggara Barat, and identify points of consistency and divergence. Fourth, based on the results of this comparison we frame how an adaptation pathways approach could be applied in the province in terms of analysis, process and governance. Finally, we contrast this with agricultural regions of developed nations such as neighbouring tropical Australia, and discuss the broader relevance of our findings for other developing countries.

2. Adaptation pathways and rural development

2.1. Five justifications for adaptation pathways

Wise et al. (in this volume) argue that there is a growing shift in climate adaptation science from a problem-orientated (i.e. estimating impacts and vulnerabilities) to a decision-orientated focus, which aims to assist decision-makers to assess and implement alternative policy options within highly uncertain, dynamic and complex social-ecological systems. Reeder and Ranger (2011) originally introduced the 'pathway' metaphor to focus on the process of decision-making, emphasising the inherent uncertainty and inter-temporal complexity of climate change. Fundamentally, this approach envisages a series of decision points where no regrets interventions are made which also maintain flexibility for potential future adaptation.

However, to date the construct has only been applied to contexts where goals are unambiguous and decision-making is centralised. As a result adaptation actions have been focused on proximate causes of vulnerability rather than the root causes such as societal institutions and values (Pelling, 2011). Wise et al. emphasise that adaptation problems are often more complicated, being nested within complex and evolving social-ecological systems, and involving multiple stakeholders across scales who have competing values, goals and knowledge influencing their decisions. Consequently a broader adaptation pathways construct is needed which fosters an iterative and adaptive governance process for designing and implementing collective action, tackling

Table 1
Summaries of the five justifications for an adaptation pathways approach (from Wise et al., in this volume), their tenability in Nusa Tenggara Barat (NTB), and points of divergence. *Abbreviations:* MDGs, Millennium Development Goals; NGOs, non-government organisations.

Justification	Tenable in NTB?	Points of divergence
1. Climate adaptation is inseparable from cultural, political, economic, environmental and development contexts	Yes: climate change and variability are inter-linked with social, economic and cultural drivers of vulnerability. Therefore responses need to consider linked system effects	Other drivers out-play climate, but this may alter after 2050. Adaptation pathways should focus on social drivers today to 'leap-frog' MDGs in next 20–30 years to reduce adaptation deficit by mid-century
2. Responses to change cross spatial and jurisdictional boundaries must be coordinated to avoid threshold effects and mal-adaptive consequences	Partially: large scale infrastructure and development projects are not reversible, and agri-business programmes do not target the needs of the poor	Cross-scale and jurisdictional responses necessary but most target institutional and governance issues, and so are no regrets
3. System trajectories are path-dependent, locked-in and difficult to change	Yes: poverty locked-in by corruption, cultural institutions, fatalism and social reproduction	High degree of system flux (e.g. decentralisation, modernisation) and opportunity for governance innovation
4. Difficulty of understanding current system state and its trajectory due to emergent properties	Yes: some aspects highly unpredictable with rapid changes in many drivers, potential thresholds and shocks, and paradoxes (e.g. empowerment of women versus declining traditional institutions)	Poverty is locked-in and resilient due to corruption, cultural institutions, fatalism and social reproduction
5. Societal processes and decisions are determined by contested rules, values and knowledge cultures	Yes: tension between formal and informal leaders; NGOs and corruption; traditional institutions and female empowerment; communities and government planning	Promotion of partnerships between formal and informal leaders, Climate Change Task Force coordinating between stakeholders

both proximate causes of vulnerability through incremental adaptation, and more systemic drivers through transformational adaptation, while managing the tensions and uncertainties that exist around these decisions and related stakeholders.

Wise et al. make five linked justifications for this broader approach (Table 1). First, climate adaptation is inseparable from the cultural, political, economic, environmental and developmental contexts in which it occurs, and society cannot consider climate change in isolation from other forces of global to local change. Second, responses to change often cross spatial and jurisdictional boundaries and must be coordinated to avoid threshold effects and mal-adaptive outcomes. Third, due to positive feedback loops, system trajectories are path-dependent, often 'locked-in' and difficult to change. Fourth, due to systems' emergent properties as they adapt to change, it is difficult to diagnose their current state and predict potential future trajectories. Fifth, societal decision-making processes which respond to change are determined by contested rules, values and knowledge cultures.

As a consequence, Wise et al. propose that researchers and decision-makers must implement adaptation pathways at two levels. First, incremental actions should be taken within prevailing governance arrangements to tackle the proximate causes of vulnerability. However, these must be modified to ensure that they are informed by and inform systemic change. Second, the influences of existing rules and values on decision-making must be understood, and a proactive approach taken to alter the current governance system to enhance society's capacity to anticipate and steer systems towards more desirable pathways in the face of global change. Importantly, this implicitly requires a paradigm shift for the interface between research, policy and practice. Not only must adaptation pathways seek to trigger change at one or both levels, but processes and tools must be developed amongst all stakeholders which can facilitate and manage the contested decision-making arena.

2.2. Rural communities and social–ecological systems

Fundamental to the adaptation pathways construct is the framing of dynamic and complex social–ecological systems. To relate the rural development context to Wise et al.'s propositions, we characterise systems in the following terms:

Livelihoods: The “the capabilities, assets (including both material and social resources) and activities required for a means of living” (Scoones, 1998, p. 5). Livelihood outcomes are determined by the vulnerability context and the availability of assets and endowments for livelihood strategies, mediated by institutions. The fundamental objective of livelihood strategies is to enhance individuals' well-being and adaptive capacity (Armitage, 2007; Plummer and Armitage, 2007).

Vulnerability: The characteristics of communities and their social, political, economic and environmental context which renders them susceptible to climate change and other hazards or shocks. This takes the 'starting-point' interpretation from Kelly and Adger (2000), referring to the processes that pre-exist within livelihoods prior to adaptation. Vulnerability is manifested as poverty, which is characterised by limited assets such as savings, education, health, land, housing, food and political empowerment (Ensor and Berger, 2009).

Drivers of change: The interdependent causal factors which can shift the system of interest past thresholds into alternative states, and originate from different scales and domains (Walker et al., 2004; Folke et al., 2010). The United Kingdom's Department for International Development (2004) considered drivers to be institutional and governance factors that mediate livelihood outcomes, while the Millennium Ecosystem Assessment (2005, p. 87) defines them as “any natural or human-induced factor that directly or indirectly causes a change in an ecosystem”, subdivided into 'direct' or 'indirect', which are the diffuse factors that influence direct drivers.

Adaptive capacity: The potential for actors within a system to respond to drivers of change, and to shape and create changes in that system (Chapin et al., 2006). The determinants of adaptive capacity include both livelihood assets, including health, educational, financial and information resources, and the institutional and political contexts which determine how these are made available and mobilised (Smit and Wandel, 2006).

Resilience: The ability of a system to retain its overall function (Walker et al., 2004). In a rural development context this implies the local and short term ability of communities to cope and bounce back from shocks based on current adaptive capacity (Scoones, 2009), also termed 'absorbing capacity' (Ensor, 2011). Transformation is required when a system is trapped in an undesirable (and often

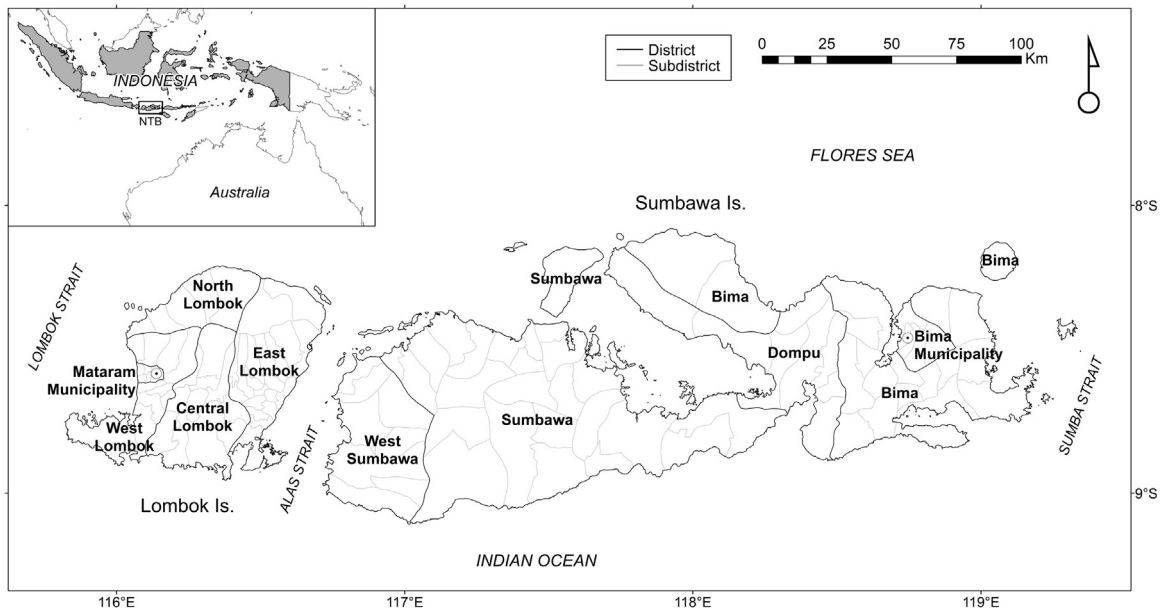


Fig. 2. Nusa Tenggara Barat (NTB) Province, Indonesia.

resilient) state (Walker et al., 2004). For rural livelihoods this may be necessary because “many production systems do not meet the needs of local communities, and some existing agricultural systems will not be viable under changed climate conditions; simple incremental adaptation will not suffice. These systems will need to be transformed into new kinds of agro-ecosystems. Such a transformational change may require that totally new germplasm, crops, farming systems, institutions, and policies are all put into place in a short space of time” (Walker et al., 2010, p. S-12). Ensor (2011) emphasises that this requires ‘purposeful adaptive capacity’ which can be mobilised to pro-actively capitalise on changing circumstances.

Hence the goal for rural development is to reduce vulnerability, expressed as poverty. This can be achieved by empowering communities and related stakeholders to increase the resilience of livelihoods, or to take advantage of change and make transformations to alternative, improved livelihoods. Development actors must therefore build both the absorbing and purposeful adaptive capacity of communities and other stakeholders (Ensor, 2011). In this context adaptation pathways seek to create decision-making processes and structures which can enhance communities’ and linked stakeholders’ capacity to influence direct (i.e. proximate) and indirect (i.e. systemic) drivers of vulnerability via no regrets, co-benefit strategies which reduce the adaptation deficit and also maintain future flexibility.

