Mengelola Hutan untuk Jasa Ekosistem Global dan Lokal: Studi Kasus Karbon, Air dan Penghidupan dari Indonesia Bagian Timur

Original
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English	Indonesian
Abstract Despite a recent increase of interest in global payment for ecosystem services (PES) mechanisms, there has been little comprehensive assessment of PES impacts on ecosystem services (ESs) at smaller scales. Better understanding of localized impacts of global PES can help balance ES deliveries for global benefits with those for meeting landscape and local level needs. Using a case study from eastern Indonesia, we assessed trade-offs and potential synergies between global PES (e.g. REDD+ for forest carbon) and landscape level ESs (e.g., water quantity, quality, regulation) and local ESs (e.g. forest products for food, energy, livelihoods). Realistic land use change scenarios and potential carbon credits were estimated based on historical land use changes and in-depth interviews with stakeholders. We applied a processbased hydrologic model to estimate changes in watershed services due to land use changes. Finally, local community's forest uses were surveyed to understand locally realized ESs. The results show empirical evidence that, without careful consideration of local impacts, a PES mechanism to protect global ESs can have negative consequences for local ecosystem services. We present management alternatives designed to maximize positive synergies between different ESs at varying scales.	**Abstrak** Meskipun belakangan ini terjadi peningkatan minat dalam mekanisme pembayaran global untuk jasa ekosistem (PES), hanya ada sedikit penilaian komprehensif tentang dampak PES pada jasa ekosistem (ES) pada skala yang lebih kecil. Pemahaman yang lebih baik tentang dampak lokal dari PES global dapat membantu menyeimbangkan pengiriman ES untuk manfaat global untuk memenuhi kebutuhan lanskap dan tingkat lokal. Dengan menggunakan studi kasus dari Indonesia bagian timur, kami menilai pertukaran (*trade-off)* dan potensi sinergi antara PES global (misalnya REDD+ untuk karbon hutan) dan ES tingkat lanskap (misalnya, kuantitas air, kualitas, regulasi) dan ES lokal (misalnya produk hutan untuk pangan, energi, penghidupan). Skenario perubahan penggunaan lahan yang realistis dan potensi kredit karbon diperkirakan berdasarkan riwayat perubahan penggunaan lahan dan wawancara mendalam dengan para pemangku kepentingan. Kami menerapkan model hidrologi berbasis proses untuk memperkirakan perubahan layanan/jasa DAS karena perubahan penggunaan lahan. Terakhir, pemanfaatan hutan masyarakat lokal disurvei untuk memahami ES yang direalisasikan secara lokal. Hasilnya menunjukkan bukti empiris bahwa, tanpa pertimbangan yang cermat terhadap dampak lokal, mekanisme PES untuk melindungi ES global dapat menimbulkan konsekuensi negatif bagi jasa ekosistem lokal. Kami menyajikan alternatif pengelolaan yang dirancang untuk memaksimalkan sinergi positif antara ES yang berbeda pada berbagai skala.

1. Introduction Globally, tropical forests account for approximately 25% of all terrestrial carbon (Bonan, 2008). Deforestation is the largest source of carbon emissions from tropical developing countries (Pan et al. 2011). The 2015 UN climate change conference in Paris reconfirmed the importance of forests in global climate regulation. The agreement explicitly included the REDD+ mechanism[1] as part of the global climate regime, where tropical and subtropical countries could receive both public and private funding for reducing carbon emissions and conserving standing forests. Indonesia has the third largest tropical forest in the world, with one of the world's fastest rates of deforestation at more than 1000 km2 of forests (476 km2 of primary forest) lost per year between 2000 and 2012 (Hansen et al., 2013; Margono et al., 2014). Indonesia has emerged as the major beneficiary of global negotiations to mitigate climate change through improved forest management (Simula, 2010). It has received the largest portion of REDD+ readiness commitments from the public sector ($757 million out of $2.8 billion total committed and dispersed from 2009 to 2014; Goldstein et al., 2015). In the private sector, carbon credits from protecting Indonesia's forests was 5.5% of all voluntary carbon transactions in 2015 (Hamrick and Goldstein, 2016). Offering financial incentives for tropical developing countries to reduce deforestation and forest degradation can be a win-win-win solution for climate mitigation, ecosystem conservation and poverty alleviation (Pistorius, 2012). However, many previous studies have warned that international intervention in the form of Payments for Ecosystem Services (PES) can exacerbate internal social problems (Blom et al., 2010; Wunder, 2008). Failure to include consideration for local uses of resources in global PES design can undermine rights of indigenous and local communities, exacerbate food and water insecurity (UN-REDD programme, 2017; Fazey et al., 2010), diminish ecological integrity and equity (Motel et al., 2009), and result in less than optimal outcomes for the ecosystem service targeted (Enrici and Hubacek, 2016; Skutsch et al., 2011). Despite a recent increase of interest in global PES mechanisms, there has been little comprehensive assessment of their impacts on localized ecosystem services (ESs) and livelihoods. Better understanding of the localized impacts is needed to find ways of balancing ES benefits at the global scale with local needs for water, food, energy and livelihoods. Using a case study from eastern Indonesia, we present a detailed assessment of trade-offs and potential synergies among global ES (forest	**1. Pendahuluan** Secara global, hutan tropis menyumbang sekitar 25% dari seluruh karbon terestrial (Bonan, 2008). Deforestasi merupakan sumber emisi karbon terbesar dari negara berkembang tropis (Pan et al. 2011). Konferensi perubahan iklim PBB 2015 di Paris menegaskan kembali pentingnya hutan dalam pengaturan iklim global. Perjanjian tersebut secara eksplisit memasukkan mekanisme REDD+[1] sebagai bagian dari rezim iklim global, di mana negara-negara tropis dan subtropis dapat menerima pendanaan publik dan swasta untuk mengurangi emisi karbon dan melestarikan hutan yang masih ada. Indonesia memiliki hutan tropis terbesar ketiga di dunia, dengan salah satu laju deforestasi tercepat di dunia di lebih dari 1000 km2 hutan (476 km2 hutan primer) hilang per tahun antara tahun 2000 dan 2012 (Hansen et al., 2013; Margono dkk., 2014). Indonesia telah muncul sebagai penerima manfaat utama dari negosiasi global untuk mitigasi perubahan iklim melalui pengelolaan hutan yang lebih baik (Simula, 2010). Ini telah menerima bagian terbesar dari komitmen kesiapan REDD+ dari sektor publik ($ 757 juta dari total $ 2,8 miliar yang berkomitmen dan tersebar dari 2009 hingga 2014; Goldstein et al., 2015). Di sektor swasta, kredit karbon dari perlindungan hutan Indonesia adalah 5,5% dari semua transaksi karbon sukarela pada tahun 2015 (Hamrick dan Goldstein, 2016). Menawarkan insentif keuangan bagi negara berkembang tropis untuk mengurangi deforestasi dan degradasi hutan dapat menjadi solusi yang saling menguntungkan untuk mitigasi iklim, konservasi ekosistem dan pengentasan kemiskinan (Pistorius, 2012). Namun, banyak penelitian sebelumnya telah memperingatkan bahwa intervensi internasional dalam bentuk Pembayaran Jasa Ekosistem (PES-*Payments for Ecosystem Services*) dapat memperburuk masalah sosial internal (Blom et al., 2010; Wunder, 2008). Kegagalan untuk memasukkan pertimbangan untuk penggunaan sumber daya lokal dalam desain PES global dapat merusak hak-hak masyarakat adat dan lokal, memperburuk kerawanan pangan dan air (Program UN-REDD, 2017; Fazey et al., 2010), mengurangi integritas dan kesetaraan ekologi (Motel et al., 2009), dan menghasilkan hasil yang kurang dari optimal untuk jasa ekosistem yang ditargetkan (Enrici dan Hubacek, 2016; Skutsch et al., 2011). Meskipun belakangan ini terjadi peningkatan minat dalam mekanisme PES global, hanya ada sedikit penilaian komprehensif tentang dampaknya terhadap jasa ekosistem lokal (ES) dan penghidupan. Pemahaman yang lebih baik tentang dampak lokal diperlukan untuk menemukan cara menyeimbangkan manfaat ES pada skala global dengan kebutuhan lokal akan air, pangan, energi, dan

carbon), landscape-level regulating services (e.g. water) and localized provisioning services (e.g., forest products for food and energy). Specific research questions are: 1) what are realistic land management scenarios to recover forest area lost and improve forest conditions?; 2) how do these scenarios affect global, landscape and local ES provisions?; 3) how do global modelling results compare with local perception in assessments of ecosystem service change; 4) what are the management alternatives to maximize positive synergies among provisions of different ESs at varying scales?	penghiudpan. Menggunakan studi kasus dari Indonesia bagian timur, kami menyajikan penilaian rinci pertukaran dan potensi sinergi antara ES global (karbon hutan), jasa pengaturan tingkat lanskap (misalnya air) dan layanan penyediaan lokal (misalnya, hasil hutan untuk pangan dan energi). Pertanyaan penelitian adalah: 1) skenario pengelolaan lahan apa yang realistis untuk memulihkan kawasan hutan yang hilang dan memperbaiki kondisi hutan?; 2) bagaimana skenario ini mempengaruhi ketentuan ES global, lanskap dan lokal?; 3) bagaimana hasil pemodelan global dibandingkan dengan persepsi lokal dalam penilaian perubahan jasa ekosistem; 4) apa alternatif pengelolaan untuk memaksimalkan sinergi positif antara ketentuan ES yang berbeda pada skala yang bervariasi?
2. Literature review: ecosystem services trade-offs and synergies The Millennium Ecosystem Assessment (MA, 2005) placed the term "ecosystem services" firmly in the policy agenda (MA, 2005; Gómez-Baggethun et al., 2010). Since then, many have advocated the urgent need to incorporate sustainable provisioning of ESs into policies and planning for managing landscapes (e.g., Daily et al., 2009; de Groot et al., 2010). However, the flows of ESs are determined not only by ecosystem functions and processes (ES supply), but also by demands from various human actors (ES demand) in multiple-scales (Fig. 1). Mouchet et al. (2014) advanced a typology to understand ES trade-offs by merging ecological and socioeconomic considerations found in previous studies. Spatial and time lags of ESs (spatial and temporal trade-offs) can occur in both supply and demand sides, in terms of production and delivery (Rodríguez et al., 2006) and benefits and costs (TEEB, 2010). Also targeting one ES can affect other ESs positively or negatively (among ESs synergies or trade-offs), and resilience of the ecosystem as a whole (reversible trade-off), as well as who "losers" and "winners" are among ES beneficiaries (beneficiaries trade-off) (Mouchet et al., 2014). The forces of globalization are intensifying interactions among ES demand and supply over distances and cross-scales (Cash et al., 2006; Liu et al., 2015). Managing ESs and anticipating changes in their spatial, temporal and societal distributions are increasingly difficult as local events (e.g. land use change in tropics) can have global consequences (e.g. climate change) (e.g. Bruckner et al., 2015; Meyfroidt et al., 2013; Lambin et al., 2011; Seto et al., 2012). Spatially distributed beneficiaries of different ESs vary also in their social and economic status, which affect their ability to influence decision-making process (TEEB,	**2. Tinjauan pustaka: pertukaran (*trade-off*) dan sinergi jasa ekosistem** *The Millennium Ecosystem Assessment* (MA, 2005) menempatkan istilah "jasa ekosistem" secara tegas dalam agenda kebijakan (MA, 2005; Gómez-Baggethun et al., 2010). Sejak itu, banyak yang mengadvokasi kebutuhan mendesak untuk memasukkan penyediaan ES yang berkelanjutan ke dalam kebijakan dan perencanaan untuk mengelola lanskap (misalnya, Daily et al., 2009; de Groot et al., 2010). Namun, aliran ES ditentukan tidak hanya oleh fungsi dan proses ekosistem (pasokan ES), tetapi juga oleh permintaan dari berbagai aktor manusia (permintaan ES) dalam berbagai skala (Gbr. 1). Mouchet dkk. (2014) mengembangkan tipologi untuk memahami pertukaran ES dengan menggabungkan pertimbangan ekologi dan sosial ekonomi yang ditemukan dalam studi sebelumnya. Jeda spasial dan waktu ES (pertukaran spasial dan temporal) dapat terjadi di sisi penawaran dan permintaan, dalam hal produksi dan pengiriman (Rodríguez et al., 2006) dan manfaat dan biaya (TEEB, 2010). Juga menargetkan satu ES dapat memengaruhi ES lainnya secara positif atau negatif (di antara sinergi atau pertukaran ES), dan ketahanan ekosistem secara keseluruhan (pertukaran yang dapat dibalik), serta siapa yang "kalah" dan "pemenang"di antara penerima ES (penerima manfaat pertukaran (Mouchet et al., 2014). Kekuatan globalisasi mengintensifkan interaksi antara permintaan dan penawaran ES dalam jarak dan lintas skala (Cash et al., 2006; Liu et al., 2015). Mengelola ES dan mengantisipasi perubahan dalam distribusi spasial, temporal dan sosialnya semakin sulit karena peristiwa lokal (misalnya perubahan penggunaan lahan di tropis) dapat memiliki konsekuensi global (misalnya perubahan iklim) (misalnya Bruckner dkk., 2015; Meyfroidt dkk., 2013; Lambin et al., 2011; Seto et al., 2012). Penerima manfaat yang tersebar

2010). There have been several studies that addressed the spatial scale of managing ES (e.g., Hein et al., 2006; Willemen et al., 2010 – both in the Netherlands) and presented empirical evidence of tradeoffs and synergies of different ES deliveries (e.g. GonzálezEsquivel et al., 2015; Grossman, 2015; Haines-Young et al., 2012; Maes et al., 2012; Mastrangelo and Laterra, 2015; Mora et al., 2016; Turner et al., 2014 – in Europe and Latin America), However, those most affected by global PES, such as REDD+, are in tropical developing countries often lacking technical capacity for data collection, analysis and management (Goetz et al., 2015). With the growing significance of global carbon governance (Biermann, 2010), there is a critical need to understand how the economic and political scale of decision-making affects ESs at different scales. We chose three groups of ESs at global, landscape (watershed level) and local community scales to contribute to our current understanding about ES associations and potential effects of global PES schemes.	secara spasial dari berbagai ES juga bervariasi dalam status sosial dan ekonomi mereka, yang mempengaruhi kemampuan mereka untuk mempengaruhi proses pengambilan keputusan (TEEB, 2010). Ada beberapa studi yang membahas skala spasial pengelolaan ES (misalnya, Hein et al., 2006; Willemen et al., 2010-keduanya di Belanda) dan menyajikan bukti empiris pertukaran dan sinergi pengiriman ES yang berbeda (misalnya GonzálezEsquivel dkk., 2015; Grossman, 2015; Haines-Young dkk., 2012; Maes dkk., 2012; Mastrangelo dan Laterra, 2015; Mora dkk., 2016; Turner dkk., 2014 -di Eropa dan Amerika Latin), Namun, yang paling terpengaruh oleh PES global, seperti REDD+, berada di negara berkembang tropis yang seringkali kekurangan kapasitas teknis untuk pengumpulan, analisis dan pengelolaan data (Goetz et al., 2015). Dengan semakin pentingnya tata kelola karbon global (Biermann, 2010), ada kebutuhan kritis untuk memahami bagaimana skala ekonomi dan politik dari pengambilan keputusan memengaruhi ES di berbagai skala. Kami memilih tiga kelompok ES pada skala global, lanskap (tingkat daerah aliran sungai) dan komunitas lokal untuk berkontribusi pada pemahaman kami saat ini tentang asosiasi ES dan potensi efek skema PES global.