3. Climate and global change, rural poverty and development in Nusa Tenggara Barat

3.1. Background

3.1.1. Geography and climate

Nusa Tenggara Barat is located in the island archipelago of eastern Indonesia, which borders northern Australia (Fig. 2). The province consists of two principal islands, Lombok (4725 km²) and Sumbawa (15,448 km²), which feature the volcanoes of Rinjani and Tabora. It has a tropical climate with a monsoon season of December–April, and is affected by the El Niño Southern Oscillation, which can generate drought periods or wetter than average years. Dry years can truncate the wet season, causing rice crop failures and food insecurity (Partridge and Ma’shum, 2002; Klock, 2007). Due to the orographic effects of the volcanoes, steep

climate gradients exist across the islands. Combined with variations in soil type, these micro-climates support diverse agricultural systems (Yasin et al., 2007).

Under the ‘business as usual’ greenhouse gas emissions scenario, by 2050 average air temperatures in Lombok may increase by 1 °C relative to the 1961–1990 average, and 2–3 °C by 2100 (Ministry of Environment, 2010). By 2100 sea surface temperature may increase by 1.2 °C, increasing the frequency of extreme weather events, and sea level may rise by 1 m. Rainfall patterns may not change significantly by 2030, but by 2080 precipitation will become concentrated into fewer events. Due to the micro-climates rainfall change will vary widely across the islands (Kirono et al., 2010).

3.1.2. Society, human development and economy

The predominant religion is Islam, which is undergoing a resurgence and politicisation (Hunter, 2004; Kingsley, 2012). There are three ethnic groups: Sasak in Lombok and Samawa and Mbojo in Sumbawa, plus immigrant Balinese, Javanese and Sundanese. Amongst the Sasak there is variation between orthodox Islam and more traditional values and beliefs (Krulfeld, 1966). Decision-making at all levels of society is patriarchal in accordance with Islamic and traditional law (Sjah et al., 2006). Following President Suharto’s regime collapse in 1998 state authority has been decentralised from national to district governments. In addition to elected or appointed leaders of formal government bodies, there are parallel informal leaders of traditional ethnic assemblies, plus religious figureheads (Fachry et al., 2011).

With a national Human Development Index of 0.613 in 2010, Indonesia has attained medium human development levels (United Nations Development Program, 2011). In 2009 Nusa Tenggara Barat had the second lowest Human Development Index amongst Indonesia’s 33 provinces, reflecting low levels of life expectancy, literacy rates, education and per capita income. Absolute poverty rates have declined from 30% in 2001 to 22% in 2010, but the province is not projected to reach the Millennium Development Goal target of 11.6% by 2015 (Kusuma, 2010). Gender inequality is reflected in a disparity in literacy rates between men (92%) and women (82%) (Fachry et al., 2011). Sixty-one percent of rural sub-districts suffer chronic food insecurity, and the majority are in Lombok (World Food Program, 2010).

In 2010 the population of Nusa Tenggara Barat was 4.5 million, with an annual growth rate of 1.17%. Fifty-eight percent of the population is rural. Although annual growth rates will decrease to <1% per annum by 2050, the population may reach 6.37 million, a 41% increase from 2010. Assuming current population distribution, 4.46 million will live on Lombok at an average density of 943 people per km², and 1.91 million on Sumbawa at a density of 124 per km² (Fachry et al., 2011).

Gross Domestic Product growth in the province has fluctuated. Following the Asian financial crisis in 1997 inflation caused the prices of many household staples to increase by over 100% (Hunter, 2004). In 2010 the province's economy grew rapidly by 6.3%, with a 10% inflation rate (Fachry et al., 2011). Public administration costs are excessively high, standards of financial management and transparency are low, and coordination between departments is limited (Kusuma, 2010).

3.1.3. Rural livelihoods and poverty

Due to the heterogeneity of cultures, human development status, micro-climates and soil types, rural livelihoods' characteristics vary over short distances. Lisson et al. (2010, p. 488) summarise farming systems in Lombok as "typified by small land areas (usually <2 ha) that support an integrated mix of crop, forage, livestock and human activities. . . These enterprises involve linkages between the 'farm' and 'household' activities that are generally acknowledged to be stronger and more mutually dependent than for western farming systems." Emigration to Malaysia to work as labourers is an important male activity, particularly when crops fail, with remittances being sent back to the household. The primary livelihood outcomes sought by farmers are fulfilling the family's basic food needs, financing children's schooling and saving for a pilgrimage to Mecca (Sjah et al., 2006).

Since decentralisation the delivery of local government services and development projects has faltered, exacerbating poverty, and landless and female-headed (i.e. widowed or divorced) households are the poorest (Hunter, 2004). Disadvantage is typified by a lack of income; polygamy, which results in a large family size and increased demand for food and staples; crop failure due to climatic variability, resulting in emigration to Malaysia by male family members; female illiteracy; health problems due to the family's inability to access or pay for preventative care, and the high and rising cost of agricultural inputs and fuel (Pikkert, 2007). Another characteristic is a passive and fatalistic world view (Krulfeld, 1966; Suharto et al., 2003). Labourers do not dispute wage rates, preferring to maintain the *status quo* and social cohesion within the community, which is important for maintaining traditional institutions such as mutual assistance practices (Jakimow, in press). These attitudes persist through generations via social reproduction, perpetuating 'cultures of poverty' (Dofford, 2011).

3.1.4. Development policies and programmes

Agriculture is a focus for government development plans, since nationally the province has a competitive advantage for many crops and fisheries, and this sector is the primary employer. Production increases are intended for all agricultural goods, lead by a flagship programme which targets cattle, maize and seaweed. This has been criticised for being driven by national productivity targets and related technological interventions, rather than focussing on farmers' needs and poverty reduction (Kusuma, 2010). Nusa Tenggara Barat is also being promoted as an international tourist destination to rival neighbouring Bali.

The province is the focus of international donor programmes which fund infrastructural, education, health and agricultural development projects. Much of this expenditure is channelled through non-government organisations. However, aid investment

is haphazard, and the lack of coordination with government programmes can result in sub-optimal outcomes (Kusuma, 2010).

3.1.5. Climate change planning

A National Action Plan Addressing Climate Change was developed in 2007 (Ministry of Environment, 2007), followed by a Climate Change Sectoral Road Map, which aims to integrate climate change adaptation and mitigation into national development plans (Ministry of National Development Planning, 2010). The Road Map has established a Climate Change Trust Fund to support the mainstreaming of climate change issues into national and provincial development plans. To date the Road Map's focus has been climate change mitigation, and there is an urgent need to promote community-scale adaptation (Djalante and Thomalla, 2012; Bohensky et al., 2012).

In 2010 the provincial government formed a Climate Change Task Force with a remit to strengthen communities' adaptive capacity, and to integrate the activities of all relevant stakeholders (Nusa Tenggara Barat Environmental and Research Agency, 2010). In 2010 strategies were formulated for each government sector to be included in the provincial development plan, but to date these have not been fully operationalised within provincial or district government expenditure. Disconnected from this process, several donors and non-government organisations have established projects to build communities' resilience to natural disasters and climate change, which is already evident in the province (Ministry of Environment, 2009; World Food Program, 2012).

3.2. NTB leaders' perspectives

3.2.1. Data collection and analysis

To provide a preliminary understanding of rural livelihoods and poverty dynamics from the perspectives of decision-makers, we gathered data from a cross-section of formal and informal leaders in Lombok and Sumbawa. Data were collated from two focus group discussions (one per island) and six interviews (three per island) held in March–June 2011. Each focus group had seven participants, consisting of provincial government department heads (four), an elected district government leader, and leaders of local non-government organisations (two), religious (two), traditional (three) and youth organisations (two). Nine were men and five were women. Interviews were held with two traditional leaders, two district government and two non-government organisation leaders, of whom four were men and two were women. Focus groups took 3–4 h and interviews 1 h, and were conducted by Indonesian co-authors in Bahasa Indonesia. Responses were digitally recorded with participants' consent and later transcribed.

Focus groups and interviews followed the same format, with a sequence of open questions that triggered discussion. Terms used were explained according to the definitions in Section 2. The questions were: (1) what are the direct and indirect drivers of change for poor rural communities in Nusa Tenggara Barat, and what are their trends; (2) what are the linkages and influences between the drivers and poverty; (3) are there any drivers which could cause sudden or irreversible change; (4) how can these be avoided to reduce poverty and improve livelihoods?

Participants were also asked to highlight any regional differences amongst drivers. Focus group and interview data were combined. Transcripts for each question were analysed by coding for key words (e.g. drought, storms), and these were grouped into themes (e.g. climate variability). Trends in drivers, themed as increasing, decreasing or constant, were derived by identifying the key words most frequently mentioned for each driver. Linkages and influences between driver themes and poverty were generalised from participants' combined descriptions, and illustrated with a causal loop diagram (Fazey et al., 2011; Howe, 2010).

Table 2

Themes for drivers of change of rural poverty, their trends (↑ increasing, ↓ decreasing, ↔ constant) and regional emphases identified by leaders. Drivers which have thresholds or could create shocks are denoted by *.

Drivers of change	Trend	Regional emphases
<i>(a) Direct</i>		
Inefficient development investment	↔	
Non-government organisations	↑↓	
Community participation in planning	↓	
Local unemployment*	↑	
Migrant labour	↔	Primarily from Lombok
Fuel and energy prices*	↑	
Mutual assistance practices	↓	Still important in Lombok
Climate variability*	↑	
Land, water and food availability	↓	Most acute in Lombok
Food prices*	↑	
<i>(b) Indirect</i>		
Decentralisation	↔	
Corruption, poor leadership and coordination*	↑	
Economic growth*	↑	
Population*	↑	Higher densities in Lombok
Low female education levels	↔	More gender equality and female leaders in Sumbawa; marriage age lower in Lombok; more polygamy in Lombok
Modernisation and information technology*	↑	
Traditional institutions	↓	Informal leaders and traditional practices stronger in Lombok
Climate change	↑	
Ecosystem condition	↓	
Poor community health and education	↔	Higher levels in Sumbawa

3.2.2. Drivers of change, poverty and causal linkages

Ten direct and 10 indirect driver themes were identified (Table 2). Of these, five had a constant trend and 15 were increasing or decreasing, indicating rapid change. There were regional differences, with traditional institutions being more influential in Lombok, and higher levels of human development and women's empowerment in Sumbawa (Table 2).