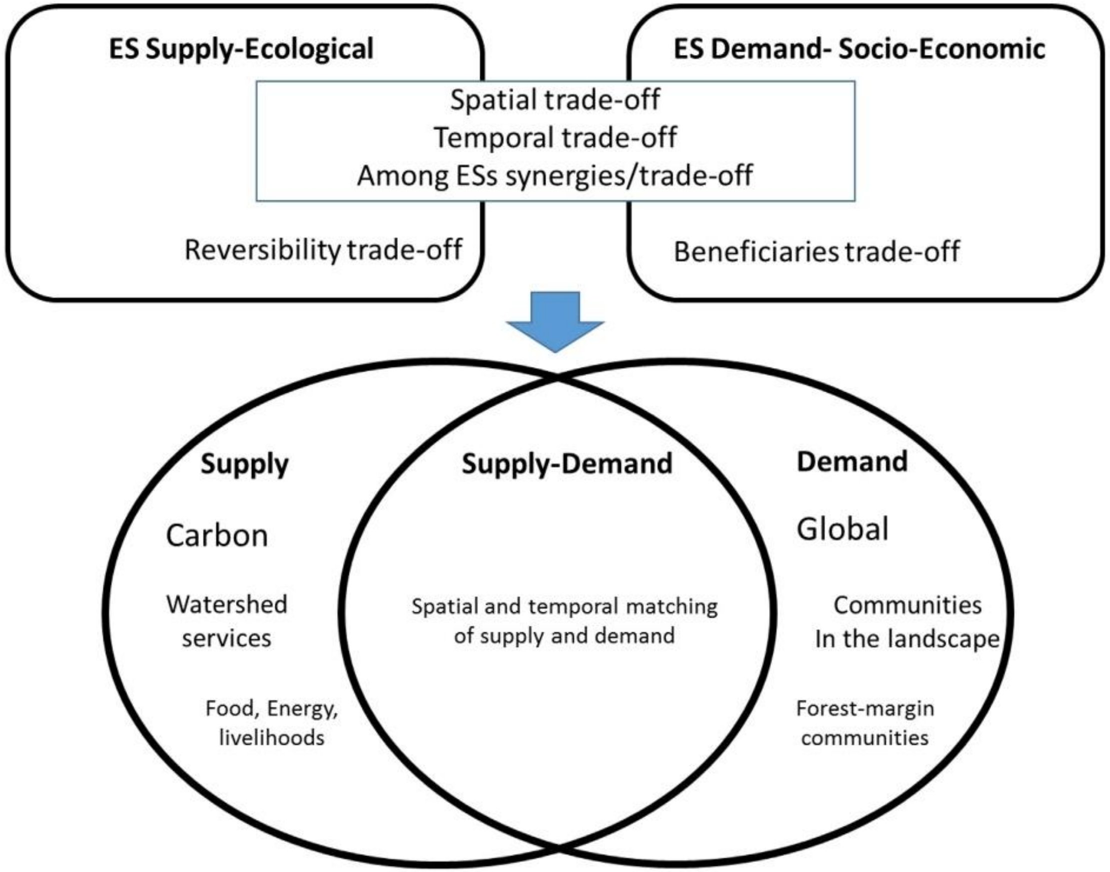

Fig. 1. Conceptual framework to assess ecosystem services trade-offs (modified from Mouchet et al. (2014)).

3. Methods **3.1. Study area** The case study area is Lombok island in Nusa Tenggara Barat (NTB) province, located in eastern Indonesia (Fig. 2). According to a recent analysis of Landsat images, the forested area of Lombok decreased 28.6% from 1990 to 2010 (Bae et al., 2014). By comparison, Indonesia's national average forest loss is 20.3% during the same period (FAO, 2010). Lombok is also one of the most densely populated and impoverished areas in Indonesia. Seventy percent of the population of NTB province lives in Lombok, although the island only constitutes a quarter of the total land area of the province (708 persons/km2	**3. Metode** **3.1. Wilayah studi** Wilayah studi kasus adalah Pulau Lombok di Provinsi Nusa Tenggara Barat (NTB), terletak di bagian timur Indonesia (Gambar 2). Menurut analisis citra Landsat baru-baru ini, kawasan hutan Lombok menurun 28,6% dari tahun 1990 hingga 2010 (Bae et al., 2014). Sebagai perbandingan, rata-rata kehilangan hutan nasional Indonesia adalah 20,3% selama periode yang sama (FAO, 2010). Lombok juga merupakan salah satu daerah terpadat dan termiskin di Indonesia. Tujuh puluh persen penduduk provinsi NTB tinggal di Lombok, meskipun pulau ini hanya mencakup seperempat dari total luas daratan

, compared to 237 persons/km2 for NTB and 132 persons/km2 nationally, as of 2014, BPS-NTB, 2015). Economic opportunities are limited to agriculture (24% of Gross Domestic Product (GDP) and 43% of employment of the province) and the mining and quarrying sector (15% of GDP and 1.8% employment) (as of 2014, BPS-NTB, 2015). NTB is among the poorest provinces of Indonesia, based on the Human Development Index (HDI), a metric that combines average life expectancy, education level, and per capita income (65.19 compared to the national average 69.55 as of 2015, BPS, 2016). Although forestry is a relatively small contributor to the wider economy of NTB (0.1% of GDP as of 2014, BPS-NTB, 2015), the forests in the northern part of the island, surrounding the Rinjani volcano complex, are an important source of subsistence and income to local communities. The forest also represents an important watershed, providing municipal water for the city of Mataram and irrigation for the major rice production regions throughout Lombok Island. The development of a program of payment for watershed services between municipal rate-payers and forest margin communities is one of the very first examples of PES systems in Indonesia (Diswandi, 2017; Pirard 2012; Prasetyo et al., 2009). The program supports forestry or agroforestry projects proposed by community groups with funds collected from the downstream city's water use fees. A multi-stakeholder group (IMP, Institusi Multi-Pihak) consisting of representatives from the World Wildlife Fund, the district forest service, a local university, a mineral water company, the district government and Mount Rinjani National Park, selects and distributes funds for selected projects (Diswandi, 2017; Schweizer et al., 2016; Pirard, 2012).	provinsi (708 jiwa / km2, dibandingkan dengan 237 jiwa / km2 untuk NTB dan 132 jiwa / km2 secara nasional, per 2014, BPS-NTB, 2015). Peluang ekonomi terbatas pada pertanian (24% dari Produk Domestik Bruto (PDB) dan 43% lapangan kerja provinsi) dan sektor pertambangan dan penggalian (15% dari PDB dan 1,8% lapangan kerja) (per 2014, BPS-NTB, 2015). NTB adalah salah satu provinsi termiskin di Indonesia, berdasarkan Indeks Pembangunan Manusia (IPM), metrik yang menggabungkan rata-rata harapan hidup, tingkat pendidikan, dan pendapatan per kapita (65,19 dibandingkan dengan rata-rata nasional 69,55 pada 2015, BPS, 2016) . Meskipun kehutanan merupakan penyumbang yang relatif kecil bagi perekonomian NTB secara keseluruhan (0,1% dari PDB per 2014, BPS-NTB, 2015), hutan di bagian utara pulau, yanmatag mengelilingi kompleks gunung berapi Rinjani, merupakan sumber penting penghidupan dan pendapatan bagi masyarakat lokal. Hutan juga merupakan daerah aliran sungai yang penting, menyediakan air untuk kota Mataram dan irigasi untuk daerah penghasil beras utama di seluruh Pulau Lombok. Pengembangan program pembayaran untuk jasa DAS antara pembayar tarif kota dan masyarakat pinggiran hutan adalah salah satu contoh pertama dari sistem PES di Indonesia (Diswandi, 2017; Pirard 2012; Prasetyo et al., 2009). Program ini mendukung proyek kehutanan atau agroforestri yang diusulkan oleh kelompok masyarakat dengan dana yang dikumpulkan dari biaya penggunaan air kota hilir. Kelompok multipihak (IMP, Institusi Multi-Pihak) yang terdiri dari perwakilan World Wildlife Fund, Dinas Kehutanan Kabupaten, Perguruan Tinggi Daerah, Perusahaan Air Mineral, Pemerintah Kabupaten dan Taman Nasional Gunung Rinjani, menyeleksi dan menyalurkan dana untuk proyek terpilih (Diswandi, 2017; Schweizer et al., 2016; Pirard, 2012).

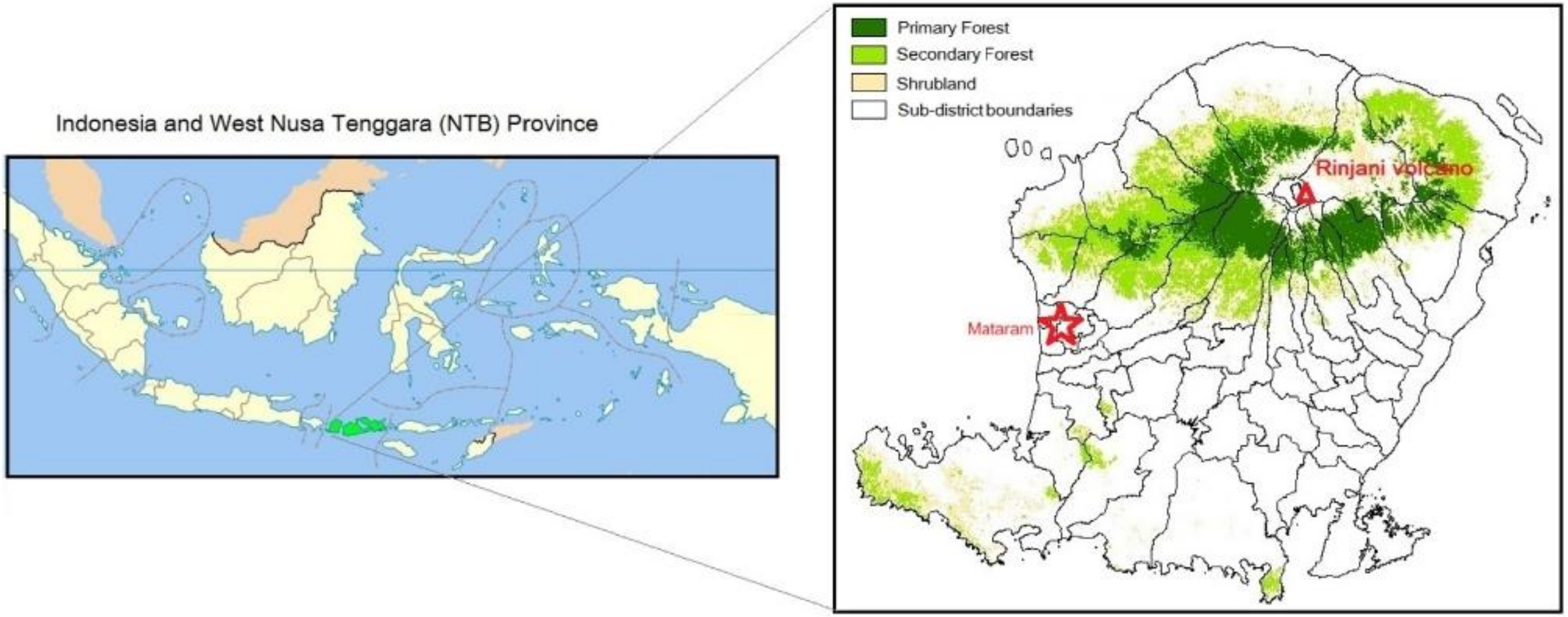

Fig. 2. Map of West Nusa Tenggara province and the remaining forests in Lombok island (Source: National Institute of Forest Science, Republic of Korea).

3.2. Research approach To assess the potential impacts of different land use change scenarios on ESs at different scales, we first identified alternative forest management scenarios that can be adopted by a future carbon PES scheme in Lombok. We then assessed the carbon, water and locally important services for food, energy and livelihoods impacts of these PES scenarios.	**3.2. Pendekatan penelitian** Untuk menilai dampak potensial dari skenario perubahan penggunaan lahan yang berbeda pada ES pada skala yang berbeda, pertama-tama kami mengidentifikasi skenario pengelolaan hutan alternatif yang dapat diadopsi oleh skema PES karbon masa depan di Lombok. Kami kemudian menilai dampak karbon, air dan layanan penting lokal untuk pangan, energi dan penghidupan dari skenario PES ini.
3.2.1. Forest management scenarios Forest carbon projects are designed to provide incentives to protect forests for the value of their standing carbon. Estimating carbon credits is essential for establishing the economic value of forest carbon projects. It includes two components: land-use and land-cover changes and the associated changes in carbon stock (VCS, 2012). Future forest management scenarios were	**3.2.1. Skenario pengelolaan hutan** Proyek karbon hutan dirancang untuk memberikan insentif untuk melindungi hutan untuk nilai karbon tetap mereka. Memperkirakan kredit karbon sangat penting untuk menetapkan nilai ekonomi proyek karbon hutan. Ini mencakup dua komponen: perubahan penggunaan lahan dan tutupan lahan dan perubahan terkait dalam stok karbon (VCS, 2012). Skenario pengelolaan hutan

developed based on analysis of historical changes in land-use and land-cover, along with analysis of drivers of deforestation and forest degradation in the area. Detail of these changes have been reported in Bae et al. (2014) and Kim et al. (2016). Table 1 shows the changes in deforestation patterns in three 5-year periods (1995–2000; 2000–2005; 2005–2010). Land use classes[2] following deforestation were projected based on the satellite imagery footprint of the most recent historical land cover pattern (2005–2010). We focus on the area around the Rinjani volcano complex, where the majority of Lombok's remaining forests are located. When the Suharto regime fell in 1998, this socio-political shift caused an abrupt interruption of central government control of forest lands that encouraged massive forest encroachment that was common throughout Indonesia at the time (e.g., Resosudarmo, 2004). Fig. 3 graphically illustrates the deforestation patterns during the three 5-year periods studied. Between 1995 and 2000, land use changes were driven by conversion of primary and secondary forests to shrubland, indicating no immediate cultivation after clearing of forest lands. After 2000, deforestation of primary forests decreased and some shrubland transitioned back to secondary forest. However, deforestation of secondary forest continued and secondary forest and shrubland are now being cultivated for dryland agriculture. In addition to examining the historical patterns of land use changes, we conducted a series of in-depth interviews (January 2015) with key informants from provincial and local government forest agencies, as well as international and local NGOs, to better understand the varied contexts of forest management. Based on this information, we develop three land-use change scenarios that represent a range of possible reforestation and restoration outcomes. These scenarios are reported in Section 4.1.	di masa depan dikembangkan berdasarkan analisis riwayat perubahan penggunaan lahan dan tutupan lahan, bersama dengan analisis pemicu deforestasi dan degradasi hutan di kawasan tersebut. Detail dari perubahan ini telah dilaporkan di Bae et al. (2014) dan Kim et al. (2016). Tabel 1 menunjukkan perubahan pola deforestasi dalam tiga periode 5 tahun (1995–2000; 2000–2005; 2005–2010). Kelas penggunaan lahan[2] setelah deforestasi diproyeksikan berdasarkan jejak citra satelit dari riwayat pola tutupan lahan terbaru (2005-2010). Kami fokus pada area di sekitar kompleks gunung berapi Rinjani, tempat sebagian besar keberadaan hutan Lombok yang tersisa. Ketika rezim Soeharto jatuh pada tahun 1998, pergeseran sosial-politik ini menyebabkan gangguan mendadak terhadap penguasaan lahan hutan oleh pemerintah pusat yang mendorong perambahan hutan besar-besaran yang umum terjadi di seluruh Indonesia pada saat itu (misalnya, Resosudarmo, 2004). Gambar. 3 menggambarkan secara grafis pola deforestasi selama tiga periode 5 tahun yang diteliti. Antara tahun 1995 dan 2000, perubahan penggunaan lahan didorong oleh konversi hutan primer dan sekunder menjadi semak belukar, menunjukkan tidak adanya penanaman yang dilakukan segera setelah pembukaan lahan hutan. Setelah tahun 2000, deforestasi hutan primer berkurang dan beberapa semak dialihkan kembali ke hutan sekunder. Namun, deforestasi hutan sekunder terus berlanjut dan hutan sekunder dan semak belukar sekarang dibudidayakan untuk pertanian lahan kering. Selain memeriksa riwayat pola perubahan penggunaan lahan, kami melakukan serangkaian wawancara mendalam (Januari 2015) dengan informan kunci dari instansi kehutanan pemerintah provinsi dan daerah, serta LSM internasional dan lokal, untuk lebih memahami berbagai konteks pengelolaan hutan. Berdasarkan informasi ini, kami mengembangkan tiga skenario perubahan penggunaan lahan yang mewakili berbagai kemungkinan hasil reboisasi dan restorasi. Skenario ini dilaporkan di Bagian 4.1.