The trends in all direct drivers were exacerbating vulnerability (Fig. 3), although increasing numbers of non-government organisations were mitigating the lack of community participation in planning. Inefficient development investment by the provincial, district and village governments was limiting the availability of basic services and infrastructure. Growing local unemployment was restricting opportunities for income generation. Migrant labour can generate remittances for families, but is risky for families. Some men fail to return, leaving their family destitute, or divorce on their return and pay the bride price for a second wife, creating a disadvantaged, female-headed household. Rising food, fuel and energy prices limit money available for family health and children's education. Reduced availability of land for growing crops, water for domestic and agricultural use elevates food insecurity. Declines in traditional mutual assistance activities which enable households to support one another leave the poor less able to cope with the effects of the other direct drivers.

Three clusters of interacting indirect drivers are particularly influential (Fig. 3). First, decentralisation and corruption together cause inefficient development investment. Second, climate change (via climate variability), population growth and ecosystem degradation reduce land, water and food availability. Third, high economic growth rates are accelerating modernisation via information technology and the westernising influence of tourism, which combined with corruption and poor leadership is eroding traditional institutions. This then exacerbates ecosystem degradation through the loss of customary stewardship, and hence reduced land, water and food availability. Paradoxically the weakening of traditional institutions also empowers women to attain improved

education, which mitigates population growth and thus ecosystem degradation and reduced land, water and food.

3.2.3. Thresholds and shocks

Eight drivers could potentially have thresholds or generate shocks (Table 2). For direct drivers, mass unemployment and sudden or extreme fuel, energy and food price rises could cause civil unrest. Extreme climate events could also indirectly cause land, water and food shortages which in turn would inflate food prices. For indirect drivers, sudden economic collapse could cause extreme fuel and energy price rises, as occurred during the Asian financial crisis in 1997. More incremental increases in corruption could cause social unrest and conflict if some communities or ethnic groups benefitted through inequitable development investment. Modernisation could force traditional institutions underpinning mutual assistance practices to disappear, also exacerbating ecosystem degradation. Finally, population growth could lead to threshold densities, particularly in Lombok, resulting in severe ecosystem degradation and critical shortages of land, water and food.

3.2.4. Priority development interventions

Six interventions were identified to reduce poverty: improved governance and leadership, promoting the role of non-government organisations, increased community participation in planning, improved coordination between formal and informal leaders, restoring traditional institutions and raising awareness of climate change (Table 3). These addressed seven drivers: three indirect and four linked direct drivers. There were also some regional priorities, with improved coordination between formal and informal leaders and restoring traditional institutions a priority in Lombok (Table 2).

4. How tenable are the justifications for adaptation pathways in Nusa Tenggara Barat?

In this section we consider the extent to which Wise et al.'s (in this volume) justifications are applicable in the province,

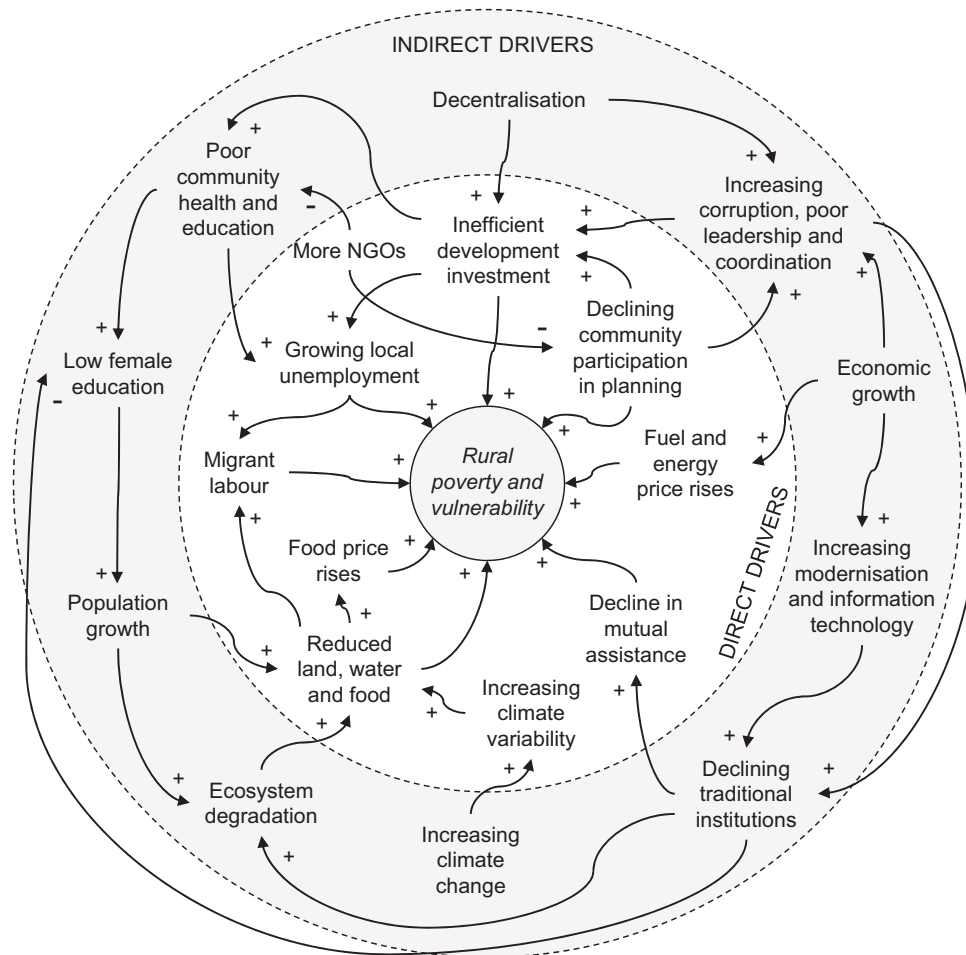


Fig. 3. Causal loop diagram showing the influences of direct (i.e. proximate causes, inner ring) and indirect drivers (i.e. systemic causes, outer ring) on each other and rural poverty and vulnerability in Nusa Tenggara Barat. A '+' polarity on an arrow indicates that if the source variable increases or decreases, the variable being influenced will also change in the same direction. A '-' polarity indicates that if the source variable increases or decreases, the variable being influenced will change in the opposite direction.

Table 3
Interventions, related indirect or direct drivers of poverty and vulnerability that they address (see Table 2 and Fig. 3), and examples of interviewed leaders' explanatory comments. Abbreviations: NGO, non-government organisation.

Intervention	Vulnerability driver addressed (direct/indirect)	Examples of interviewees' explanatory comments (leader's role)
Improved governance and leadership	Corruption, poor leadership (indirect) Inefficient development investment (direct)	"Government must give priority to the interests of the people" (traditional) "Improve systems and processes of development planning and budgeting" (district government) "Elected representatives must be able to become an extension of the people, and deliver their aspirations" (NGO) "Public aspirations must be respected, acted upon quickly and transparently" (NGO) "Leaders must set a good example" (traditional)
Promote the role of NGOs	NGOs (direct) Corruption (indirect) Inefficient development investment (direct)	"Increase the role of NGOs and community organisations as independent agencies to monitor the performance of government and promote equitable development" (NGO) "Monitoring and evaluation of government projects involving various parties, including NGOs" (traditional) "Organise discussion forums to enable community to voice concerns" (traditional)
Increase community participation in planning	Community participation in planning (direct)	"Increase participation of civil leaders, community leaders, religious leaders, youth and women in various aspects of planning development" (NGO) "We need to form multi-party and multi-stakeholder partnerships" (district government)
Improved coordination between formal and informal leaders	Poor coordination between formal and informal leaders (indirect)	"Coordination between the bureaucrats and informal leaders (i.e. religious, traditional and community leaders), both men and women" (traditional)
Restore traditional institutions	Declining traditional institutions (indirect) Decline in mutual assistance (direct)	"Increase the role of local institutions and the values of local wisdom, which are the social capital of a region" (traditional)
Raise climate change awareness	Climate change (indirect) Climate variability (direct)	"Build the capacity of communities for climate change adaptation by increasing awareness, because society is not ready to face it" (NGO)

based on the context of rural communities and poverty presented above.

4.1. *Climate adaptation is inseparable from cultural, political, economic, environmental and development contexts*

This is clearly tenable. According to the leaders, vulnerability is influenced by 10 direct and 10 indirect drivers, of which climate change and variability are only two. Perhaps as a consequence the leaders' interventions focussed largely on social issues. Further, climate variability is not directly linked to vulnerability, but together with population growth and ecosystem degradation it exacerbates declines in land, water and food, and thus vulnerability. Hence from the perspective of reducing poverty, climate variability and change cannot be tackled in isolation from these other interacting drivers.

However, the predominance of social drivers is likely to alter with time. Applying projections to population, economic growth and climate change illustrates this (Fig. 4a). Prior to 2050 population growth may decline to <1% per annum, but this will still result in high population densities, particularly in Lombok. Growth in national Gross Domestic Product is projected to remain high at 5.3% per annum in 2011–2030 (Indexmundi, 2012a), but may slow to 3.4% per annum by 2030–2060 as the population ages (Johansson et al., 2012), and this projection does not account for acute fluctuations such as the 1997 Asian financial crisis. In contrast, major changes in rainfall, temperatures and sea level are only likely to occur after mid-century. Consequently social issues and complex non-linear relationships between them will continue to dominate the vulnerability context prior to 2050; only after mid-century will climate change potentially become the over-riding driver.

This has implications for government and donor-funded development aiming to eradicate poverty. Nusa Tenggara Barat must reach a maximum poverty rate of 11.6% by 2015, and then aim for living standards equivalent to nations with high human development. This requires an increase in the Human Development Index from less than 0.613 (the Indonesian national Human Development Index in 2010) towards 0.9 (the highest-ranking national Human Development Indices; United Nations Development Program, 2011) (Fig. 4a). However, considering the potentially extreme impacts of climate change after mid-century, this elevated standard of living must be achieved rapidly. If the Human Development Index is a crude surrogate for adaptive capacity (because it is an indicator of income, health and educational status, and hence livelihood assets), then a 'leap-frogging' of the Millennium Development Goals is necessary in the next 20–30 years to redress poor communities' adaptation deficit. These improvements need to be made via adaptation pathways which can implement no regrets strategies, with a focus on social drivers. If not, mal-adaptive outcomes are possible which when combined with acute climate impacts could suppress human well-being to sub-Millennium Development Goal levels (Fig. 4a).

4.2. *Responses to change cross spatial and jurisdictional boundaries must be coordinated to avoid threshold effects and mal-adaptive consequences*

Participants identified six interventions which aimed to reduce rural communities' vulnerability. cursory analysis suggests that they would all cross spatial scales, sectors and jurisdictions. For example, the improvement of governance and leadership to tackle corruption and inefficient development requires a national initiative which should be replicated at all levels of society and government (Kusuma, 2010), and would simultaneously promote community participation in decision-making, facilitated by non-government organisations. It seems unlikely that these interventions would lead

to unexpected and undesirable threshold effects in the absence of coordination, however. With the possible exception of restoring traditional institutions, which may limit women's empowerment and education, the strategies are likely to be no regrets.

Nonetheless, there are two potential risks which were not explicitly mentioned by the leaders. The first is top-down, sectoral development programmes intended to generate economic growth and employment which may result in mal-adaptive outcomes. Large infrastructure projects are of particular concern because they are not easily reversible (Stafford Smith et al., 2011). For example, government and donor-financed irrigation and dam projects have benefited elites in Lombok, and future climate or population-driven declines in water availability are not considered in their design and location (Klock, 2007). Similarly, large scale agri-business programmes focus on productivity increases rather than the needs of the poor. Second is the uncoordinated nature of donor funding, which can result in sub-optimal outcomes (Kusuma, 2010). Taken together, such uni-lateral, top-down and strategically mis-aligned development investment may result in sub-optimal and even mal-adaptive outcomes for vulnerable households and communities.

4.3. *System trajectories are path-dependent, locked-in and difficult to change*

The fact that absolute poverty rates have declined from 30% in 2001 to 22% in 2010, and that the 2015 Millennium Development Goal target of 11.6% is not likely to be achieved indicates that poverty is difficult to eradicate. In addition, these trends mask relative poverty rates, which may remain consistently high. The leaders' perspectives showed that this is largely attributable to systemic institutional factors such as corruption and poor coordination between informal and formal leaders which cause inefficient development investment, and hence poor health, education and employment outcomes. Similarly, the prevailing patriarchal traditional culture discourages female education, with knock-on effects on family size and population growth. Two other factors not explicitly mentioned by leaders were the important and growing influence of religion, which for the Muslim majority demands that saving for a pilgrimage to Mecca is an important livelihood objective, and the passive world view of the poor.

Yet significant flux is also apparent, providing a window for proactive innovation in governance. Decentralisation presents an opportunity for the evolution of autonomous district-scale government which could include effective community participation. There are emerging national and provincial government initiatives which integrate climate change into development plans. Cultural change is also evident. Although declining traditional institutions undermine mutual assistance practices and ecosystem stewardship, this also facilitates gender equality, female education and the control of population growth. However, given poor individuals' passive attitude, the impetus to take advantage of the current flux must come from other actors.

4.4. *Difficulty of understanding current system state and its trajectory due to emergent properties*

The current state of vulnerable rural systems appears to be easily determined. Poverty is locked-in by direct drivers, many of which are influenced by institutional factors, and each reinforces the resilience of the system in an undesirable state. Conversely, trends in the majority of drivers are causing rapid change. Leaders also identified eight drivers with thresholds which could irreversibly alter livelihoods, and the current status of these relative to the thresholds is unclear.

Some paradoxes create additional unpredictability. The erosion of traditional institutions may exacerbate vulnerability

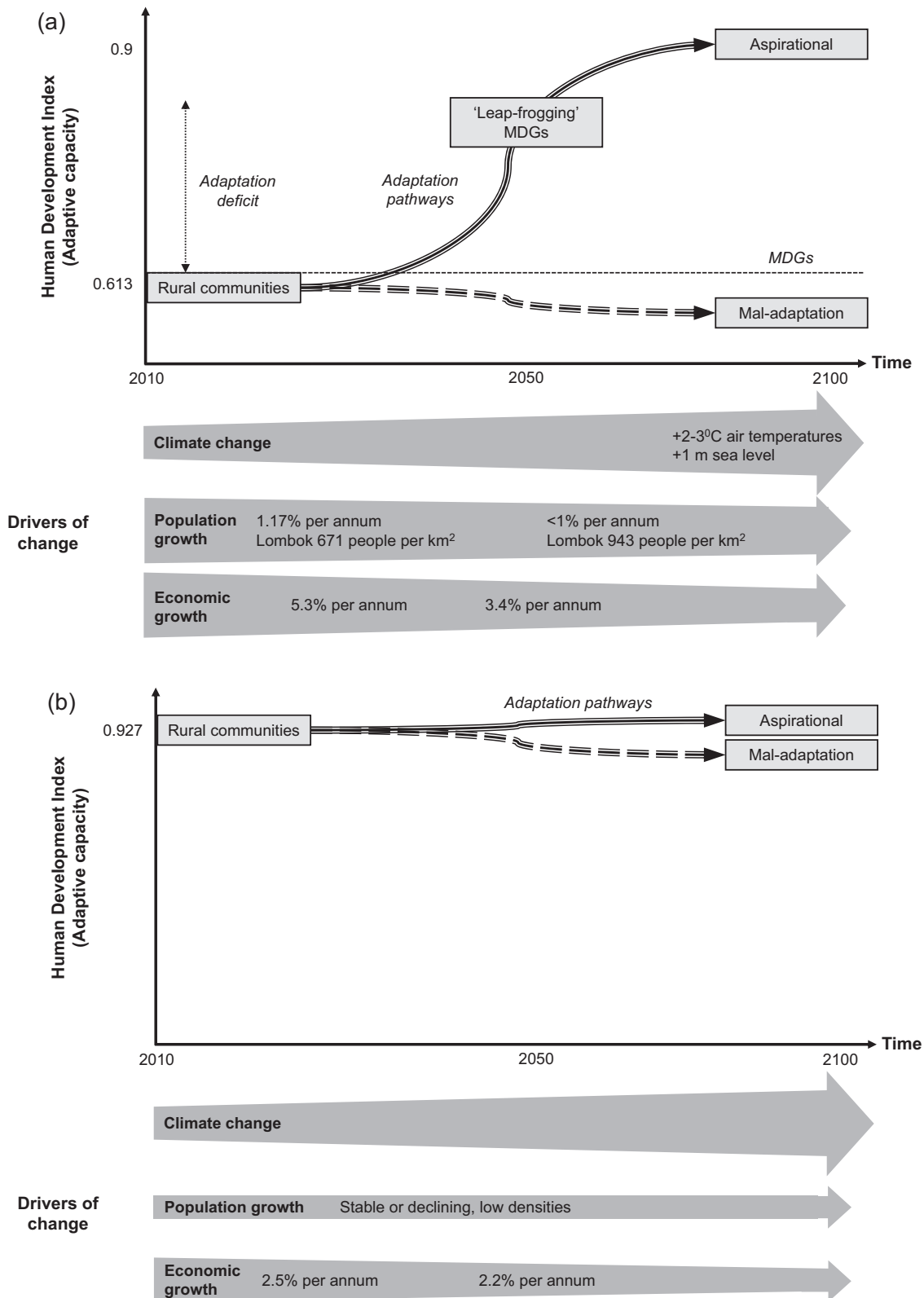


Fig. 4. Adaptation pathways framed in terms of Human Development Index (HDI) and adaptive capacity objectives for rural communities in (a) Nusa Tenggara Barat and (b) northern Australia. In Nusa Tenggara Barat, an approximation of the HDI required for rural communities to attain the Millennium Development Goals (MDGs) is shown. Pathways are shown relative to the trends and magnitude of three indirect drivers of change. The width of each driver's arrow infers its magnitude relative to other drivers. For Nusa Tenggara Barat, climate and population growth relate to the province, and economic growth to the Indonesian economy. For Australia, drivers are generalised at the national level.

by undermining mutual assistance practices, but this also empowers women and enables their education, potentially reducing population growth and other dependent drivers. A passive world view discourages the poor from challenging wage

rates in order to maintain mutual assistance practices; if their attitude altered they could potentially earn higher income, but at the expense of community cohesion. Combined with the current system flux and rapid change, these paradoxes make it difficult to

predict how emergent properties will be expressed. This uncertainty is amplified by the heterogeneity of livelihood systems, both between Lombok and Sumbawa and at a local scale.

4.5. Societal processes and decisions are determined by contested rules, values and knowledge cultures

The small sample size of interviewed leaders prevented any meaningful assessment of differences in values or knowledge cultures between their roles or gender. However, the combined interview and focus group data indicate some contestation amongst decision-makers more generally. There is tension between the influence of formal and informal leaders, particularly in Lombok. Corruption is viewed as a problem that needs to be tackled, and non-government organisations function as independent monitors with a potentially provocative role. The omission of communities by government from planning processes and the suppression of women's empowerment by traditional institutions are also contentious issues.

Yet many of the rules and values underpinning these tensions are changing. In Sumbawa women are becoming more influential, with higher education levels, later marriage and growing representation as leaders and in politics. Traditional institutions are declining as a consequence of modernisation. Partnerships between formal and informal leaders are being proposed, and the Climate Change Task Force aims to improve coordination between sectors and stakeholders.

5. Research and policy considerations in applying adaptation pathways

In this section we consider methods and processes required to apply an adaptation pathways approach in the province, given the results of our analysis (summarised in Table 1). We refine Wise et al.'s (in this volume) recommendation that research and policy should develop incremental strategies that address the proximate causes (i.e. direct drivers) of vulnerability within existing governance arrangements, and transformational strategies which seek to change the rules and values underpinning systemic causes (i.e. indirect drivers), addressed under three linked themes: analysis, process and governance.

5.1. Analysis: combining livelihoods with multi-scale systems analysis

To account for the proximate causes of vulnerability, and to understand the current adaptive capacity of communities, livelihoods analysis provides a logical foundation because it is based on the principles that “people matter, contexts are important, with a focus on capacities and capabilities rather than needs, and a normative emphasis on poverty and marginality”; further, “drawing on diverse disciplinary perspectives and cutting across sectoral boundaries, livelihoods perspectives provide an essential counter to the monovalent approaches that have dominated development enquiry and practice” (Scoones, 2009, p. 13). These principles are important in Nusa Tenggara Barat because of the marked degree of heterogeneity amongst livelihood systems across the islands, requiring a fine-scale resolution of analysis, rather than a sectoral approach. Also, because of the nascent national and provincial government planning processes for mainstreaming climate change into development, and the lack of coordination between government and donors, there is a short term imperative for autonomous adaptation (*sensu* Adger et al., 2003), which requires the formulation of no regrets, co-benefit strategies founded on poorer households' existing assets and capabilities.

Livelihood analysis can be applied to diagnose vulnerability and adaptive capacity through regional scale typologies (e.g. O'Brien et al., 2004; Nelson et al., 2010a) or local scale ‘place-based’

assessments (e.g. Paavola, 2008; Mertz et al., 2010; Schwarz et al., 2011; Fernandez-Himenez et al., 2012). Although the adaptation pathways approach intentionally moves away from such a problem-orientated focus, this is still a necessary preliminary step in Nusa Tenggara Barat, where little data exists with which to prioritise interventions.