Table 1
Historical Land Use Changes in Lombok (Unit: ha; Source: Bae et al. (2014)).

Land Use Class	1995	2000	2005	2010	Changes 1995–2000	Changes 2000–2005	Changes 2005–2010
Primary forest	54,881	53,140	51,114	51,111	−1741	−2025	−4
Secondary forest	105,064	77,452	69,752	67,258	−27,612	−7700	−2494
Shrubland	12,767	33,627	42,052	34,419	20,859	8425	−7633
All other uses	285,495	293,989	295,289	305,419	8494	1300	10,131

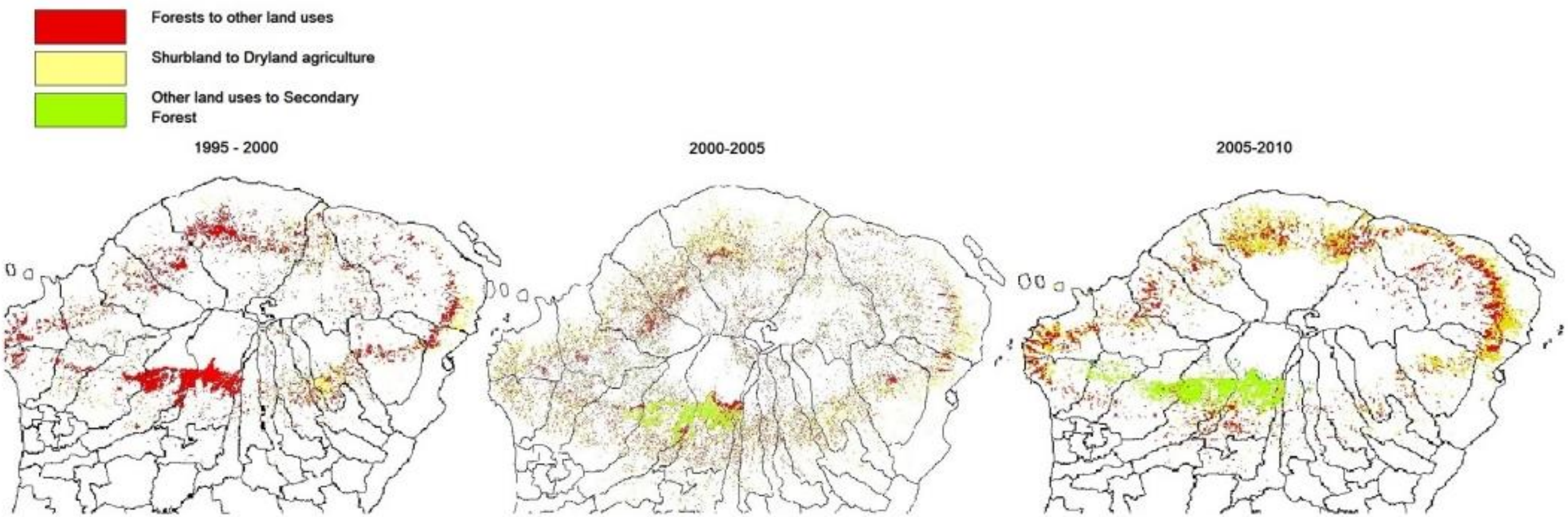

Fig. 3. Changes in forested area for three 5-year periods (Data source: National Institute of Forest Science, Republic of Korea).

3.2.2. Carbon assessment To estimate the impacts of the projected future land use changes on carbon stocks, we used the area-weighted average of carbon stock for each carbon pool for forest and shrubland, based on field inventory (Table 2). The estimated changes of carbon stock are based only on land use class change in each scenario and do not incorporate other variations within land use classes. For all other land uses, the carbon stocks were assumed to retain the level of soil carbon in shrubland[3].	**3.2.2 Penilaian karbon** Untuk memperkirakan dampak proyeksi perubahan penggunaan lahan di masa depan terhadap stok karbon, kami menggunakan rata-rata stok karbon untuk setiap penyimpan karbon untuk hutan dan semak, berdasarkan inventarisasi lapangan (Tabel 2). Estimasi perubahan stok karbon hanya didasarkan pada perubahan kelas penggunaan lahan di setiap skenario dan tidak memasukkan variasi lain dalam kelas penggunaan lahan. Untuk semua penggunaan lahan lainnya, stok karbon diasumsikan dapat menahan tingkat karbon tanah di semak belukar[3].

Table 2
Carbon stock by land use type (metric ton of carbon/ha ± standard deviation) (Source: Bae et al. (2014)).

	Total	Living vegetation				Dead trees	Litters	Soils
		Aboveground			Below Ground			
		Sub-total	Tree	Under growth				
Primary forest	206.6 (±76.66)	109.9	108.6 (±59.89)	1.3 (±1.15)	29.7 (±16.12)	18.3 (±26.05)	1.7 (±1.25)	47.0 (±17.52)
Secondary forest	181.1 (±120.88)	97.8	96.2 (±85.74)	1.6 (±0.99)	26.4 (±23.03)	21.4 (±31.73)	1.8 (±0.84)	33.7 (±13.08)
Shrub land	75.3 (±6.74)	26.5	24.8 (±2.30)	1.7 (±0.98)	7.2 (±0.89)	16.7 (±6.76)	1.6 (±0.43)	23.4 (±3.72)

3.2.3. Hydrological modelling	3.2.3. Pemodelan hidrologi
We utilized a process-based hydrologic model, WaterWorld V 3.31, to project the hydrological impacts of the land-use change scenarios. WaterWorld is a spatially explicit, globally applicable model for calculating monthly water balance, runoff, water quality (including agricultural pollutants and soil erosion) and their spatial distributions under baseline and alternative land use change scenarios (Mulligan, 2013). WaterWorld V 3.31 uses globally available data sets from remote sensing, along with limited in situ precipitation data to reveal how forest restoration can affect water provisioning and regulating services (Mulligan, 2013). WaterWorld V 3.31 calculates water balance as a sum of wind driven rainfall, fog and snowmelt (not applicable in this case) minus actual evapotranspiration. Water infiltrates according to regional infiltration capacities (Gleeson et al., 2011), mediated by slope gradient and tree cover (lower gradient and greater tree cover lead to higher infiltration rates within the geology-controlled regional limits). Infiltration is calculated based on global permeability data using the lithology developed by Gleeson et al. (2011). The infiltration model takes the mean soil-conditioned hydraulic conductivity as the infiltration rate and increases it towards one standard deviation higher than the mean in each pixel as tree cover increases and slope decreases. Higher tree cover encourages infiltration, shallower slopes provide greater opportunity for it to occur. Infiltration is also limited by available porosity and declines in a linear fashion as the soil store fills. Infiltrated water joins subsurface base flow and travels much more slowly to streams than water running over the land surface. Infiltrated water flows downslope along subsurface flow lines dictated by surface topography and at rates dictated by the local infiltration rates of the soil that water is passing through. Infiltrated water may re-emerge as surface runoff anywhere downslope where soil	Kami menggunakan model hidrologi berbasis proses, WaterWorld V 3.31, untuk memproyeksikan dampak hidrologi dari skenario perubahan penggunaan lahan. WaterWorld adalah model spasial eksplisit yang dapat diterapkan secara global untuk menghitung neraca air bulanan, limpasan, kualitas air (termasuk polutan pertanian dan erosi tanah) dan distribusi spasialnya di bawah skenario baseline dan skenario perubahan penggunaan lahan alternatif (Mulligan, 2013). WaterWorld V 3.31 menggunakan kumpulan data yang tersedia secara global dari penginderaan jauh, bersama dengan data curah hujan *in situ* yang terbatas untuk mengungkapkan bagaimana restorasi hutan dapat mempengaruhi penyediaan air dan pengaturan jasa (Mulligan, 2013). WaterWorld V 3.31 menghitung neraca air sebagai jumlah curah hujan yang didorong angin, kabut dan pencairan salju (tidak berlaku dalam kasus ini) dikurangi evapotranspirasi aktual. Infiltrat air menurut kapasitas infiltrasi regional (Gleeson et al., 2011), dimediasi oleh kemiringan lereng dan tutupan pohon (gradien yang lebih rendah dan tutupan pohon yang lebih besar mengarah pada tingkat infiltrasi yang lebih tinggi dalam batas regional yang dikontrol oleh geologi). Infiltrasi dihitung berdasarkan data permeabilitas global menggunakan litologi yang dikembangkan oleh Gleeson et al. (2011). Model infiltrasi mengambil rata-rata konduktivitas hidrolik terkondisi tanah sebagai laju infiltrasi dan meningkatkannya menuju satu standar deviasi yang lebih tinggi dari rata-rata pada setiap piksel seiring dengan peningkatan tutupan pohon dan penurunan kemiringan. Tutupan pohon yang lebih tinggi mendorong infiltrasi, lereng yang lebih dangkal memberikan peluang lebih besar untuk terjadi. Infiltrasi juga dibatasi oleh porositas yang tersedia dan menurun secara linier saat timbunan tanah terisi. Resapan air bergabung dengan aliran dasar bawah permukaan dan bergerak

conditions (subsurface flow rates) or water conditions (volume of water in relation to soil thickness mediated storage capacity) dictate. This tends to occur most at the base of hillslopes and in channels where regolith thickness is less and thus water emerges at the surface as baseflow. There is no separate deep groundwater model. WaterWorld models all subsurface moisture as a single per pixel unit. Tree cover also increases the rate of evapotranspiration and the rate of interception of fog, where it occurs. The model was applied to the current conditions in Lombok to produce information on the current hydrological ESs and also model their changes under different land use change scenarios. We also assessed local perception of watershed services linked with forest conditions through focus group discussions (FGD) and survey.	jauh lebih lambat ke sungai daripada air yang mengalir di atas permukaan tanah. Resapan air mengalir ke bawah lereng sepanjang garis aliran bawah permukaan yang ditentukan oleh topografi permukaan dan dengan kecepatan yang ditentukan oleh tingkat infiltrasi lokal dari tanah yang dilewati air. Resapan air dapat muncul kembali sebagai limpasan permukaan di mana saja di lereng bawah di mana kondisi tanah (laju aliran bawah permukaan) atau kondisi air (volume air dalam kaitannya dengan kapasitas penyimpanan yang dimediasi ketebalan tanah). Hal ini cenderung terjadi paling banyak di dasar lereng bukit dan di saluran dimana ketebalan regolit lebih sedikit sehingga air muncul di permukaan sebagai aliran dasar. Tidak ada model air tanah dalam yang terpisah. WaterWorld memodelkan semua kelembaban bawah permukaan sebagai satu unit per piksel. Tutupan pohon juga meningkatkan laju evapotranspirasi dan laju intersepsi kabut, di mana kabut itu terjadi. Model tersebut diterapkan pada kondisi saat ini di Lombok untuk menghasilkan informasi tentang hidrologi ES saat ini dan juga memodelkan perubahannya di bawah berbagai skenario perubahan penggunaan lahan. Kami juga menilai persepsi lokal tentang jasa DAS terkait dengan kondisi hutan melalui FGD dan survei.
3.2.4. Locally important ecosystem services for food, energy and livelihoods To understand how local community members utilize and benefit from forest ecosystem services, in-person surveys were conducted at four locations (Fig. 4). Survey locations were selected based on their proximity to forests with different designated functions, forest governance status, and permitted activities. State forests in Indonesia are classified into three designated functional categories (ROI, 1999)[4]: ‘Production Forest’ for providing forest products; ’Protection Forest’ for ecosystem protection, such as watershed and soil conservation; and ‘Conservation Forest’ for protecting biodiversity and ecosystem conservation. Production and Protection Forests in NTB province are managed by Forest Management Units (Kesatuan Pengelolaan Hutan, or KPH) that were created by the central government but are more or less decentralized (See Kim et al., 2016; Sahide et al., 2016 for more complete information on the Forest Management Units). Conservation Forest is directly managed by the National Park (i.e. Conservation Forest Management Unit) under the central government authority. We selected one community adjacent to Production Forest (A), one near	**3.2.4. Jasa ekosistem penting secara lokal untuk pangan, energi dan penghidupan** Untuk memahami bagaimana anggota masyarakat lokal memanfaatkan dan mendapatkan manfaat dari jasa ekosistem hutan, survei tatap muka dilakukan di empat lokasi (Gbr. 4). Lokasi survei dipilih berdasarkan kedekatannya dengan hutan dengan fungsi peruntukan yang berbeda, status tata kelola hutan, dan kegiatan yang diizinkan. Hutan negara di Indonesia diklasifikasikan ke dalam tiga kategori fungsi (ROI, 1999)[4]: 'Hutan Produksi' untuk menyediakan hasil hutan; 'Hutan Lindung' untuk perlindungan ekosistem, seperti daerah aliran sungai dan konservasi tanah; dan 'Hutan Konservasi' untuk melindungi keanekaragaman hayati dan konservasi ekosistem. Hutan Produksi dan Lindung di provinsi NTB dikelola oleh Kesatuan Pengelolaan Hutan (KPH) yang dibuat oleh pemerintah pusat tetapi kurang lebih terdesentralisasi (Lihat Kim et al., 2016; Sahide et al., 2016 untuk informasi lebih lengkap tentang Kesatuan Pengelolaan Hutan). Hutan Konservasi secara langsung dikelola oleh Taman Nasional (yaitu Kesatuan Pengelolaan Hutan Konservasi) di bawah kewenangan pemerintah pusat. Kami memilih satu komunitas yang berdekatan dengan Hutan Produksi (A),

Protection Forest (B), and one near Conservation Forest (C), i.e., near the Rinjani National Park (Fig. 4). We also included an additional community near a Protection Forest that recently gained official recognition as "Community Forest" (Hutan Kemasyarakatan, or HKm) (D). Community Forest is one of the legal mechanisms that communities can use to gain recognition for their usufruct rights (ROI, 2007). However, the legal process of establishing HKm is complicated, involving both local and central government agencies, and it can take years to gain formal approval (Intarini et al., 2015), which explains why less than 1% of Indonesia's forests are managed by communities with HKm status (Stevens et al., 2014)[5] . This particular community gained HKm status through intense facilitation supported by an international NGO (Flora and Fauna International) that initiated a REDD+ demonstration project in the area.

The various forest designations offer alternative levels of forest protection. As such, they differ in terms of the activities that local people are permitted to undertake in the forest. Table 3 provides a summary of permitted activities by forest designation.

We conducted surveys across locations A, B, C, and D (January 2015) to assess the importance that community members attach to local forest ESs across the four locations. A list of locally important forest ESs was drawn up, following scoping focus group discussions with community members and local stakeholders. These services were then grouped into three groups of provisioning services and one regulating service:

- Naturally occurring non-timber forest products (NTFP), such as bamboo, honey and cattle feed;
- Agroforest products, such as various fruits and cash crops (e.g., coffee and cacao);
- Timber forest products, including fuelwood; and
- Water regulation services.

Although cultural services of forests were also identified to be significant to these forest margin communities, it is difficult to measure those services and link them to forest conditions. Thus they were not explicitly investigated in our study. The survey questionnaire comprised five sections. First, we collected background information on the respondents, including their proximity to the forest. Next, we asked a general question on the extent to which the services they obtain from the forest sustains their needs and how this has changed over the past 5 years. The third and fourth sections respectively collected

satu komunitas di dekat Hutan Lindung (B), dan satu komunitas di dekat Hutan Konservasi (C), yaitu di dekat Taman Nasional Rinjani (Gbr. 4). Kami juga menyertakan komunitas tambahan di dekat Hutan Lindung yang baru-baru ini mendapatkan pengakuan resmi sebagai Hutan Kemasyarakatan, atau HKm (D). HKm merupakan salah satu mekanisme hukum yang dapat digunakan masyarakat untuk mendapatkan pengakuan atas hak guna hasil mereka (ROI, 2007). Namun, proses hukum pembentukan HKm rumit, melibatkan instansi pemerintah pusat dan daerah, dan butuh waktu bertahun-tahun untuk mendapatkan persetujuan resmi (Intarini dkk., 2015), yang menjelaskan mengapa kurang dari 1% hutan Indonesia dikelola oleh masyarakat dengan status HKm (Stevens et al., 2014)[5]. Komunitas khusus ini memperoleh status HKm melalui fasilitasi intensif yang didukung oleh LSM internasional (Flora dan Fauna International) yang memprakarsai proyek percontohan REDD+ di daerah tersebut.

Berbagai peruntukan hutan menawarkan tingkat alternatif perlindungan hutan. Dengan demikian, mereka berbeda dalam hal kegiatan yang boleh dilakukan oleh masyarakat lokal di hutan. Tabel 3 memberikan ringkasan kegiatan yang diizinkan berdasarkan peruntukan hutan.

Kami melakukan survei di seluruh lokasi A, B, C, dan D (Januari 2015) untuk menilai pentingnya anggota masyarakat menyertakan ES hutan lokal di empat lokasi. Daftar ES hutan yang penting secara lokal telah dibuat, setelah FGD dengan anggota masyarakat dan pemangku kepentingan lokal. Layanan ini kemudian dikelompokkan menjadi tiga kelompok layanan penyediaan dan satu layanan pengaturan:

- Hasil hutan bukan kayu alami (HHBK), seperti bambu, madu dan pakan ternak;
- Produk agroforestry, seperti berbagai buah-buahan dan tanaman komersial (misalnya kopi dan kakao);
- Hasil hutan kayu, termasuk kayu bakar; dan
- Layanan pengaturan air.

Meskipun jasa budaya hutan juga diidentifikasi penting bagi masyarakat sekitar hutan ini, sulit untuk mengukur jasa tersebut dan mengaitkannya dengan kondisi hutan. Jadi mereka tidak diselidiki secara eksplisit dalam penelitian kami. Kuesioner survei terdiri dari lima bagian. Pertama, kami mengumpulkan informasi latar belakang responden, termasuk kedekatan mereka dengan hutan. Selanjutnya, kami mengajukan pertanyaan umum

detailed information on the levels of consumption of provisioning and regulating services. Finally, we collected information on respondent's preferences for alternative future forest management options. The surveys were administered in-person by (trained) local enumerators, who conducted the surveys in the respondent's home in the local language. A sampling frame was developed for identifying respondents following consultation with community leaders and aimed to obtain a representative sample of community members. Survey data was analyzed separately for the four locations. After analyzing the data, we held a workshop with community members in each location to share our findings, elicit feedback on our preliminary results, and explore possible future options to more effectively manage the forests (March 2016).	tentang sejauh mana layanan yang mereka peroleh dari hutan memenuhi kebutuhan mereka dan bagaimana hal ini berubah selama 5 tahun terakhir. Bagian ketiga dan keempat masing-masing mengumpulkan informasi rinci tentang tingkat konsumsi layanan penyediaan dan pengaturan. Terakhir, kami mengumpulkan informasi tentang preferensi responden untuk opsi alternatif pengelolaan hutan di masa depan. Survei dilakukan secara langsung oleh enumerator lokal (terlatih), yang melakukan survei di rumah responden dalam bahasa lokal. Kerangka sampling dikembangkan untuk mengidentifikasi responden setelah berkonsultasi dengan tokoh masyarakat dan bertujuan untuk mendapatkan sampel perwakilan dari anggota masyarakat. Data survei dianalisis secara terpisah untuk empat lokasi. Setelah menganalisis data, kami mengadakan lokakarya dengan anggota masyarakat di setiap lokasi untuk berbagi temuan kami, mendapatkan umpan balik tentang hasil awal kami, dan mengeksplorasi kemungkinan opsi masa depan untuk mengelola hutan secara lebih efektif (Maret 2016).

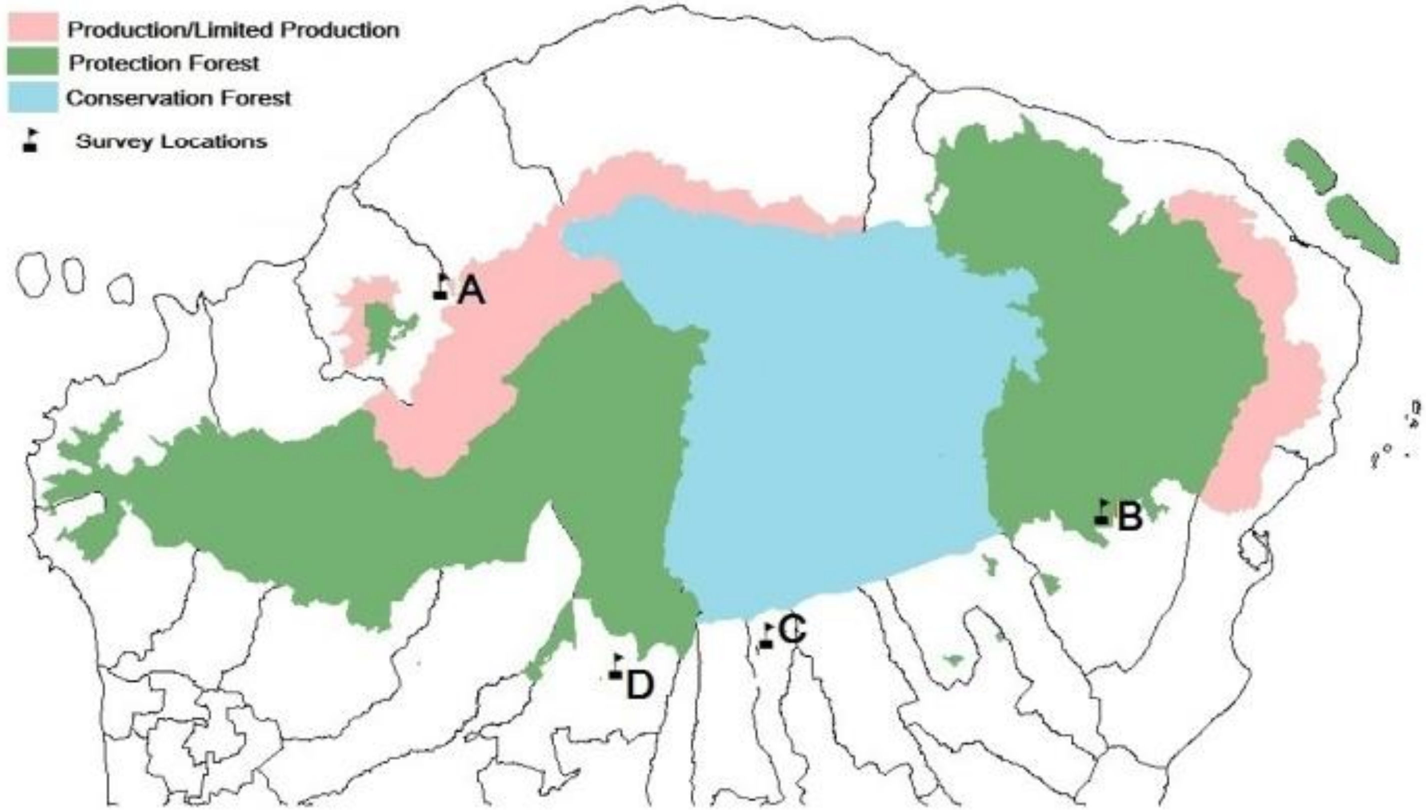

Fig. 4. Survey locations (A–D) and designated forest functions.

Table 3
Forest Classification and Permitted Activities (Source: Rosenbarger et al. (2013)[1]).

Forest classification by function/ Permitted activities[2]	Timber Extraction	Cultivating medicinal/ decorative plants, fungi, apiculture, swiftlet nests, capturing wildlife, cattle feed	Utilization of environmental services (water flow, ecotourism, biodiversity, environmental protection, carbon absorption and storage)	Extraction of non-timber forest products (rattan, bamboo, honey, resin, fruits, fungi)	Research, science, education, cultivation activities, cultural activities, and limited tourism
Production Forest (A)	Y[3]	Y	Y	Y	Y
Protection Forest (B, D[4])		Y	Y	Y	Y
Conservation Forest (C)		Y[5]		Y[5]	Y

[1] Compiled from: Government Regulation No. 6 of 2007, Minister of Forestry Regulation No. 13 of 2009, Minister of Forestry Regulation No. 37 of 2007, Minister of Forestry Regulation No. 49 of 2008.
[2] These activities can be legally allowed with permits granted by regent/mayor/governor or minister (depending on area jurisdictions). Although these activities reflect *de facto* uses, two communities in the study area (A and B) do not hold permits.
[3] There is no timber concession in the study area.
[4] The "Community Forest" status of community D means that the forest utilization permit (IUPHKm) was granted to this community for a period of 35 years.
[5] These activities are not allowed in Conservation Forest, but the community C is in "Traditional Zone", specially designated for very limited community uses for their livelihoods, including collecting cattle feeds.

4. Results **4.1. Land use change scenarios** Three future (30-year projection) land use change scenarios were developed based on spatial data on recent land use changes (2005–2010), combined with current forest management plans obtained from key informant interviews (January 2015). The scenarios included a Business-As-Usual scenario and two management scenarios aimed at improving forest condition.	**4. Hasil** **4.1. Skenario perubahan penggunaan lahan** Tiga skenario perubahan penggunaan lahan di masa depan (proyeksi 30 tahun) dikembangkan berdasarkan data spasial perubahan penggunaan lahan belakangan (2005-2010), dikombinasikan dengan rencana pengelolaan hutan saat ini yang diperoleh dari wawancara informan kunci (Januari 2015). Skenario tersebut meliputi skenario *Business-As-Usual* dan dua skenario pengelolaan yang bertujuan untuk memperbaiki kondisi hutan.
4.1.1. Business-As-Usual (BAU) scenario There has been little decrease of primary forests in the study area since 2000, although secondary forest and shrubland have changed to other land uses, primarily dryland agriculture. Under this scenario, these current trends in land use change would continue unabated, resulting in 10% of currently forested land being converted to dryland agriculture. We used the latest available land-use data (2010) as the starting point for our simulations. The projected land use changes for the next 10 and 30 years are shown in Table 4.	**4.1.1. Skenario *Business-As-Usual (*BAUP)** Terjadi sedikit penurunan hutan primer di wilayah studi sejak tahun 2000, meskipun hutan sekunder dan semak belukar telah berubah menjadi penggunaan lahan lain, terutama pertanian lahan kering. Di bawah skenario ini, tren perubahan penggunaan lahan saat ini akan terus berlanjut, mengakibatkan 10% dari lahan berhutan saat ini dikonversi menjadi pertanian lahan kering. Kami menggunakan data penggunaan lahan terbaru yang tersedia (2010) sebagai titik awal untuk simulasi kami. Perubahan

	penggunaan lahan yang diproyeksikan untuk 10 dan 30 tahun ke depan ditunjukkan pada Tabel 4.

Table 4
Potential Land Use Changes under the Business-As-Usual Scenario (ha).

Land Use Class	Present	In 10 years	In 30 years
Primary forest	51,111	51,111	51,111
Secondary forest	67,258	65,462	60,537
Shrubland	34,419	29,030	14,255
All other land uses	305,419	312,604	332,304

4.1.2. Community partnership (CP) scenario Forest Management Units (KPHs) in Lombok currently use a spatial planning approach, in which the remaining primary forests are defined as core protected zones, and surrounding secondary forests are designated for community use. The agencies are developing programs to assure de facto usufruct rights for communities and allow agroforestry development through partnership agreements (kemitraan) in the secondary forest (Jang and Bae, 2014). The optimistic, yet realistic, scenario would be that this program will succeed at buffering encroachment into the primary forest, and the partnership agreements will expand to all forests around Mount Rinjani managed by KPHs. The resulting land use changes would increase the area of secondary forests to the 1995 level (i.e. before the period of rapid deforestation) with 50% of forest restoration occurring in the first 10 years. In this scenario, secondary forests would include well-managed agroforestry areas with forest cover converted from shrubland (32% increase of total forests in 30 years), while the area of primary forests would remain unchanged (Table 5).	4.1.2. **Skenario kemitraan masyarakat (CP)** Kesatuan Pengelolaan Hutan (KPH) di Lombok saat ini menggunakan pendekatan perencanaan tata ruang, dimana hutan primer yang tersisa ditetapkan sebagai zona lindung inti, dan hutan sekunder di sekitarnya ditetapkan untuk digunakan oleh masyarakat. Badan-badan tersebut mengembangkan program untuk memastikan hak guna hasil *de facto* bagi masyarakat dan memungkinkan pengembangan agroforestry melalui kesepakatan kemitraan di hutan sekunder (Jang dan Bae, 2014). Optimis namun realistis, skenario program ini akan berhasil menahan perambahan ke hutan primer, dan kesepakatan kemitraan akan meluas ke semua hutan di sekitar Gunung Rinjani yang dikelola oleh KPH. Perubahan tata guna lahan yang dihasilkan akan meningkatkan luas hutan sekunder ke tingkat 1995 (yaitu sebelum periode masifnya deforestasi) dengan 50% restorasi hutan terjadi dalam 10 tahun pertama. Dalam skenario ini, hutan sekunder akan mencakup kawasan agroforestry yang dikelola dengan baik dengan tutupan hutan dikonversi dari semak belukar (peningkatan 32% dari total luasan hutan dalam 30 tahun), sedangkan kawasan hutan primer tidak akan berubah (Tabel 5).

Table 5
Potential Land Use Changes under the Community Partnership Scenario (ha).

Land Use Class	Present	In 10 years	In 30 years
Primary forest	51,111	51,111	51,111
Secondary forest	67,258	89,522	105,064
Shrubland	34,419	33,675	12,767
All other land uses	305,419	283,899	289,265

4.1.3. Forest restoration (FR) scenario This scenario presents the realistic upper limit of a reforestation scenario. It would require an intervention, for example a REDD+-type carbon project, that would lead to restoring all Lombok's forests to the 1995 levels with 50% of forest restoration occurring in the first 10 years. The resulting land use changes would include 7% increase of primary forest and 56% increase of total forest in 30 years (Table 6).	**4.1.3. Skenario restorasi hutan (FR)** Skenario ini menyajikan batas maksimal yang realistis dari skenario reboisasi. Diperlukan intervensi, misalnya proyek karbon berjenis REDD+, yang akan memulihkan semua hutan Lombok ke tingkat tahun 1995 dengan 50% restorasi hutan terjadi dalam 10 tahun pertama. Perubahan penggunaan lahan yang dihasilkan akan mencakup peningkatan 7% hutan primer dan 56% peningkatan total hutan dalam 30 tahun (Tabel 6).