However, these assessments are only likely to identify short term (5–10 years) incremental ‘coping’ strategies tailored to build community resilience to proximate causes of vulnerability and shocks, including current climate variability (Fig. 5). A livelihoods focus often fails to fully incorporate influences from higher scales (De Haan and Zoomers, 2005; Scoones, 2009), potentially overlooking indirect drivers or interventions which may have unintended, maladaptive outcomes locally (Walker et al., 2010). It also ignores limits to adaptation (Dow et al., 2013), and transformation potentially required to pre-empt impending shifts in indirect global drivers such as climate change, which is of relevance for 20–50 years time but requires pro-active planning today (Scoones, 2009). This issue is imperative in the province considering the need to identify no regrets, co-benefit strategies necessary to leap-frog the Millennium Development Goals by mid-century, and the pre-eminence of systemic social factors. Hence a methodology which can integrate livelihoods within multi-scale systems analysis is required.

5.2. Process: multi-stakeholder participation with relevant future horizons

Fundamental to the application of an adaptation pathways approach is the intentional development of multi-stakeholder decision-making processes and tools. A livelihoods perspective is highly compatible here because it employs participatory methods, which can empower communities (Chambers and Conway, 1992) and hence build their adaptive capacity (Ensor, 2011). However, this will present several particular challenges in Nusa Tenggara Barat. First, considering the inherent tensions between formal and informal leaders and perceived corruption, power dynamics are likely to be influential. Also, marginalised communities must be adequately represented, including disadvantaged households and women. This is clearly a priority considering the disenfranchisement of communities from development planning, but may be difficult because many of the poorest have a passive attitude. Non-government organisations will be key independent stakeholders in these processes, and could facilitate community representation. Thus stakeholder analyses which can appropriately assess actors' power, legitimacy and urgency (e.g. Mitchell et al., 1997; André et al., 2012) will be pre-requisites to any processes.

Second, the involvement of scientists presenting complex information on issues such as climate change may lack credibility for lay audiences (Cash et al., 2006; Gidley et al., 2009; Shaw et al., 2009). This challenge will be greatest when engaging communities, potentially reducing them to the position of powerless spectators, and separating them from the important learning process of analysis and reflection (Fazey et al., 2010). Hence participatory methods must be developed which can generate the co-production of knowledge and learning by policy, community and research stakeholders alike, mitigating power imbalances and creating ownership of problems and solutions (Ballard, 2005; Brown, 2008; Gidley et al., 2009).

Scenario planning is one such tool, which by exploring and visualising potential future development pathways can challenge values and assumptions, bridge stakeholders' world views, stimulate innovation and create an anticipatory ‘adaptation window’ (Shaw et al., 2009; Ravera et al., 2011). The method is also easily understood by participants with limited formal education, and is effective for integrating scientific information with local knowledge and empowering participants (Enfors et al., 2008), stimulating

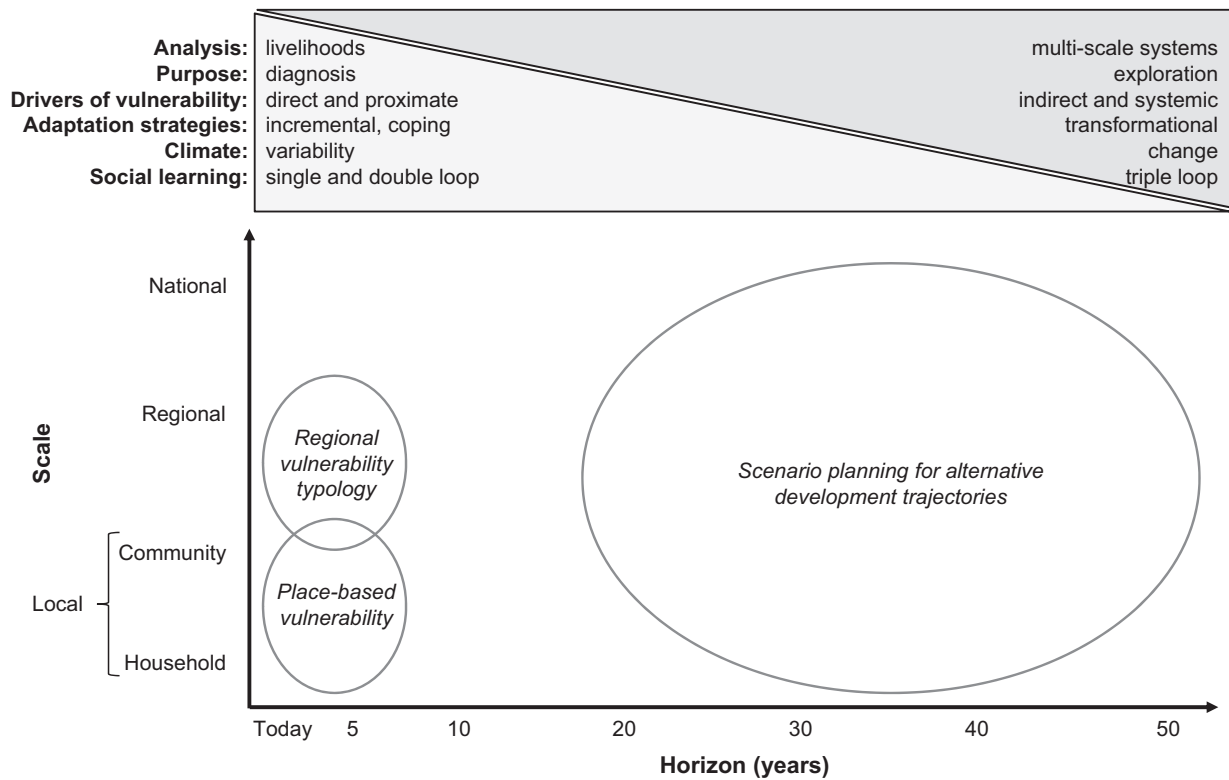


Fig. 5. Examples of participatory research and decision-making tools (ovals), the time horizons and scales concerned, and the relative emphases for analysis, purpose, drivers of vulnerability, adaptation strategies, climate change and social learning (top).

collaborative partnerships (Wollenberg et al., 2000). However, outcomes may be biased by community members' narrow experience of local scale drivers, requiring the integration of stakeholders' perspectives from higher levels (Enfors et al., 2008). Many participants may also have culturally-determined perceptions of the future which will be difficult to modify (Wollenberg et al., 2000). Nonetheless, researchers must encourage the analysis of medium and long term horizons. A 20–50 year horizon can anticipate major shifts in indirect, systemic drivers and enable an exploration of alternative development trajectories, with an emphasis on the local scale but including higher level and cross-scale issues (Fig. 5). It also allows more careful consideration of potentially mal-adaptive infrastructural investment, which is a risk in the province.

Linked to the horizon of analysis is the opportunity for stepwise social learning, regarded as central to building adaptive capacity (Pahl-Wostl, 2009). Single-loop learning involves an incremental improvement of actions without questioning the underlying assumptions; double-loop learning refers to a re-visiting of assumptions about cause and effect; and triple-loop learning re-assesses underlying values and beliefs, potentially resulting in changes in governance norms (Armitage et al., 2009). Hence a longer horizon enables a more radical learning process (Brown, 2008), encouraging triple-loop learning which can address the systemic drivers of vulnerability (Fig. 5). This will be necessary in Nusa Tenggara Barat to challenge the institutional drivers which are locking-in poor communities to resilient, potentially mal-adaptive development trajectories.

5.3. Governance: adaptive co-management and livelihood innovation niches

Designing innovative multi-stakeholder governance which is iterative, adaptive and can foster conflict resolution is a key

objective of adaptation pathways, but there are no blueprints, and experimentation is required (Randall et al., 2012; Maani, 2013). One potentially suitable model is adaptive co-management, because it blends power and knowledge-sharing amongst stakeholders from multiple levels with reflective learning and innovation in order to maintain a social-ecological system within its current state, or to transform it (Folke et al., 2005, 2010; Olsson et al., 2006). This approach has been applied to effectively manage livelihoods nested within complex social-ecological systems (Armitage, 2007; Plummer and Armitage, 2007), stakeholders in conflict over iconic species (Butler et al., 2008, 2011; Butler, 2011) and climate change risk assessments (Pahl-Wostl, 2009; May and Plummer, 2011). It also encourages the evolution of institutions (Wollenberg et al., 2000), which are key to enhancing rural communities' adaptive capacity (e.g. Marschke and Berkes, 2006; Sallu et al., 2010) and grassroots innovation for social and technological transitions (Brown, 2008; Westley et al., 2011; Leach et al., 2012).

However, this model has never been applied with reference to the adaptation pathways construct in developing countries. Due to the current administrative flux in the province there is a window in which to establish and test such a governance model. There are emerging national and provincial government processes to mainstream climate change into development planning, and to create partnerships between stakeholders. Resources are available from the Climate Change Trust Fund and donor projects, and decentralisation presents an opportunity for the evolution of autonomous district-scale government which can include effective community participation.

One feasible entry point is the establishment of 'livelihood innovation niches' within vulnerable communities identified from a regional typology. These would apply place-based vulnerability assessments and multi-stakeholder scenario planning tools to

identify no regrets, co-benefit strategies which maintain future flexibility. Such case studies could explicitly create 'safe arenas' for innovation in governance and technology where transformative practice can develop amongst more fluid and emergent rules, and without penalty for failure (Berghout et al., 2010; Westley et al., 2011). Akin to the Millennium Villages Programme, they would demonstrate appropriate strategies which can then be scaled out to similar neighbouring communities (Carr, 2008; Clemens and Demombynes, 2010), perhaps utilising a vulnerability typology (Fig. 5). Concentrating at the local scale would match governance structures to the need for rapid, context-specific decision-making and problem-solving (Walker et al., 2010; Westley et al., 2011). An adaptive co-management structure could be established and tested for each case study, shaped by the local context and the inclusion of multi-scale stakeholders. However, experience of collaborative management of forests in Indonesia under similar conditions of political instability and social flux suggests that such governance models will have to be spontaneous and highly flexible (Wollenberg et al., 2007).

6. Conclusions

Our analysis suggests that the construct of adaptation pathways is an appropriate framework for mainstreaming climate adaptation and mitigation into development and poverty alleviation in Nusa Tenggara Barat, which so far has not been achieved by ongoing government and donor programmes. Wise et al.'s (in this volume) justifications are largely tenable (Table 1). Provincial leaders' responses indicated that the causes of community vulnerability are indeed highly complex and dynamic, influenced by 20 interacting drivers which are generating rapid change, of which climate variability and change are only two. Decision-making is also contested due to tensions around formal and informal leadership, corruption, community participation in planning and female empowerment. Hence a process must be designed which can identify and implement no regrets and co-benefit strategies which do not foreclose future adaptation options, while pro-actively addressing proximate and systemic causes of vulnerability and related contested values and rules.