Table 6
Potential Land Use Changes under the Forest Restoration Scenario (ha).

Land Use Class	Present	In 10 years	In 30 years
Primary forest	206.6	52,996	54,881
Secondary forest	67,258	89,522	105,064
Shrubland	34,419	33,675	12,767
All other land uses	305,419	282,014	285,495

4.2. Changes in carbon stock and potential carbon market values Table 7 shows land use changes under two scenarios compared to the BAU scenario, as well as resulting total carbon stock changes. For example, secondary forests in Lombok, which contain an average of 181.1 metric tons of carbon per ha, are projected to increase by 24,060 ha in 10 years under CP scenario (from 65,462 ha under BAU to 89,522 ha under CP scenario). After	**4.2. Perubahan stok karbon dan nilai pasar karbon potensial** Tabel 7 menunjukkan perubahan penggunaan lahan dalam dua skenario dibandingkan dengan skenario BAU, serta menghasilkan perubahan total stok karbon. Misalnya, hutan sekunder di Lombok, yang rata-rata mengandung 181,1 metrik ton karbon per ha, diproyeksikan meningkat 24.060 ha dalam 10 tahun di bawah skenario CP (dari 65.462 ha di bawah BAU menjadi 89.522 ha

combining changes in carbon stock with all land uses, total carbon stock under CP scenario would be a 4.0 million metric tCO2e increase for the first 10-year period, and a 6.9 million metric tCO2e over the thirty year project period. FR scenario will result in increase of 4.3 million metric tCO2e from BAU scenario REL for first 10 years and 7.6 million metric tCO2e over the 30 year project period. Carbon price (USD/metric tCO2e) in voluntary carbon market varies by sources, although it is commonly higher for forest carbon. REDD+ projects for avoided planned deforestation ($1.9) and avoided unplanned deforestation ($5.5)[6] generally resulted in forest carbon offsets whose values were lower than those from sustainable agriculture/agroforestry ($7.4), tree planting ($8.9) and improved forest management ($9.8) projects (average prices per metric tCO2e in 2014 from Goldstein et al., 2015). Even at the lower end of carbon price ($5) and emission reduction, we can expect at least $35 million of expected value generated for a 30-year forest carbon project in Lombok (Table 8). However, this amount indicates the carbon credit potential, not necessarily the actual payments required to start a project.	di bawah skenario CP). Setelah menggabungkan perubahan stok karbon dengan semua penggunaan lahan, total stok karbon di bawah skenario CP akan meningkat 4,0 juta metrik tCO2e untuk periode 10 tahun pertama, dan 6,9 juta metrik tCO2e selama periode proyek 30 tahun. Skenario FR akan menghasilkan peningkatan sebesar 4,3 juta metrik tCO2e dari skenario BAU REL selama 10 tahun pertama dan 7,6 juta metrik tCO2e selama periode proyek 30 tahun. Harga karbon (USD/metrik tCO2e) di pasar karbon sukarela bervariasi menurut sumbernya, meskipun biasanya lebih tinggi untuk karbon hutan. Proyek-proyek REDD+ untuk pencegahan deforestasi terencana ($1,9) dan pencegahan deforestasi yang tidak direncanakan ($5,5)[6] umumnya menghasilkan penggantian kerugian karbon hutan yang nilainya lebih rendah daripada proyek-proyek pertanian/agroforestry berkelanjutan ($7,4), penanaman pohon ($8,9) dan pengelolaan hutan yang lebih baik ($ 9,8) (harga rata-rata per metrik tCO2e pada tahun 2014 dari Goldstein et al., 2015). Bahkan pada harga karbon terendah ($5) dan pengurangan emisi, kami dapat mengharapkan setidaknya $35 juta dari nilai yang diharapkan yang dihasilkan untuk proyek karbon hutan selama 30 tahun di Lombok (Tabel 8). Namun, jumlah ini menunjukkan potensi kredit karbon, belum tentu pembayaran sebenarnya yang diperlukan untuk memulai sebuah proyek.

Table 7
Land use and Carbon stock change under CP and FR scenarios.

Land Use Class	Carbon Stock (metric ton/ha)	Community Partnership scenario (change from BAU) (ha)		Forest Restoration scenario (change from BAU) (ha)	
		In 10 years	In 30 years	In 10 years	In 30 years
Primary forest	206.6	0	0	1885	3770
Secondary forest	181.1	24,060	44,527	24,060	44,527
Shrubland	75.3	4645	−1488	4645	−1488
All other land uses	23.4	−28,705	−43,039	−30,590	−46,809
Total carbon stock change (metric tCO_2e)		4,035,338	6,944,681	4,380,670	7,635,345

Table 8
Potential Undiscounted Total Market Values of Forest-sequestered Carbon in Lombok (USD millions).

Carbon Price (USD/metric tCO_2e)	Carbon Value (in USD millions)			
	Community Partnership		Forest Restoration	
	10-year	30-year	10-year	30-year
$5	20.18	34.72	21.90	38.18
$7.50	30.27	52.09	32.86	57.27
$10	40.35	69.45	43.81	76.35

4.3. Hydrological modelling results	4.3. Hasil pemodelan hidrologi
WaterWorld V3.31 results predicted that CP and FR scenarios would result in decreased local annual water balance and runoff in most locations in Lombok due to increased evapotranspiration from tree cover. Fig. 5 shows the changes in average surface water runoff and water balance under CP and FR scenarios. The differences between catchments reflect differences in the amount of tree cover change as well as the effects of varying fog frequency, rainfall totals and slope. The WaterWorld metric for water quality is termed the human footprint on water quality (Mulligan, 2010, 2013) and indicates the impact of upstream land use on downstream water quality as a percent of water that fell as rain on human impacted land uses. Water quality was predicted to increase in the afforested areas because of reduced agricultural inputs, but reduced runoff through greater evapotranspiration can also translate to concentrated pollutants downstream from the remaining agricultural lands. Since most populations are at lower elevations (e.g. residents in the city of Mataram. For the location, see Fig. 1) and most forest are at higher elevations, this can mean a minimal or negative effects from increasing forest cover on water quality to downstream beneficiaries. Moreover, although increased infiltration does lead to a greater fraction of water as subsurface flow, WaterWorld V3.31 shows the impact of reduced water balance is greater so dry season flows decrease as tree cover increases in this region. Overall, the water modeling showed no net benefits from recovering tree cover in terms of water supply and water quality downstream, except locally at a few remote very cloudy sites.	Hasil WaterWorld V3.31 memperkirakan bahwa skenario CP dan FR akan menghasilkan penurunan neraca air tahunan lokal dan limpasan di sebagian besar lokasi di Lombok karena peningkatan evapotranspirasi dari tutupan pohon. Gambar 5 menunjukkan perubahan limpasan air permukaan rata-rata dan neraca air di bawah skenario CP dan FR. Perbedaan antara daerah tangkapan mencerminkan perbedaan dalam jumlah perubahan tutupan pohon serta pengaruh frekuensi kabut, total curah hujan dan kemiringan yang berbeda-beda. Metrik WaterWorld untuk kualitas air menunjukkan jejak manusia pada kualitas air (Mulligan, 2010, 2013) dan mengindikasikan dampak penggunaan lahan di hulu pada kualitas air di hilir sebagai persentase air yang turun sebagai hujan pada penggunaan lahan yang dipengaruhi oleh manusia. Kualitas air diperkirakan akan meningkat di area yang dihutankan karena berkurangnya input pertanian, tetapi berkurangnya limpasan melalui evapotranspirasi yang lebih besar juga dapat menyebabkan polutan terkonsentrasi di hilir dari lahan pertanian yang tersisa. Karena sebagian besar populasi berada di dataran yang lebih rendah (misalnya penduduk di kota Mataram. Untuk lokasinya, lihat Gambar 1) dan sebagian besar hutan berada pada topografi yang lebih tinggi, ini dapat berarti efek minimal atau negatif dari peningkatan tutupan hutan pada kualitas air kepada penerima manfaat di bagian hilir. Selain itu, meskipun peningkatan infiltrasi menyebabkan fraksi air yang lebih besar sebagai aliran bawah permukaan, WaterWorld V3.31 menunjukkan dampak penurunan neraca air lebih besar sehingga aliran musim kemarau berkurang seiring dengan peningkatan tutupan pohon di wilayah ini. Secara keseluruhan, pemodelan air tidak menunjukkan manfaat

	bersih dari pemulihan tutupan pohon dalam hal pasokan air dan kualitas air di hilir, kecuali secara lokal di beberapa lokasi terpencil yang sangat keruh.

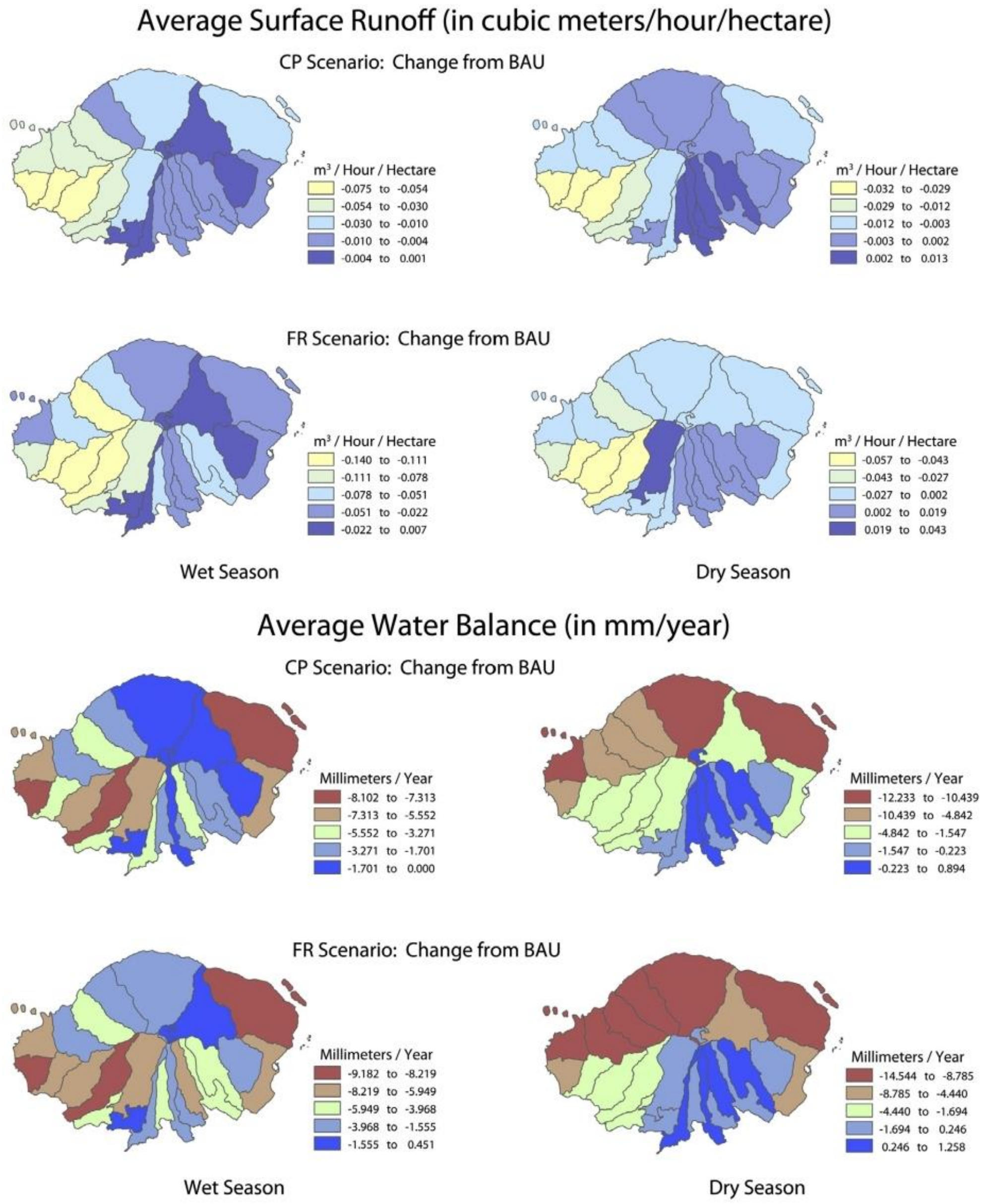

Fig. 5. Changes in Average Surface Runoff (m^3/h/ha) and Water Balance (mm/year) from recovery of secondary forests in Community Partnership (CP) scenario and recovery of secondary and primary forests in Forest Restoration (FR) scenario.

4.4. Local perceptions of forest ESs To assess potential impacts of future land use change scenarios on provisioning services that sustain food, energy and livelihoods of local communities, we surveyed 408 individuals across the four forest locations. During the surveys, respondents were asked to report on their household's level of consumption of forest ESs obtained from the forest (NTFPs, agroforest products, and timber products), and their perceived market values of these ecosystem services (Section 4.4.1). We also asked respondents to indicate what services they would like to see being enhanced through future forest management actions (Section 4.4.2).	**4.4. Persepsi lokal tentang ES hutan** Untuk menilai dampak potensial dari skenario perubahan penggunaan lahan di masa depan terhadap penyediaan layanan yang menopang pangan, energi dan penghidupan masyarakat lokal, kami menyurvei 408 individu di empat lokasi hutan. Selama survei, informan diminta untuk melaporkan tingkat konsumsi rumah tangga mereka atas ES hutan yang diperoleh dari hutan (HHBK, produk agroforestry, dan produk kayu), dan nilai pasar yang mereka rasakan dari jasa ekosistem ini (Bagian 4.4.1). Kami juga meminta responden untuk menunjukkan layanan apa yang mereka ingin ditingkatkan melalui tindakan pengelolaan hutan di masa depan (Bagian 4.4.2).
4.4.1. Locally important provisioning services from forests The majority (80%) of respondents reported that their household utilizes some forest ESs (Table 9). The community near the Protection forest (B) reported highest level of use (98% of respondents), followed by A near Production forest (86%), C near Conservation forest (81%), D Community forest (53%). Agroforest products were utilized most widely (69%), while smaller portions of respondents reported utilization of Natural NTFP (49%) and Timber (47%). The specific forest products utilized vary by locations: coffee (67%), banana (56%) and fern (49%) were most popular in A community; jackfruit (86%) and banana (82%) in the B community; fern (69%) and forage (58%) in C community; and coffee (35%) and Jackfruit (34%) in D Community forest. Fuelwood collection was higher in A near the Protection forest (79%), compared to other areas around where one-third of respondents reported collection. These variations are due to differences in permitted activities across different forest designations (See Table 3), as well as ease of access to markets and other socio-economic variables. For example, a previous study showed that domestic energy needs can be often met by deadwoods and branches collected in household gardens and fuelwood extraction from forests is highly correlated with opportunity to sell fuelwoods (Lee et al., 2015). We also explored the economic value of the products collected from different locations. To calculate these values, reported volumes collected were multiplied by reported prices. When the price was missing but the respondent reported some level of extraction, the mean price was used. To get a conservative estimate of the values and avoid outliers skewing the data, we	**4.4.1. Penyediaan jasa yang penting secara lokal dari hutan** Mayoritas (80%) responden melaporkan bahwa rumah tangga mereka menggunakan beberapa ES hutan (Tabel 9). Masyarakat sekitar Hutan Lindung (B) melaporkan tingkat penggunaan tertinggi (98% responden), diikuti oleh A sekitar Hutan Produksi (86%), C sekitar Hutan Konservasi (81%), D Hutan Kemasyarakatan (53%). Produk agroforestry dimanfaatkan paling luas (69%), sementara sebagian kecil responden melaporkan pemanfaatan HHBK Alami (49%) dan Kayu (47%). Hasil hutan spesifik yang dimanfaatkan berbeda-beda di setiap lokasi: kopi (67%), pisang (56%) dan pakis (49%) paling umum di komunitas A; nangka (86%) dan pisang (82%) pada masyarakat B; pakis (69%) dan hijauan (58%) di komunitas C; dan kopi (35%) dan Nangka (34%) di Hutan Kemasyarakatan D. Pengumpulan kayu bakar lebih tinggi di A sekitar hutan Lindung (79%), dibandingkan dengan daerah lain di mana sepertiga responden melaporkan pengumpulan. Variasi ini disebabkan oleh perbedaan aktivitas yang diizinkan di berbagai peruntukan hutan (Lihat Tabel 3), serta kemudahan akses ke pasar dan variabel sosio-ekonomi lainnya. Sebagai contoh, penelitian sebelumnya menunjukkan bahwa kebutuhan energi dalam negeri seringkali dapat dipenuhi oleh kayu mati dan ranting yang dikumpulkan di kebun rumah tangga dan ekstraksi kayu bakar dari hutan sangat berkorelasi dengan peluang untuk menjual kayu bakar (Lee et al., 2015). Kami juga mengeksplorasi nilai ekonomi produk yang dikumpulkan dari berbagai lokasi. Untuk menghitung nilai-nilai ini, volume yang dilaporkan dikumpulkan dikalikan dengan harga yang dilaporkan. Ketika harga tidak ada tetapi responden melaporkan beberapa tingkat ekstraksi, harga rata-rata digunakan. Untuk mendapatkan perkiraan nilai yang paling mendekati dan