There are some important contextual nuances that should be taken into account, however. Social drivers currently out-play climate variability and change, and these should be prioritised to reduce the adaptation deficit, and strategies must avoid potential mal-adaptation for future climate effects. While poverty may be entrenched, there is considerable flux due to decentralisation, modernisation and erosion of traditional institutions, which provides an opportunity for governance innovation. Furthermore, many values and rules governing decision-making are changing, such as women's empowerment in Sumbawa, the influence of non-government organisations and potential collaboration between formal and informal leaders in Lombok. These trends also present some paradoxes, illustrated by the decline in traditional institutions precipitated by modernisation, which erodes customary ecosystem stewardship and mutual assistance practices that are important for the poor, but enables women's education and leadership. Similar contradictions between tradition, religion and modernity are evident in other regions of Indonesia (Dofford, 2011). Hence a major challenge for adaptation pathway planning will be the mitigation of such trade-offs, and the identification of positive synergies.

Taken together, these differences mean that the objectives and application of adaptation pathways in a developing context such as Nusa Tenggara Barat are likely to differ from agricultural regions of a developed country. For example, neighbouring Australia (Fig. 2) is categorised as a very highly developed nation, and with a Human Development Index of 0.927 was ranked second in the world in

2010 (United Nations Development Program, 2011). Rural communities will aspire to maintain or moderately improve their already relatively high living standards (Fig. 4b). This objective may be more attainable than in Nusa Tenggara Barat due to the greater stability in drivers' projected trends, and lesser magnitudes of change. Although climate change is likely to follow a similar trend to Nusa Tenggara Barat, with potentially extreme changes after mid-century (Palutikof, 2010), population growth in rural areas is steady or declining, and densities are extremely low (Australian Bureau of Statistics, 2011). Australia's Gross Domestic Product was 2.5% per annum in 2010 (Indexmundi, 2012b), and is projected to decline to an average of 2.2% per annum in 2030–2060 as the population ages (Johansson et al., 2012). Assuming that the Human Development Index is a crude indicator of adaptive capacity, such communities may be relatively better prepared for post-2050 climate impacts. Hence the objective of adaptation pathways will be to maintain already high levels of human development, and the opportunity cost of mal-adaptive pathways is likely to be lower than in the province (Fig. 4).

A further difference is the scale of analysis and the focus for adaptation. In Australia agriculture and fisheries are segregated into 'industries' which are typified by homogenous agri-business systems across extensive regions, and lack the fine-scale cultural and ecological heterogeneity found amongst communities in Nusa Tenggara Barat. For example, the cattle industry covers large areas of northern Australian rangelands (Stafford Smith et al., 2007), and the sugar cane industry extends along the north-eastern coast (Thorburn et al., 2011), with local economies based on the production and processing of these commodities. Although these regions and economies are influenced by drivers such as soil and water quality and global commodity markets (Stafford Smith et al., 2007; Walker et al., 2009; Butler et al., 2013), climate change is the primary concern, justifying adaptation responses at an industry and farm business level in relative isolation from other drivers (e.g. Webster et al., 2009; Nelson et al., 2010a,b; Marshall, 2010; Park et al., 2012).

The provincial leaders provided a comprehensive representation of both the direct and indirect drivers of rural vulnerability, and recommended interventions to tackle some systemic factors. However, perhaps due to their embedded positions within the system, they did not mention some in-cultured factors such as the fatalistic and passive world view of the poor, or the resurgent influence of Islam. The numbers interviewed was also small, preventing more extensive analysis such as the contrasting of different types of leaders' perceptions of drivers and interventions, or gendered comparisons. Nonetheless these data provide a useful preliminary indication of the range of proximate and systemic factors perceived to be important by decision-makers in any forthcoming planning processes, plus potential oversights and contested issues.

We also considered appropriate processes and tools required to implement adaptation pathways. Due to the apparent flux in the system there is a window of opportunity to apply these within livelihood innovation niches, which could generate autonomous local-scale adaptation through the application of livelihoods analysis, participatory scenario planning and experimental adaptive co-management. However, there are several challenges inherent in this approach. First, the high degree of heterogeneity amongst livelihoods and their vulnerability due to the steep cultural and climatic gradients across the islands potentially limits the opportunities for out-scaling, requiring costly replications of planning processes. Second, power dynamics amongst competing stakeholders, and knowledge cultures including science and traditional world views, will need to be carefully facilitated during participatory processes. Third, it may be difficult to engage the poorest communities due to their passive attitudes, which may

also create a hurdle for analysing long term horizons and visioning potentially transformative change.

The general context of rural vulnerability in Nusa Tenggara Barat is likely to be mirrored in many other developing regions. The heterogeneity and dynamism of livelihood systems and the complex array of formal and informal institutions are evident in Africa (e.g. Paavola, 2008; Nielsen and Reenberg, 2010; Sallu et al., 2010; Béné et al., 2011) and Asia (e.g. Marschke and Berkes, 2006; Fernandez-Himenez et al., 2012). The magnitude and escalating rates of change, often rooted in globalised economics and politics, and the relevance of drivers other than climate are also commonplace (e.g. Armitage and Johnson, 2006; Schwarz et al., 2011; Fazey et al., 2011; Butler et al., submitted for publication). The slow pace of planned climate adaptation through National Adaptation Programmes of Action is also a common theme (Saito, 2012), necessitating local autonomous action. Decentralisation processes are also widespread, resulting in weak government support for poverty relief and disaster response (Ravera et al., 2011), but providing opportunities for the evolution of scale-appropriate social and technological innovation through local autonomy (Marschke and Berkes, 2006; Walker et al., 2010). Hence our framing of adaptation pathways may be relevant elsewhere.

Through collaboration between the Climate Change Task Force, donors, non-government organisations, leaders and communities, a potentially solid foundation exists in the province for the application of our proposed approach. This will create an important research agenda, enriched by scientists' potential role as catalysts for change through participatory research. Key research challenges will be the design and evaluation of processes and tools to identify, implement and evaluate no regrets, co-benefit strategies which will steer vulnerable communities towards development trajectories that can 'leap-frog' the Millennium Development Goals, and redress the adaptation deficit by mid-century.

Acknowledgements

The authors were supported by the AusAID-CSIRO Research for Development Alliance. Mark Stafford Smith, Liana Williams, Toni Darbas and Adi Gunawan provided helpful comments which improved earlier versions of the paper.