removed the top and bottom 10% of the value distribution. Average overall values of forest ESs utilized per household per year were highest in the Production forest ($141), followed by Community forest ($116), Protection Forest ($85) and Conservation forest ($46). Table 9 provides further detail of the distribution of values by ESs by location. Highest values were found for Palm ($918 for 6% of Community forest users), Coffee ($262 for 67% of Production forest users and $64 for 35% of Community forest) and Durian ($81 for 13% of Community forest users and $75 for 33% of Production forest users). Timber products were largely restricted to fuelwood with relatively low value ($4/household/yr). Forest products most likely to be consumed by the household are: melinjo (94%), forage (91%), jackfruit (88%), taro (83%) and fern (83%), while cacao (92%) and palm (83%) were the products most likely to be sold. Our findings demonstrate that there was a significant variability in terms of forest uses by communities.	menghindari faktor yang dapat membuat data bias, kami menghapus 10% teratas dan terbawah dari distribusi nilai. Nilai keseluruhan rata-rata dari ES hutan yang digunakan per rumah tangga per tahun adalah yang tertinggi di Hutan Produksi ($141), diikuti oleh Hutan Kemasyarakatan ($116), Hutan Lindung ($85) dan Hutan Konservasi ($46). Tabel 9 memperlihatkan rincian lebih lanjut tentang distribusi nilai menurut ES berdasarkan setiap lokasi. Nilai tertinggi ditemukan untuk Kelapa Sawit ($918 untuk 6% pengguna hutan Kemasyarakatan), Kopi ($262 untuk 67% pengguna hutan Produksi dan $64 untuk 35% hutan Kemasyarakatan) dan Durian ($81 untuk 13% pengguna hutan Kemasyarakatan dan $75 untuk 33% pengguna hutan produksi). Produk kayu sebagian besar terbatas pada kayu bakar dengan nilai yang relatif rendah ($4/rumah tangga/tahun). Hasil hutan yang paling banyak dikonsumsi oleh rumah tangga adalah: melinjo (94%), hijauan (91%), nangka (88%), talas (83%) dan pakis (83%), sedangkan kakao (92%) dan sawit. (83%) adalah produk yang kemungkinan besar akan dijual. Temuan kami menunjukkan bahwa ada variabilitas yang signifikan dalam hal pemanfaatan hutan oleh masyarakat.

Table 9
Level of use (% of respondents reporting collection from forests) and value of forest ESs (USD/household/yr).

Type of service	Forest ESs[1]	Production forest (A)		Protection forest (B)		Conservation forest (C)		Community forest (D)		All forests %			
		%	Value	%	Value	%	Value	%	Value	%	Value	Con-sumed	Sold
Natural NTFP	Bamboo	2	18.52	18	13.35	6	4.23	26	11.25	13	10.83	51	49
	Forage	5	31.11	15	39.21	58	44.39	10	26.67	22	40.49	91	9
	Fern	49	4.22	4	1.63	69	1.48	13	5.04	34	2.86	83	17
	Sub-total	**50**	**8.41**	**32**	**20.21**	**81**	**27.14**	**33**	**14.37**	**49**	**18.18**		
Agroforest Products	Jackfruit	13	2.79	86	4.23	49	2.47	34	3.31	46	3.47	88	12
	Durian	33	74.80	7	38.27	8	16.89	13	81.63	16	66.46	60	40
	Avocado	17	8.63	29	18.45	43	5.42	3	18.04	23	10.20	44	56
	Mangosteen	3	18.89	0	0.00	0	0.00	1	18.52	1	18.80	44	56
	Melinjo	3	1.44	13	2.55	0	0.00	0	0.00	4	2.31	94	6
	Cacao	28	15.99	14	9.94	0	0.00	0	0.00	11	13.74	8	92
	Coffee	67	262.39	24	50.40	0	0.00	35	63.82	32	171.94	50	50
	Banana	56	14.95	82	15.01	0	0.00	23	13.66	42	14.89	36	64
	Taro	2	14.07	2	2.93	0	0.00	3	4.19	2	7.27	83	17
	Palm	0	0.00	0	0.00	0	0.00	6	918.52	1	918.52	17	83
	Candlenut	0	0.00	16	15.75	5	16.44	3	7.03	6	14.87	31	69
	Other	0	0.00	18	117.18	1	6.73	1	13.46	5	117.45	76	24
	Sub-total	**84**	**142.86**	**96**	**49.04**	**57**	**14.15**	**40**	**103.89**	**69**	**77.70**		
Timber products	Fuelwood	35	7.17	80	3.59	36	2.99	35	5.92	48	4.56	87	13
	Tools	4	0.74	0	0.00	0	0.00	1	1.85	1	0.96	100	0
	Sub-total	**37**	**6.66**	**79**	**3.59**	**37**	**2.99**	**34**	**5.40**	**47**	**4.41**		
	All forest ESs[2]	**86**	**141.49**	**98**	**84.98**	**81**	**46.25**	**53**	**115.63**	**80**	**93.46**		

[1] No uses were reported for some NTFPs (e.g. langsat, and rattan) and timber products (materials for building and fencing).
[2] Total % of respondents whose household obtained some values from forest ESs; Mean aggregate value of services obtained from the forest (USD/household/yr).

4.4.2. Perceived importance of forest ESs

We asked respondents to indicate which services they would like to see improved by future forest management plans. Both water regulation (91% of respondents) and agroforest products (81%) were considered to be important by most respondents; a finding that is consistent across all four forest locations (Table 10). The overriding importance placed on water regulation can be illustrated by a comment made by one respondent "[Other ecosystem services] are what we need to live, but water is life". The higher importance ranking of agroforest products may be explained by the fact that more people used and obtained higher values of services from agroforest products than the other forest ESs categories (Table 9). Natural NTFP (40%) and timber (27%) were considered to be less important. However, there were significant

4.4.2. Persepsi pentingnya ES hutan

Kami meminta responden untuk menunjukkan layanan mana yang mereka ingin ditingkatkan dengan rencana pengelolaan hutan di masa depan. Pengaturan air (91% responden) dan produk agroforestry (81%) dianggap penting oleh sebagian besar responden; temuan yang konsisten di keempat lokasi hutan (Tabel 10). Kepentingan utama yang ditempatkan pada pengaturan air dapat diilustrasikan dengan komentar yang dibuat oleh salah satu responden "[Jasa ekosistem lain] adalah apa yang kita butuhkan untuk hidup, tetapi air adalah kehidupan." Peringkat kepentingan yang lebih tinggi dari produk agroforestry dapat dijelaskan oleh fakta bahwa lebih banyak orang menggunakan dan memperoleh nilai jasa yang lebih tinggi dari produk agroforestry daripada kategori ES hutan lainnya (Tabel 9). HHBK alami (40%)

differences between locations in terms of the importance of these services. Natural NTFPs were considered important (67%) in the Conservation forests, while timber resources were considered important (76%) in the production forest. These differences in preferences reflect the activities that are permitted in the different types of forest. Analysis of the socioeconomic characteristics of respondents indicated that, generally, there was little difference between the socio-economics of the people living in the different forests.	dan kayu (27%) dianggap kurang penting. Namun, terdapat perbedaan yang signifikan antar lokasi dalam hal pentingnya layanan ini. HHBK alami dianggap penting (67%) di hutan konservasi, sedangkan sumber daya kayu dianggap penting (76%) di hutan produksi. Perbedaan preferensi ini mencerminkan aktivitas yang diizinkan di berbagai jenis hutan. Analisis karakteristik sosial ekonomi responden menunjukkan bahwa secara umum terdapat sedikit perbedaan antara sosial ekonomi masyarakat yang tinggal di hutan yang berbeda.

Table 10
Importance of local forest ESs in future forest management plans by study location.

Forest service	Production forest	Protection forest	Conservation forest	Community forest	All respondents
	% of respondents stating that forest service was important				
Natural non-timber forest products	44	26	67	24	40
Agroforest products	92	70	1	86	81
Timber forest products	78	10	1	17	27
Water regulation	96	90	88	90	91

5. Discussion **5.1. Forest management, PES and the delivery of global and local services** In this research, we explored the potential impacts of alternative land use change scenarios on ecosystem services across different scales from global to landscape and local levels. Our analysis identified two scenarios: a community partnership (CP) scenario which largely focused on increasing the area of secondary forest; and a forest restoration (FR) scenario which increased the area of both secondary and primary forest. In terms of global ES, it is clear that both of these scenarios can generate significant global carbon benefits: over a 30-year period the CP scenario was estimated to generate between \$35 million to \$69 million in carbon values, while the FR scenario would generate between \$38 million and \$76 million (at carbon price \$5 to \$10 per metric tCO_2e). Impacts of recovering primary and secondary forests on the ESs at landscape and local levels are less clear. The results from the global hydrological model, WaterWorld V3.31, employed here showed that the impacts of alternative scenarios on the delivery of watershed services are generally negative at the whole island scale. However, the community	**5. Pembahasan** **5.1. Pengelolaan hutan, PES dan penyampaian layanan global dan lokal** Dalam penelitian ini, kami mengeksplorasi dampak potensial dari skenario perubahan penggunaan lahan alternatif pada jasa ekosistem di berbagai skala dari global hingga lanskap dan tingkat lokal. Analisis kami mengidentifikasi dua skenario: skenario kemitraan masyarakat (CP) yang sebagian besar berfokus pada peningkatan kawasan hutan sekunder; dan skenario restorasi hutan (FR) yang meningkatkan luas hutan sekunder dan primer. Dalam hal ES global, jelas bahwa kedua skenario ini dapat menghasilkan manfaat karbon global yang signifikan: selama periode 30 tahun, skenario CP diperkirakan menghasilkan nilai karbon antara \$35 juta hingga \$69 juta, sedangkan skenario FR akan menghasilkan nilai karbon antara \$38 juta dan \$76 juta (dengan harga karbon \$5 hingga \$10 per metrik tCO_2e). Dampak pemulihan hutan primer dan sekunder pada ES di tingkat lanskap dan lokal kurang jelas. Hasil dari model hidrologi global, WaterWorld V3.31, yang digunakan di sini menunjukkan bahwa dampak skenario alternatif pada penyampaian layanan DAS umumnya negatif di seluruh skala pulau. Namun, survei masyarakat

surveys showed that local community members strongly believe that declining of watershed services, especially water yield during dry season, is linked to historical events of deforestation and forest degradation.

In terms of local ESs, greatest benefits per household are found where communities are allowed to cultivate and utilize agroforest products (Table 9). Extraction of natural NTFP and timber is important to some, but generally are valued less. Estimation of an aggregate value of the local ESs in our study area is difficult due to overlapping land use classes and forest functions (Table 3) and also uncertainty of land tenure arrangements. For our analysis, we aggregated the average annual household value of forest ESs for each forest type with the number of households in our study area that have agriculture as their main occupation (Table 11). Our target population for this aggregation was the 23 sub-districts surrounding mount Rinjani. These sub-districts had a population of 1.313 million (with average household size of 3.57) as of 2010 and about 51.5% of population in the area reported agriculture as their main occupation, according to the latest census (BPS/NTB, 2012). The total value of locally provided forest ESs, we aggregate the average household values (Table 9) to the 51.5% of households (Table 9). The value of local ESs delivered by forests of Lombok is currently estimated at $16 million to $18 million annually. Aggregated (undiscounted) over 30 years, the total value ranges from $486 million to $564 million.

To allow a comparison of the carbon values (Table 8) with changes in values of locally provided forest ESs under different land use scenarios, we assume increase in forests in CP and FR scenarios (shown in Table 5 and 6) would be distributed to different forests according to the current ratio (Table 12)[7].

Although the predicted changes in locally provided forest ESs values associated with the CP or FR scenarios are approximate, we can demonstrate that these values are higher than the carbon values ($35.7–$69 m over 30 years for the Community Partnership scenario and $38–$76 m for the Forest Restoration scenario).

Opportunity costs are the forgone economic benefits of alternative land use, in this case dryland agriculture. Communities in the area cultivate various crops, including maize, chili, cassava, peanuts, etc (Collins Higgins Consulting Group, 2012). Lombok is also one of the largest producers of tobacco in Indonesia (Lee et al., 2015). Profitability of dryland agriculture varies a great

menunjukkan bahwa anggota masyarakat setempat sangat yakin bahwa penurunan layanan DAS, terutama hasil air selama musim kemarau, terkait dengan riwayat peristiwa deforestasi dan degradasi hutan.

Dalam hal ES lokal, manfaat terbesar per rumah tangga ditemukan dimana masyarakat diizinkan untuk membudidayakan dan memanfaatkan produk agroforestry (Tabel 9). Ekstraksi HHBK alami dan kayu penting bagi sebagian orang, tetapi umumnya dihargai lebih rendah. Sulit untuk memperkirakan nilai agregat ES lokal di wilayah studi kami karena tumpang tindih kelas penggunaan lahan dan fungsi hutan (Tabel 3) dan juga ketidakpastian pengaturan kepemilikan lahan. Untuk analisis kami, kami mengumpulkan nilai rata-rata tahunan rumah tangga dari ES hutan untuk setiap jenis hutan dengan jumlah rumah tangga di wilayah studi kami dimana pertanian sebagai pekerjaan utama mereka (Tabel 11). Populasi target kami untuk agregasi ini adalah 23 kecamatan di sekitar gunung Rinjani. Kecamatan-kecamatan ini memiliki populasi 1,313 juta (dengan rata-rata ukuran rumah tangga 3,57) pada tahun 2010 dan menurut sensus terakhir, dilaporkan bahwa sekitar 51,5% penduduk di wilayah tersebut menjadikan sektor pertanian sebagai pekerjaan utama mereka (BPS / NTB, 2012). Nilai total ES hutan yang disediakan secara lokal, kami menggabungkan nilai rata-rata rumah tangga (Tabel 9) ke 51,5% rumah tangga (Tabel 9). Nilai ES lokal yang dihasilkan oleh hutan Lombok saat ini diperkirakan mencapai $16 juta hingga $18 juta per tahun. Diagregasi (tidak dihitung) selama 30 tahun, nilai total berkisar dari $486 juta hingga $564 juta.

Untuk memungkinkan perbandingan nilai karbon (Tabel 8) dengan perubahan nilai ES hutan yang disediakan secara lokal di bawah skenario penggunaan lahan yang berbeda, kami mengasumsikan peningkatan hutan dalam skenario CP dan FR (ditunjukkan pada Tabel 5 dan 6) akan didistribusikan ke berbagai hutan menurut rasio saat ini (Tabel 12)[7].

Meskipun prediksi perubahan dalam nilai ES hutan yang disediakan secara lokal yang terkait dengan skenario CP atau FR adalah perkiraan, kami dapat menunjukkan bahwa nilai ini lebih tinggi dari nilai karbon ($35,7– $69 juta selama 30 tahun untuk skenario Kemitraan Masyarakat dan $38– $76 juta untuk skenario Restorasi Hutan).

Biaya peluang merupakan manfaat ekonomi yang hilang dari penggunaan lahan alternatif, dalam hal ini pertanian lahan kering. Masyarakat di daerah

deal among different varieties of crops and year-to-year. For example, tobacco can go from a net profit to a net loss depending on weather conditions ($465–$1,132/ha under normal condition to $371 to $477/ ha in a bad year e.g., 2002) (Keyser and Juita, 2005). Net revenue from maize in similar areas has been reported around $180/ha/yr (Da Silva and Murdolelono, 2010). Table 13 presents opportunity costs of carbon sequestration undiscounted and Net Present Value (NPV) with 10% discount rate over 30-year period per metric tCO_2e with a range of per ha profitability (following the methodology described in White et al., 2010). Opportunity costs are lower than the current carbon price. Here we can draw a number of broad conclusions on the ES associations and potential effects of global PES scheme. First, the value of local ESs are potentially greater than that of global ES (carbon) and opportunity costs are low. Thus, carbon PES schemes (such as REDD+) need to be developed in a way to maximize synergies among global and local ESs. Carbon payments can provide the initial capital investment needed for creating nurseries and planting trees, but recovered forests can also provide income overtime for communities to maintain forests. Each community can develop a benefit-sharing mechanism under the partnership agreement (kemitraan) with KPHs or through Community Forest arrangement. For example, community D has started tree planting projects with REDD+ demonstration fund facilitated by an NGO (FFI/Indonesia). The species selection was negotiated with the community, and the result was mostly fruit trees planted. Second, higher benefits can be obtained by encouraging secondary forests (retaining artificial gaps in the canopy to 50–60%), while meeting community needs for NTFP, agroforest products and timber. Community partnership scenario is focusing on recovery of secondary forests, which is possible through agroforestry with significant forest covers. A previous study in the area shows that carbon stored in agroforestry land with significant forest cover (178 metric ton/ha, Markum et al., 2013), is similar to that in secondary forests (181 metric ton/ha, Table 2). Forest Restoration scenario included additional reforestation to recover primary forests. From the community point of view, primary forest does not generate significant economic revenues, although there may be cultural and religious significance that this study did not capture. Additional carbon payment expected from primary forest can motivate communities to recover primary forests for conservation purposes.	tersebut membudidayakan berbagai tanaman, termasuk jagung, cabai, singkong, kacang tanah, dll (Collins Higgins Consulting Group, 2012). Lombok juga merupakan salah satu penghasil tembakau terbesar di Indonesia (Lee et al., 2015). Profitabilitas pertanian lahan kering sangat bervariasi antara varietas tanaman yang berbeda dan dari tahun ke tahun. Misalnya, tembakau dapat berubah dari laba bersih menjadi rugi bersih tergantung pada kondisi cuaca ($ 465– $ 1,132 / ha dalam kondisi normal menjadi $ 371 hingga $ 477 / ha pada tahun yang buruk misalnya, 2002) (Keyser dan Juita, 2005). Pendapatan bersih dari jagung di area serupa telah dilaporkan sekitar $ 180 / ha / tahun (Da Silva dan Murdolelono, 2010). Tabel 13 menyajikan biaya peluang dari penyerapan karbon yang tidak dihitung dan Net Present Value (NPV) dengan tingkat potongan 10% selama periode 30 tahun per metrik tCO_2e dengan kisaran profitabilitas per ha (mengikuti metodologi yang dijelaskan dalam White et al., 2010). Biaya peluang lebih rendah dari harga karbon saat ini. Di sini kita dapat menarik sejumlah kesimpulan umum tentang asosiasi ES dan potensi dampak skema PES global. Pertama, nilai ES lokal berpotensi lebih besar daripada nilai ES global (karbon) dan biaya peluangnya rendah. Karenanya, skema PES karbon (seperti REDD+) perlu dikembangkan dengan cara memaksimalkan sinergi antara ES global dan lokal. Pembayaran karbon dapat memberikan investasi modal awal yang diperlukan untuk membuat pembibitan dan penanaman pohon, tetapi hutan yang pulih juga dapat memberikan pendapatan tambahan bagi masyarakat untuk memelihara hutan. Setiap komunitas dapat mengembangkan mekanisme pembagian manfaat di bawah kesepakatan kemitraan dengan KPH atau melalui pengaturan Hutan Kemasyarakatan. Misalnya, komunitas D telah memulai proyek penanaman pohon dengan dana percontohan REDD+ yang difasilitasi oleh sebuah LSM (FFI / Indonesia). Pemilihan spesies telah dirundingkan dengan masyarakat, dan hasilnya sebagian besar ditanam pohon buah-buahan. Kedua, manfaat yang lebih tinggi dapat diperoleh dengan mendorong hutan sekunder (mempertahankan celah buatan di kanopi hingga 50–60%), sambil memenuhi kebutuhan masyarakat akan HHBK, produk agroforestry, dan kayu. Skenario kemitraan masyarakat berfokus pada pemulihan hutan sekunder, yang dimungkinkan melalui agroforestry dengan tutupan hutan yang luas. Studi sebelumnya di kawasan tersebut menunjukkan bahwa karbon yang tersimpan di lahan agroforestri dengan tutupan hutan yang signifikan (178 metrik ton / ha, Markum et al., 2013), serupa dengan di hutan sekunder (181 metrik ton / ha, Tabel 2). Skenario Restorasi Hutan termasuk reboisasi

	tambahan untuk memulihkan hutan primer. Dari sudut pandang masyarakat, hutan primer tidak menghasilkan pendapatan ekonomi yang signifikan, meskipun mungkin terdapat signifikansi budaya dan agama yang tidak ditangkap oleh studi ini. Pembayaran karbon tambahan yang diharapkan dari hutan primer dapat memotivasi masyarakat untuk memulihkan hutan primer untuk tujuan konservasi.

Table 11
Aggregate value of locally provided forest ESs.

	Value per year (USD/Household)[1]	Number of affected Households[2]	Value per year (million USD)	Undiscounted value over 30 years[3] (million USD)
Production forest	$121	44,104	$6.2	$187
Protection forest	$83–$61	84,311	$7.2–$9.7	$241–$292
Conservation forest	$38	61,044	$2.8	$85
Total		189,460	$16.2–$18.8	$486–$564

[1] $121 for Production Forest ($141 for 86% of the community utilizing forest products); $83 for Protection Forests ($85 for 98% of the community utilizing forest products) and $61 for Community Forests in Protection Forest ($115 for 53% of the community utilizing forest products) and $38 for Conservation Forest ($46 for 81% of the community utilizing forest products).
[2] Aggregated population of sub-districts near each designated forest function X 51.5% with agriculture as the main occupation based on the 2010 population census.
[3] Not accounting for population growth/discounting rate/forest product value change.

Table 12
Changes in value of locally provided forest ESs.

	Undiscounted value over 30 years[3] (million USD)	CP scenario[1]		FR scenario[2]	
		Forest area changes (%)	Changes in values (million USD)	Forest area changes (%)	Changes in values (million USD)
Production forest	$187	7.52	$14.1	8.20	$15.3
Protection forest	$241–$292	18.05	$43.5–52.5	19.68	$47.4–57.5
Conservation forest	$85	12.03	$10.2	13.12	$11.2
Total	$486–$564	37.6	$67.8–76.8	41	$73.9–84.0

[1] 44,527 ha or 37.6% increase in total forest area.
[2] 48,297 ha or 41% increase in total forest area.
[3] Not accounting for population growth/discounting rate/forest product value change.

Table 13
Opportunity costs of carbon sequestration (Value/metric tCO_2e for 30-year).

Profitability of Dryland Agriculture (USD/ha)	Community Partnership (Dryland Agriculture → Agroforest: 44,527 ha)		Forest Restoration (Dryland Agriculture → Agroforest: 44,527 ha & 3,770 ha to primary forest)	
	Undiscounted	NPV with 10% discounting rate	Undiscounted	NPV with 10% discounting rate
$150	$0.01	$0.002	$0.02	$0.005
$250	$0.13	$0.04	$0.13	$0.04
$500	$0.44	$0.14	$0.43	$0.14
$1000	$1.05	$0.33	$1.03	$0.32
$2000	$2.27	$0.71	$2.21	$0.70

*Profitability of Dryland Agriculture/ha – ES value of Forest /ha (Primary Forest: $54.58 = $2.8 million/51,111 ha; Secondary/Agroforest: $144.22 = $9.7 million/67,258 ha); Primary forest = 206.6 metric tCO_2e/ha; Secondary forest = 206.6 metric tCO_2e/ha; Dryland Agriculture = Primary forest = 23.4 metric tCO_2e/ha.

5.2. Data discrepancies: reconciling global modelling and local perceptions	5.2. Perbedaan data: merekonsiliasi pemodelan global dan persepsi lokal
A key debate in ecosystem service assessments relates to identifying what is the most appropriate source of data to measure ecosystem service change (TEEB, 2010). Evaluating watershed services is especially challenging because hydrological impacts can occur anywhere downstream of the site of service production (van Noorwijk et al., 2016). It is not easy to discern the roles of land use change from other influencing factors, such as climate variability,	Perdebatan utama dalam penilaian jasa ekosistem berkaitan dengan mengidentifikasi sumber data apa yang paling tepat untuk mengukur perubahan jasa ekosistem (TEEB, 2010). Mengevaluasi layanan DAS sangat menantang karena dampak hidrologi dapat terjadi di mana saja di bagian hilir lokasi produksi jasa (van Noorwijk et al., 2016). Tidak mudah untuk membedakan peran perubahan penggunaan lahan dari faktor-faktor lain yang

landscape-level changes, and spatial distribution of soil and vegetation types (Bruijnzeel, 2004). In this research, we used both global models (e.g. WaterWorld V3.31) and local knowledge (in-person surveys) to assess the impact of forest management on water regulation. Global models have a wide appeal in that they are usually based on the theoretically sound scientific knowledge and can be applied almost anywhere in the world at relatively low costs. In the absence of long term observation records, collecting local data may require surveys with local stakeholders/communities, which is often based on implicit and experiential knowledge rather than scientific evidence (Christie, 2012). In our research, we found discrepancies between these two data sources, particularly in terms of the predicted impact of forest management on water regulation services. WaterWorld V3.31 showed that more tree cover decreases baseflow in both dry and wet seasons in most places due to increased evapotranspiration, while increasing baseflow in some places due to enhanced infiltration. This is supported by many studies that indicate higher evapotranspiration of trees than other cover types (Kaimowitz, 2004; Calder, 2001; Van Dijk et al., 2007). The overall effects of both scenarios were negative on watershed services. However, residents frequently reported contrasting views based on experiences and observations. In surveys conducted in Lombok communities in 2002, residents reported that springs had gone dry in response to forest clearing (WWF, 2002). According to Pirard (2012), 43% of the large springs surrounding Rinjani dried up in the decade 1992–2002, while approximately 30% of the Mount Rinjani was deforested during the same decade. Klock and Sjah (2011) reported that, during the previous twenty years, more than 400 springs dried up on Mount Rinjani, most likely from deforestation. The Jakarta Post (2014) reported that there are 107 springs currently utilized in Lombok, with many other sources not yet recorded by the government and under the control of local residents. In the above article, a local Village Head is quoted as emphasizing the function of forests as a sponge, absorbing water and releasing it gradually, thus enhancing water regulation and quality. Our community survey also confirm that water regulation was considered important to people living in the forest margins and the follow-up focus group discussions highlighted the strong local belief that retaining and enhancing forest cover protected water supply and water quality. The prevailing scientific paradigm for linking forests to water has shifted since the early 1980ies when several reviews, both in the temperate zone and the	mempengaruhi, seperti variabilitas iklim, perubahan tingkat lanskap, dan distribusi spasial jenis tanah dan vegetasi (Bruijnzeel, 2004). Dalam penelitian ini, kami menggunakan model global (misalnya WaterWorld V3.31) dan pengetahuan lokal (survei langsung) untuk menilai dampak pengelolaan hutan terhadap pengaturan air. Model global memiliki daya tarik yang luas karena biasanya didasarkan pada pengetahuan ilmiah yang kuat secara teoritis dan dapat diterapkan hampir di mana saja di dunia dengan biaya yang relatif rendah. Jika tidak ada catatan observasi jangka panjang, pengumpulan data lokal mungkin memerlukan survei dengan pemangku kepentingan / komunitas lokal, yang seringkali didasarkan pada pengetahuan implisit dan pengalaman daripada bukti ilmiah (Christie, 2012). Dalam penelitian kami, kami menemukan perbedaan antara kedua sumber data ini, terutama dalam hal perkiraan dampak pengelolaan hutan terhadap jasa pengaturan air. WaterWorld V3.31 menunjukkan bahwa lebih banyak tutupan pohon mengurangi aliran dasar di musim kemarau dan musim hujan di sebagian besar tempat karena peningkatan evapotranspirasi, sekaligus meningkatkan aliran dasar di beberapa tempat karena peningkatan infiltrasi. Hal ini didukung oleh banyak penelitian yang menunjukkan evapotranspirasi pohon yang lebih tinggi dibandingkan jenis tutupan lainnya (Kaimowitz, 2004; Calder, 2001; Van Dijk et al., 2007). Efek keseluruhan dari kedua skenario itu negatif pada layanan DAS. Namun, warga sering melaporkan perbedaan pandangan berdasarkan pengalaman dan pengamatan. Dalam survei yang dilakukan di masyarakat Lombok pada tahun 2002, penduduk melaporkan bahwa mata air telah mengering sebagai akibat dari pembukaan hutan (WWF, 2002). Menurut Pirard (2012), 43% mata air besar di sekitar Rinjani mengering dalam dekade 1992–2002, sementara sekitar 30% Gunung Rinjani mengalami deforestasi selama dekade yang sama. Klock dan Sjah (2011) melaporkan bahwa, selama dua puluh tahun sebelumnya, lebih dari 400 mata air mengering di Gunung Rinjani, kemungkinan besar akibat deforestasi. The Jakarta Post (2014) melaporkan bahwa saat ini terdapat 107 mata air yang dimanfaatkan di Lombok, dengan banyak sumber lain yang belum tercatat oleh pemerintah dan di bawah kendali penduduk setempat. Dalam artikel di atas, dikutip Kepala Desa setempat yang menekankan fungsi hutan sebagai spons, menyerap air dan melepaskannya secara bertahap, sehingga meningkatkan pengaturan dan kualitas air. Survei komunitas kami juga mengkonfirmasi bahwa pengaturan air dianggap penting bagi orang-orang yang tinggal di sekitar hutan dan FGD lanjutan menyoroti kepercayaan lokal yang kuat bahwa mempertahankan dan meningkatkan tutupan hutan melindungi pasokan air dan kualitas air.

humid tropics, show that there is little empirical evidence for forests storing excess water during wet periods and releasing it during dry periods, so called sponge theory (Bosch and Hewlett, 1982; Ghimire et al., 2014a; Ilstedt et al., 2016). Since then, many studies supported trade-off theory, which means less water yields with increasing tree covers (Ilstedt et al., 2016). Deforestation, especially in the tropics, does contribute soil degradation and increase in impermeable surface, which lead to locally observed negative hydrological effects. However, there is limited evidence for reforestation increasing soil hydraulic conductivities (Ghimire et al., 2013; Ghimire et al., 2014a,b). Moreover changes in water resources reflect not only the changes in ecosystem services (modelled here) but also the impacts of farmer behavior of water use and irrigation practices, which was not part of this study. Also, relying only on anecdotal data could lead to an erroneous conclusion regarding changes in spring discharge conditions caused by forest change. As noted above, illegal logging, encroachment and occupation reached its peak after the fall of the Suharto regime in 1998. Loss of forest cover notwithstanding, climate variation could have had a bearing on residents' perception of the effects of forest clearing. Long-term precipitation records shows that there are a great deal variations in precipitation during dry season among different locations and also years leading up to 1998 were dry, especially around the Mataram city in low elevation. Fig. 6 shows average precipitation records from six weather stations around the city of Mataram and four weather stations near the survey locations around Rinjani Mountain. It is very possible that declining spring discharge was more directly related to climate than to land use change. Furthermore, the existence of the PES mechanism between the city of Mataram and the communities in their upper watershed area may have raised expectation of forest-margin communities that they may be able to be compensated for managing forest for watershed services that they provide. It may be especially true for the community D that gained Community Forest recognition and their forest represents important watershed for another city (city of Praya).