References

- Adger, W.N., 2006. Vulnerability. *Global Environmental Change* 16, 268–281.
- Adger, W.N., Huq, S., Brown, K., Conway, D., Hulme, M., 2003. Adaptation to changing climate in the developing world. *Progress in Development Studies* 3, 179–195.
- André, K., Simonsson, L., Gerger Swartling, A., Linner, B.-O., 2012. Method development for identifying and analysing stakeholders in climate adaptation processes. *Journal of Environmental Policy and Planning* 14, 243–261.
- Armitage, D., 2007. Building resilient livelihoods through adaptive co-management: the role of adaptive capacity. In: Armitage, D., Berkes, F., Doubleday, N. (Eds.), *Adaptive Co-management: Collaboration, Learning and Multi-level Governance*. UBC Press, Vancouver, Canada, pp. 62–82.
- Armitage, D., Johnson, D., 2006. Can resilience be recognised with globalization and increasingly complex resource degradation in Asian coastal regions? *Ecology and Society* 11, 2., <http://www.ecologyand society.org/vol11/iss1/art2>.
- Armitage, D., Plummer, R., Berkes, F., Arthur, R., Charles, A.T., Davidson-Hunt, I., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McCooney, P., Pinkerton, E.W., Wollenberg, E.K., 2009. Adaptive co-management for social-ecological complexity. *Frontiers in Ecology and Environment* 7, 95–102.
- Australian Bureau of Statistics, 2011. Regional Population Growth, Australia 2009–2010. Issue 3218.0., <http://www.abs.gov.au/ausstats/abs@nsf/Products/3218.0~2009-10~Main+Features~Main+Features#PARALINK17> (accessed 20.12.12).
- Ballard, D., 2005. Using learning processes to promote change for sustainable development. *Action Research* 3, 135–156.
- Barnett, J., O'Neill, S., 2010. Maladaptation. *Global Environmental Change* 20, 211–213.
- Béné, C., Evans, L., Mills, D., Ovie, S., Raji, A., Tafida, A., Kodio, A., Sinaba, F., Morand, P., Lemoalle, J., Andrew, N., 2011. Testing resilience thinking in a poverty context: experience from the Niger River basin. *Global Environmental Change* 21, 1173–1184.
- Berghout, F., Verbong, G., Wieczorek, A.J., Raven, R., Lebel, L., Bai, X., 2010. Sustainability experiments in Asia: innovations shaping alternative development pathways. *Environmental Science and Policy* 13, 261–271.
- Bohensky, E.L., Smajgl, A., Brewer, T., 2012. Patterns in household-level engagement with climate change in Indonesia. *Nature Climate Change Online*. <http://dx.doi.org/10.1038/NCLIMATE1762>.
- Brooks, N., Anderson, S., Ayers, J., Burton, I., Tellam, I., 2011. Tracking Adaptation and Measuring Development. IIED Climate Change Working Paper No. 1, November 2011. International Institute for Environment and Development, London, UK.
- Brown, V.A., 2008. *Leonardo's Vision: A Guide to Collective Thinking and Action*. Sense Publishers, Rotterdam, The Netherlands.
- Butler, J.R.A., 2011. The challenge of knowledge integration in the adaptive co-management of conflicting ecosystem services provided by seals and salmon. *Animal Conservation* 14, 599–601.
- Butler, J.R.A., Middlemas, S.J., McKelvey, S.A., McMyn, I., Leyshon, B., Walker, I., Thompson, P.M., Boyd, L.L., Duck, C., Armstrong, J.D., Graham, I.M., Baxter, J.M., 2008. The Moray Firth Seal Management Plan: an adaptive framework for balancing the conservation of seals, salmon, fisheries and wildlife tourism in the UK. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18, 1025–1038.
- Butler, J.R.A., Middlemas, S.J., Graham, I.M., Harris, R.N., 2011. Perceptions and costs of seal impacts on salmon and sea trout fisheries in the Moray Firth, Scotland: implications for the adaptive co-management of special areas of conservation. *Marine Policy* 35, 317–323.
- Butler, J.R.A., Wong, G., Metcalfe, D., Honzak, M., Pert, P.L., Bruce, C., Kroon, F.J., Brodie, J., 2013. An analysis of trade-offs between multiple ecosystem services and stakeholders linked to land use and water quality management in the Great Barrier Reef, Australia. *Agriculture, Ecosystems and Environment* 180, 176–191.
- Butler, J.R.A., Skewes, T., Mitchell, D., Pontio, M., Hills, T., submitted for publication. Stakeholder perceptions of ecosystem service declines in Milne Bay, Papua New Guinea: is human population a more critical driver than climate change? *Marine Policy* (submitted for publication).
- Carr, E.R., 2008. The millennium village project and African development: problems and potentials. *Progress in Development Studies* 8, 333–344.
- Cash, D.W., Borck, J.C., Patt, A.G., 2006. Countering the loading-dock approach to linking science and decision making: comparative analysis of El Niño/Southern Oscillation (ENSO) forecasting systems. *Science Technology and Human Values* 31, 465–494.
- Chambers, R., Conway, G., 1992. Sustainable Rural Livelihoods: Practical Concepts for the 21st Century. IDS Discussion Paper 296. Institute of Development Studies, Brighton, Sussex, UK.
- Chapin, F.S., Lovcraft, A.L., Zavaleta, E.S., Nelson, J., Robards, M.D., Kofinas, G.P., Trainor, S.F., Peterson, G.D., Huntingdon, H.P., Naylor, R.L., 2006. Policy strategies to address sustainability of Alaskan boreal forests in response to a directionally changing climate. *Proceedings of the National Academy of Sciences of the United States of America* 103, 16637–16643.
- Clemens, M.A., Demombynes, G., 2010. When does Rigorous Impact Evaluation Make a Difference? The Case of the Millennium Villages. Center for Global Development, WA, USA.
- De Haan, L., Zoomers, A., 2005. Exploring the frontiers of livelihoods research. *Development and Change* 36, 27–47.
- Department for International Development, 2004. Drivers of Change. Public Information Note, September 2004. Department of International Development (DfID), London, UK., <http://www.gsdrc.org/docs/open/DOC59.pdf>.
- Djalante, R., Thomalla, F., 2012. Disaster risk reduction and climate change adaptation in Indonesia. *International Journal of Disaster Resilience in the Built Environment* 3, 166–180.
- Dofford, S., 2011. Six case histories illustrating perpetual poverty in Indonesia. *Journal of Educational and Social Research* 1, 21–30.
- Dow, K., Berkhouf, F., Preston, B.L., Klein, R.J.T., Midgley, G., Shaw, M.R., 2013. Limits to adaptation. *Nature Climate Change* 3, 305–307.
- Enfors, E.I., Gordon, L.J., Peterson, G.D., Bossio, D., 2008. Making investments in dryland development work: participatory scenario planning in the Makanya catchment, Tanzania. *Ecology and Society* 13, 42., <http://www.ecologyandsociety.org/vol13/iss2/art42>.
- Ensor, J., 2011. *Uncertain Futures: Adapting Development to a Changing Climate*. Practical Action Publishing, Rugby, UK.
- Ensor, J., Berger, R., 2009. *Understanding Climate Change Adaptation: Lessons from Community-based Approaches*. Practical Action Publishing, Rugby, UK.
- Eriksen, S., Aldunce, P., Bahinipati, C.S., Martins, R.d'A., Molefe, J.I., Nhemachena, C., O'Brien, K., Olorunfemi, F., Park, J., Sygna, L., Ulsrud, K., 2011. When not every response to climate change is a good one: identifying principles for sustainable adaptation. *Climate and Development* 3, 7–20.
- Fachry, A., Hanartani, Supartiningsih, S., Butler, J.R.A., 2011. Social, Cultural and Economic Trends in NTB and their Drivers of Change. AusAID-CSIRO Research for Development Alliance, University of Mataram, NTB Government. CSIRO Climate Adaptation Flagship/University of Mataram, Brisbane/Lombok.
- Fazey, I., Kesby, M., Evely, A., Latham, I., Wagatora, D., Hagasua, J.-E., Reed, M.S., Christie, M., 2010. A three-tiered approach to participatory vulnerability assessment in the Solomon Islands. *Global Environmental Change* 20, 713–728.
- Fazey, I., Pettorelli, N., Kenter, J., Wagatora, D., Schuett, D., 2011. Maladaptive trajectories of change in Makira, Solomon Islands. *Global Environmental Change* 21, 1275–1289.

- Fernandez-Himenez, M.E., Batkhisig, B., Batbuyan, B., 2012. Cross-boundary and cross-level dynamics increase vulnerability to severe winter disasters (dzud) in Mongolia. *Global Environmental Change* 22, 836–851.
- Folke, C., Hahn, T., Olsson, P., Norberg, J., 2005. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* 30, 441–473.
- Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T., Rockström, J., 2010. Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society* 15, 20. <http://www.ecologyandsociety.org/vol15/iss4/art20>.
- Gidley, J.M., Fien, J., Smith, J.-A., Thomsen, D.C., Smith, T.F., 2009. Participatory futures methods: towards adaptability and resilience in climate vulnerable communities. *Environmental Policy and Governance* 19, 427–440.
- Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change. *Global Environmental Change* 19, 240–247.
- Howe, P., 2010. Archetypes of famine and response. *Disasters* 34, 30–54.
- Hunter, C.L., 2004. Local issues changes: the post-new order situation in rural Lombok. *Sojourn* 19, 100–122.
- Indexmundi, 2012a. <http://www.indexmundi.com/Indonesia> (accessed 20.12.12).
- Indexmundi, 2012b. <http://www.indexmundi.com/Australia> (accessed 20.12.12).
- International for Agricultural Development, 2010. *Rural Poverty Report 2011 – New Realities, New Challenges: New Opportunities for Tomorrow's Generation*. International Fund for Agricultural Development, Rome, Italy.
- Jakimow, T., in press. Decentralised governance as sites for self-formation: a comparison of practices of welfare distribution in Telangana, India and Central Lombok, Indonesia. *International Journal of Asian Studies* (in press).
- Johansson, Å., Guillemette, Y., Murtin, F., 2012. Looking to 2060: Long Term Global Growth Prospects. OECD Economic Policy Papers No. 03. Organisation for Economic Cooperation and Development, OECD Publishing. In: <http://www.oecd.org/eco/economicoutlookanalysisandforecasts/2060%20policy%20paper%20FINAL.pdf>.
- Kelly, P.M., Adger, W.N., 2000. Theory and practice in assessing vulnerability to climate change and assessing adaptation. *Climate Change* 47, 325–352.
- Kingsley, J.J., 2012. Peacemakers or peace-breakers? Provincial elections and religious leadership in Lombok, Indonesia. *Project MUSE Indonesia* 93 (1) 53–82. In: <http://muse.jhu.edu>.
- Kirono, D.G.C., McGregor, J., Nguyen, K., Katzfey, J., Kent, D., 2010. *Regional Climate Change Simulation and Training Workshop on Climate Change Over Eastern Indonesia and Vietnam*. Report to the AusAID–CSIRO Research for Development Alliance, Canberra, Australia.
- Klock, J., 2007. Agricultural water development in Lombok, Indonesia, from the 1980 to the present: perspectives on sustainability. In: Klock, J., Sjah, T. (Eds.), *Water Management in Lombok, Indonesia: Challenges and Solutions*. Mataram University Press, Lombok, Indonesia, pp. 1–18.
- Krulfeld, R., 1966. Fatalism in Indonesia: a comparison of socio-religious types on Lombok. *Anthropological Quarterly* 39, 180–190.
- Kusuma, A. (Ed.), 2010. *Public Expenditure Analysis of Nusa Tenggara Barat. Australia-Nusa Tenggara Assistance for Regional Autonomy*. The World Bank, University of Mataram Report for the NTB Provincial Government. Bappeda, Mataram, Indonesia.
- Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A.C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C., Olsson, P., 2012. Transforming innovation for sustainability. *Ecology and Society* 17, 11. <http://dx.doi.org/10.5751/ES-04933-170211>.
- Lisson, S., MacLeod, N., McDonald, C., Corfield, J., Pengelly, B., Wirajaswadi, L., Rahman, R., Bahar, S., Padjung, R., Razak, N., Puspadi, K., Dahlanuddin Sutaryono, Y., Saenong, S., Panjaitan, T., Hadiawati, L., Ash, A., Brennan, L., 2010. A participatory farming systems approach to improving Bali cattle production in the smallholder crop–livestock systems of Eastern Indonesia. *Agricultural Systems* 103, 486–497.
- Maani, K., 2013. *Decision-making for Climate Change Adaptation: A Systems Thinking Approach*. Report for the National Climate Change Adaptation Research Facility, Griffith University, Queensland, Australia.
- Marshall, N.A., 2010. Understanding social resilience to climate variability in primary enterprises and industries. *Global Environmental Change* 20, 36–43.
- Marschke, M.J., Berkes, F., 2006. Exploring strategies that build livelihood resilience: a case from Cambodia. *Ecology and Society* 11, 42. In: <http://www.ecologyandsociety.org/vol11/iss1/art42>.
- May, B., Plummer, R., 2011. Accommodating the challenges of climate change adaptation and governance in conventional risk management: Adaptive Collaborative Risk Management (ACRM). *Ecology and Society* 16, 47. In: <http://www.ecologyandsociety.org/vol16/iss1/art47>.
- Mertz, O., Mbow, C., Østergaard Nielsen, J., Maiga, A., Diallo, D., Reenberg, A., Diouf, A., Barbier, B., Bouzou Moussa, I., Zorom, M., Ouattara, I., Dabi, D., 2010. Climate factors play a limited role for past adaptation strategies in West Africa. *Ecology and Society* 15, 25. In: <http://www.ecologyandsociety.org/vol15/iss4/art25>.
- Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: A Framework for Assessment*. Island Press, Washington, DC.
- Ministry of Environment, 2007. *National Action Plan Addressing Climate Change*. Indonesia Ministry of Environment (Kementerian Lingkungan Hidup), Jakarta, Indonesia.
- Ministry of Environment, 2009. *Risk and Adaptation Assessment to Climate Change in Lombok Island West Nusa Tenggara Province*. Indonesia Ministry of the Environment (Kementerian Lingkungan Hidup), GIZ, WWF, Jakarta, Indonesia.
- Ministry of Environment, 2010. *National Action Plan Addressing Climate Change*. Indonesia Ministry of the Environment (Kementerian Lingkungan Hidup), Jakarta, Indonesia.
- Ministry of National Development Planning, 2010. *Indonesia Sectoral Roadmap for Climate Change*. State Ministry of National Development Planning (BAPPENAS), Jakarta, Indonesia.
- Mitchell, R., Agle, B., Wood, D., 1997. Towards a theory of stakeholder identification and salience: defining the principle of who and what really counts. *Academy of Management Review* 22 (4) 853–886.
- Nielsen, J.O., Reenberg, A., 2010. Cultural barriers to climate adaptation: a case study from northern Burkina Faso. *Global Environmental Change* 20, 142–152.
- Nelson, R., Kocic, P., Crimp, S., Meinke, H., Howden, S.M., 2010a. The vulnerability of Australian rural communities to climate variability and change: Part I – conceptualising and measuring vulnerability. *Environmental Science and Policy* 13, 8–17.
- Nelson, R., Kocic, P., Crimp, S., Martin, P., Meinke, H., Howden, S.M., de Voil, P., Nidumolu, U., 2010b. The vulnerability of Australian rural communities to climate variability and change: Part I – Integrating impacts with adaptive capacity. *Environmental Science and Policy* 13, 18–27.
- Nusa Tenggara Barat Environmental and Research Agency, 2010. *Work Plan for Adaptation and Mitigation to Climate Change in NTB Province*. Badan Lingkungan Hidup dan Penelitian (BLHP), Mataram, Indonesia.
- O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L., West, J., 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change* 14, 303–313.
- Olsson, P., Gunderson, L.H., Carpenter, S.R., Ryan, P., Lebel, L., Folke, C., Holling, C.S., 2006. Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. *Ecology and Society* 11, 18. In: <http://www.ecologyandsociety.org/vol11/iss1/art18>.
- Pahl-Wostl, C., 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change* 19, 354–365.
- Palutikof, J., 2010. The view from the front line: adapting Australia to climate change. *Global Environmental Change* 20, 218–219.
- Park, S.E., Marshall, N., Jakku, E., Dowd, A.M., Howden, S.M., Mendham, E., 2012. Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change* 22, 115–126.
- Partridge, I.J., Ma'shum, M. (Eds.), 2002. *Will it Rain? The Effect of the Southern Oscillation and El Niño in Indonesia*. The State of Queensland Department of Primary Industries, Brisbane, Australia.
- Paavola, J., 2008. Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy* 11, 642–654.
- Pelling, M., 2011. *Adaptation to Climate Change: From Resilience to Transformation*. Routledge, London.
- Perch, L., 2011. Mitigation of What and by What? Adaptation by Whom and for Whom? Dilemmas in Delivering for the Poor and the Vulnerable in International Climate Policy. Working Paper 79. International Policy Centre for Inclusive Growth, Brasilia, Brazil. In: <http://www.ipc-undp.org/pub/IPC-WorkingPaper79.pdf>.
- Perch, L., Gimenez Stahlberg, S., Potiara, C., 2010. Benefits Sharing: Blending Climate Change and Development in National Policy Efforts. One Pager No. 121. International Policy Centre for Inclusive Growth, Brasilia, Brazil.
- Pikkert, J.J.J., 2007. Pro-poor irrigation options for farmers in eastern Lombok: an ethnographic case study. In: Klock, J., Sjah, T. (Eds.), *Water Management in Lombok, Indonesia: Challenges and Solutions*. Mataram University Press, Lombok, Indonesia, pp. 19–31.
- Plummer, R., Armitage, D.R., 2007. A resilience-based framework for evaluating adaptive co-management: linking ecology, economics and society in a complex world. *Ecological Economics* 61, 62–74.
- Randall, A., Capon, T., Sanderson, T., Merrett, D., Hertzler, G., 2012. *Making Decisions Under the Risks and Uncertainties of Future Climates*. Report for the National Climate Change Adaptation Research Facility, Griffith University, Queensland, Australia.
- Ranger, N., Garbett-Shiels, S.-L., 2011. *How can Decision-makers in Developing Countries Incorporate Uncertainty about Future Climate Risks into Existing Planning and Policy-making Processes?* Policy Paper March 2011. Centre for Climate Change Economics and Policy, Grantham Institute on Climate Change and the Environment, University of Leeds, UK.
- Ravera, F., Tarrasón, D., Simelton, E., 2011. Envisioning adaptive strategies to change: participatory scenarios for agropastoral semiarid systems in Nicaragua. *Ecology and Society* 16, 20. In: <http://www.ecologyandsociety.org/vol16/iss1/art20>.
- Reeder, T., Ranger, N., 2011. How do you adapt in an uncertain world? Lessons from the Thames Estuary 2100 project, World Resources Report, Washington DC. Available online at: <http://www.worldresourcesreport.org>.
- Saito, N., 2012. Mainstreaming climate change adaptation in least developed countries in South and Southeast Asia. *Mitigation and Adaptation Strategies for Global Change*, <http://dx.doi.org/10.1007/s11027-012-9392-4>.
- Sallu, S.M., Twyman, C., Stringer, L.C., 2010. Resilient or vulnerable livelihoods? Assessing livelihood dynamics and trajectories in rural Botswana. *Ecology and Society* 15, 3. In: <http://www.ecologyandsociety.org/vol15/iss4/art3>.
- Schwarz, A.-M., Béné, C., Bennett, G., Bosco, D., Hilly, Z., Paul, C., Posala, R., Sibiti, S., Andrew, N., 2011. Vulnerability and resilience of remote rural communities to shocks and global changes: empirical analysis from Solomon Islands. *Global Environmental Change* 21, 1128–1140.
- Scoones, I., 1998. *Sustainable Rural Livelihoods. A Framework for Analysis*. Institute for Development Studies, Brighton, UK.

- Scoones, I., 2009. Livelihoods perspectives and rural development. *Journal of Peasant Studies* 36, 1.
- Shaw, A., Sheppard, S., Burch, S., Flanders, D., Wiek, A., Carmichael, J., Robinson, J., Cohen, S., 2009. Making local futures tangible – synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building. *Global Environmental Change* 19, 447–463.
- Sjah, T., Cameron, D., Woodford, K., 2006. Extension service and farmer decision making on new cropping lands in East Lombok, Indonesia. *Journal of International Agricultural and Extension Education* 13, 39–55.
- Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16, 282–292.
- Smith, D., Vivekananda, J., 2011. Adapting to Change: The Linked Challenges of Building Resilient Communities. *Poverty in Focus* No. 23. International Policy Centre for Inclusive Growth, Brasilia, Brazil, pp. 17–19.
- Stafford Smith, D.M., McKeon, G.M., Watson, I.W., Henry, B.K., Stone, G.S., Hall, W.B., Howden, S.M., 2007. Learning from episodes of degradation and recovery in variable Australian rangelands. *Proceedings of the National Academy of Sciences of the United States of America* 104, 20690–20695.
- Stafford Smith, D.M., Horrocks, L., Harvey, A., Hamilton, C., 2011. Rethinking adaptation in a 4 °C world. *Philosophical Transactions of the Royal Society A* 369, 196–216.
- Suharto, I., Usman, A., Agustijanto, P., 2003. Poor farming households survive a drought-prone Indonesian island: key findings of a livelihood study. *Fieldnotes* 12, 1–7. In: http://cip-upward.org/main/AMC/snap-ins/DOC/DOC_DocumentsViewer.asp?DocID=250.
- Thorburn, P.J., Biggs, J.S., Attard, S.J., Kemei, J., 2011. Environmental impacts of fully irrigated sugarcane production. *Agriculture Ecosystems and Environment* 144, 1–12.
- United Nations, 2012. We Can End Poverty 2015: Millennium Development Goals. In: <http://www.un.org/millenniumgoals/bkgd.shtml> (accessed 03.01.13).
- United Nations Development Program, 2011. Human Development Report 2011: Sustainability and Equity: A Better Future for all. United Nations Development Program, NY, USA.
- Walker, B.H., Holling, C.S., Carpenter, S., Kinzig, A., 2004. Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society* 9, 5. In: <http://www.ecologyandsociety.org/vol9/iss2/art5>.
- Walker, B.H., Abel, N., Anderies, J.M., Ryan, P., 2009. Resilience, adaptability, and transformability in the Goulburn-Broken Catchment, Australia. *Ecology and Society* 14, 12. In: <http://www.ecologyandsociety.org/vol14/iss1/art12>.
- Walker, B., Sayer, J., Andrew, N.L., Campbell, B.M., 2010. Should enhanced resilience be an objective of natural resource management research for developing countries? *Crop Science* 50, S-10–S-19.
- Webster, A.J., Thorburn, P.J., Roebeling, P.C., Horan, H.L., Biggs, J.S., 2009. The expected impact of climate change on nitrogen losses from wet tropical sugarcane production in the Great Barrier Reef region. *Marine and Freshwater Research* 60, 1159–1164.
- Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., Thompson, J., Nilsson, M., Lambin, E., Sendzimir, J., Banerjee, B., Galaz, V., van der Leeuw, S., 2011. Tipping towards sustainability: emerging pathways of transformation. *Ambio* 40, 762–780.
- Wise, R.M., Fazey, I., Stafford Smith, M., Park, S.E., Eakin, H.C., Archer van Garderen, E.R.M., Campbell, B., in this volume. Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, <http://dx.doi.org/10.1016/j.gloenvcha.2013.12.002> (in this volume).
- Wollenberg, E., Edmunds, D., Buck, L., 2000. Using scenarios to make decisions about the future: anticipatory learning for the adaptive co-management of community forests. *Landscape and Urban Planning* 47, 65–77.
- Wollenberg, E., Iwan, R., Limberg, G., Moeliono, M., Rhee, S., Sudana, M., 2007. Facilitating cooperation during times of chaos: spontaneous orders and muddling through in Malinau District, Indonesia. *Ecology and Society* 12, 3. In: <http://www.ecologyandsociety.org/vol12/iss1/art3/> (online).
- World Food Program, 2010. Food Security and Vulnerability Atlas of Nusa Tenggara Barat. United Nations World Food Program, Sekretariat Dewan Ketahanan Pangan, Kementerian Pertanian and Pemerintah Provinsi, NTB, Jakarta.
- World Food Program, 2012. Indonesia: Strengthening Community Resilience to Climate Change in Lombok. In: <http://www.wfp.org/node/3486/4551/259143> (accessed 10.01.13).
- Yasin, I., Ma'shum, M., Idris, H., Abawi, Y., 2007. The impact of inter-annual climate variability on water resource and crop production in Lombok. In: Klock, J., Sjah, T. (Eds.), *Water Management in Lombok, Indonesia: Challenges and Solutions*. Mataram University Press, Lombok, Indonesia, pp. 53–87.