WaterWorld V3.31 simulates the impacts of forests versus other land uses on hydrological impacts based on high resolution remotely sensed data. It is a very detailed process model developed specifically for data poor mountainous and tropical environments. However, its results cannot be field-validated without long-term spring discharge measurement data, and are not without limitations. Change in land cover and forest canopy structure have complex effects on fog input, rainfall interception, throughfall, stemflow, infiltration and

Paradigma ilmiah yang berlaku untuk menghubungkan hutan dengan air telah bergeser sejak awal 1980-an ketika beberapa tinjauan, baik di zona beriklim sedang dan tropis lembab, menunjukkan bahwa ada sedikit bukti empiris untuk hutan yang menyimpan kelebihan air selama periode basah dan melepaskannya selama periode kemarau, yang disebut teori spons (Bosch dan Hewlett, 1982; Ghimire et al., 2014a; Ilstedt et al., 2016). Sejak itu, banyak penelitian mendukung teori pertukaran, yang berarti hasil air lebih sedikit dengan meningkatnya tutupan pohon (Ilstedt et al., 2016). Deforestasi, terutama di daerah tropis, memang berkontribusi pada degradasi tanah dan peningkatan permukaan kedap air, yang menyebabkan efek hidrologi negatif yang diamati secara lokal. Namun, ada bukti terbatas bahwa reboisasi meningkatkan konduktivitas hidrolik tanah (Ghimire et al., 2013; Ghimire et al., 2014a, b). Selain itu, perubahan sumber daya air tidak hanya mencerminkan perubahan pada jasa ekosistem (dimodelkan di sini) tetapi juga dampak perilaku petani dalam penggunaan air dan praktik irigasi, yang bukan merupakan bagian dari studi ini. Selain itu, hanya mengandalkan data anekdot dapat mengarah pada kesimpulan yang salah tentang perubahan kondisi pelepasan mata air yang disebabkan oleh perubahan hutan. Seperti disebutkan di atas, pembalakan liar, perambahan dan pendudukan mencapai puncaknya setelah jatuhnya rezim Suharto pada tahun 1998. Terlepas dari hilangnya tutupan hutan, variasi iklim dapat mempengaruhi persepsi penduduk tentang efek pembukaan hutan. Catatan curah hujan jangka panjang menunjukkan bahwa terdapat banyak variasi curah hujan selama musim kemarau di antara lokasi yang berbeda dan juga tahun-tahun menjelang tahun 1998 terjadi kemarau, terutama di sekitar kota Mataram dengan dataran rendah. Gambar 6 menunjukkan catatan curah hujan rata-rata dari enam stasiun cuaca di sekitar kota Mataram dan empat stasiun cuaca di dekat lokasi survei di sekitar Gunung Rinjani. Sangat mungkin bahwa penurunan debit mata air lebih terkait langsung dengan iklim daripada perubahan penggunaan lahan. Lebih lanjut, keberadaan mekanisme PES antara kota Mataram dan masyarakat di daerah hulu DAS mereka mungkin telah meningkatkan harapan masyarakat sekiatar hutan bahwa mereka mungkin dapat diberi kompensasi untuk mengelola hutan untuk jasa DAS yang mereka sediakan. Ini mungkin benar terutama untuk komunitas D yang mendapatkan pengakuan Hutan Kemasyarakatan dan hutan mereka merupakan DAS penting untuk kota lain (kota Praya).

WaterWorld V3.31 mensimulasikan dampak hutan versus penggunaan lahan

runoff generation (Bruijnzeel et al., 2011; Dietz et al., 2006, 2004). Some have argued that in contrast to other land use cover types, natural and recovered tropical rainforests throughout the world exhibit greater leaf litter, soil organic matter, and soil bioturbation by roots and fauna, as well as less soil surface sealing due to rainsplash, soil compaction by farm equipment, and impervious surface as part of infrastructure, all of which allow for enhanced infiltration and reduced soil erosion (Kumagai et al., 2009; Hairiah et al., 2006; Bruijnzeel, 2004; Calder, 2001; Mapa, 1995). The net result of enhanced infiltration beneath recovered forest can be greater groundwater recharge, which can lead to improved dry season baseflow (Dias et al., 2015; Ogden et al., 2013; Peña-Arancibia et al., 2012; Bruijnzeel et al., 2006; Bruijnzeel, 2004). Forests do tend to increase evapotranspiration substantially compared with rain-fed agriculture and even higher infiltration rates cannot compensate for less water being available for infiltration and runoff. However, this basic assumption may be problematic in a tropical setting where atmospheric moisture is abundant; low vapor pressure deficit may result in reforestation having a negligible effect on evapotranspiration (Brauman, 2012). Malmer et al. (2010) argued that the data to formulate hydrological effects of land use change in global models are often generated outside the tropics with stable soil conditions and there is "complete lack of research on how forestation on degraded land affect hydrological functioning at the landscape scale." Empirical longterm spring discharge measurement data are needed to compliment and refine global models based on globally available datasets, in order to accurately evaluate land management practices that enhance watershed services (Wohl et al., 2012; Jose, 2009; Locatelli and Vignola, 2009). What is clear from the above discussions is that there are number of factors that might affect the accuracy of both the global models and local opinions. Simply focusing on increasing tree covers can have negative impacts on watershed services and set up false expectations among local communities. For example, empirical studies in other seasonal dry tropics showed that reforestation with pine species in densely populated areas did little to increase soil hydraulic conductivities while increasing water uses of vegetation (compared to pasture) (Ghimire et al., 2013; Ghimire et al., 2014a,b). Another study showed that hydrological benefits of reforestation can be maximized by considering the rates of evapotranspiration of different tree species, as well as tree size, age and density in planning reforestation projects (Ilstedt et al., 2016). Thus, global PES schemes must consider further details within a land use class (e.g. species selection, tree density, soil management, and	lainnya pada dampak hidrologi berdasarkan data penginderaan jauh resolusi tinggi. Ini adalah model proses yang sangat rinci yang dikembangkan khusus untuk data lingkungan pegunungan dan tropis yang miskin. Namun, hasilnya tidak dapat divalidasi di lapangan tanpa data pengukuran debit pegas jangka panjang, dan bukannya tanpa batasan. Perubahan tutupan lahan dan struktur kanopi hutan memiliki efek kompleks pada masukan kabut, intersepsi curah hujan, aliran air, aliran batang, infiltrasi dan aliran permukaan (Bruijnzeel et al., 2011; Dietz et al., 2006, 2004). Beberapa orang berpendapat bahwa berbeda dengan jenis tutupan penggunaan lahan lainnya, hutan hujan tropis alami dan yang telah pulih di seluruh dunia menunjukkan lebih banyak serasah daun, bahan organik tanah, dan bioturbasi tanah oleh akar dan fauna, serta lebih sedikit penyegelan permukaan tanah karena percikan hujan, pemadatan tanah oleh peralatan pertanian, dan permukaan yang kedap air sebagai bagian dari infrastruktur, yang kesemuanya memungkinkan peningkatan infiltrasi dan pengurangan erosi tanah (Kumagai et al., 2009; Hairiah et al., 2006; Bruijnzeel, 2004; Calder, 2001; Mapa, 1995). Hasil bersih dari peningkatan infiltrasi di bawah hutan yang pulih dapat berupa imbuhan air tanah yang lebih besar, yang dapat mengarah pada peningkatan aliran dasar musim kemarau (Dias et al., 2015; Ogden et al., 2013; Peña-Arancibia et al., 2012; Bruijnzeel et al. ., 2006; Bruijnzeel, 2004). Hutan cenderung meningkatkan evapotranspirasi secara substansial dibandingkan dengan pertanian tadah hujan dan bahkan tingkat infiltrasi yang lebih tinggi tidak dapat mengimbangi ketersediaan air yang lebih sedikit untuk infiltrasi dan limpasan. Namun, asumsi dasar ini mungkin bermasalah di lingkungan tropis di mana kelembaban atmosfer melimpah; defisit tekanan uap rendah dapat menyebabkan reboisasi memiliki efek yang dapat diabaikan pada evapotranspirasi (Brauman, 2012). Malmer dkk. (2010) berpendapat bahwa data untuk merumuskan efek hidrologi dari perubahan penggunaan lahan dalam model global sering kali dihasilkan di luar daerah tropis dengan kondisi tanah yang stabil dan ada "penelitian yang kurang lengkap tentang bagaimana hutan di lahan terdegradasi mempengaruhi fungsi hidrologi pada skala lanskap." Data pengukuran debit mata air jangka panjang empiris diperlukan untuk melengkapi dan menyempurnakan model global berdasarkan kumpulan data yang tersedia secara global, untuk mengevaluasi secara akurat praktik pengelolaan lahan yang meningkatkan layanan DAS (Wohl et al., 2012; Jose, 2009; Locatelli dan Vignola, 2009) . Yang jelas dari pembahasan di atas adalah bahwa ada sejumlah faktor yang mungkin mempengaruhi akurasi model global dan opini lokal. Hanya dengan berfokus pada peningkatan tutupan pohon dapat berdampak negatif pada

landscape configurations) and measures to mitigate potential negative impacts.	layanan daerah aliran sungai dan menimbulkan ekspektasi yang keliru di antara masyarakat lokal. Sebagai contoh, studi empiris di daerah tropis kering musiman lainnya menunjukkan bahwa reboisasi dengan spesies pinus di daerah padat penduduk tidak banyak meningkatkan konduktivitas hidrolik tanah sambil meningkatkan penggunaan air untuk vegetasi (dibandingkan dengan padang rumput) (Ghimire et al., 2013; Ghimire et al. , 2014a, b). Studi lain menunjukkan bahwa manfaat hidrologi reboisasi dapat dimaksimalkan dengan mempertimbangkan laju evapotranspirasi berbagai jenis pohon, serta ukuran, umur dan kepadatan pohon dalam perencanaan proyek reboisasi (Ilstedt et al., 2016). Dengan demikian, skema PES global harus mempertimbangkan rincian lebih lanjut dalam kelas penggunaan lahan (misalnya pemilihan spesies, kerapatan pohon, pengelolaan tanah, dan konfigurasi lanskap) dan langkah-langkah untuk mengurangi potensi dampak negatif.

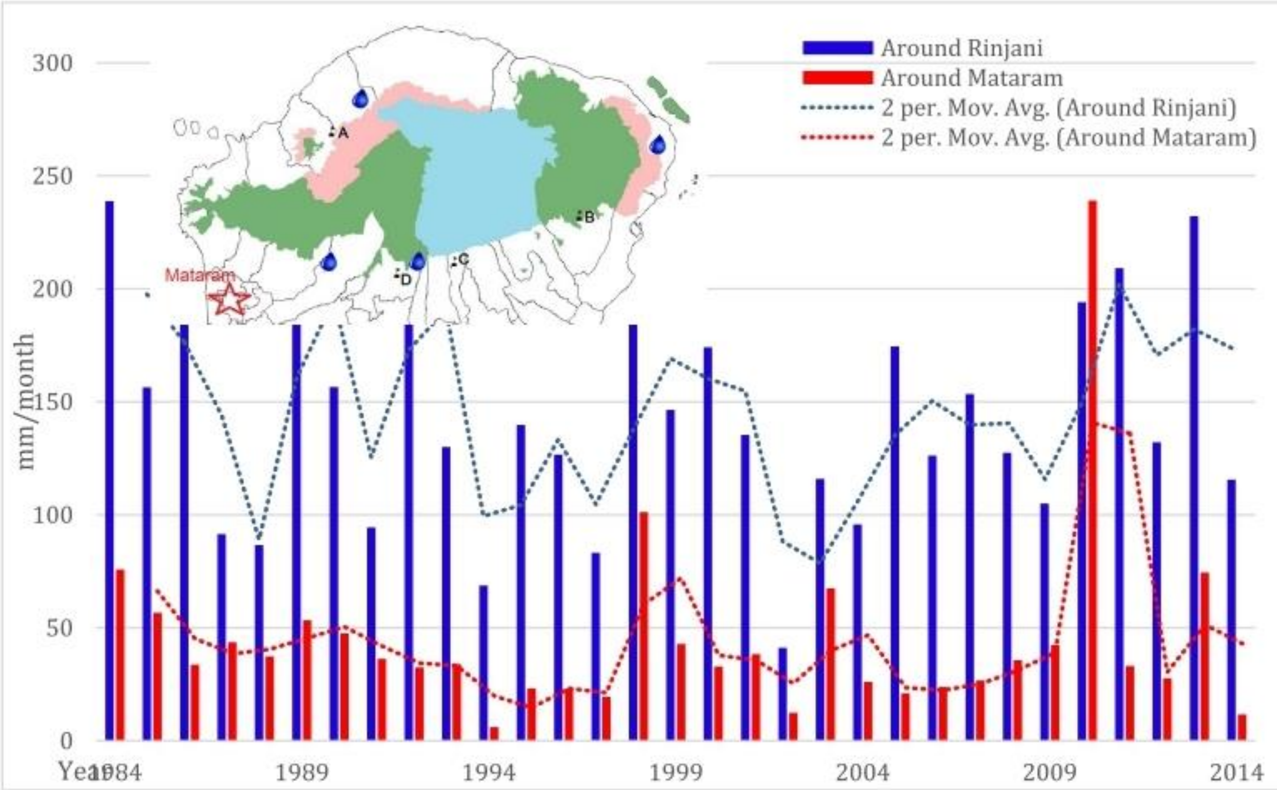

Fig. 6. Precipitation records from 1984 to 2014 during dry season: average precipitation from four weather stations near the survey sites around Rinjani Mt and average of six weather stations around the City of Mataram, Lombok, Indonesia (Source: Information Board of Water Resources Province of NTB, 2016).

5.3. Tradeoffs and synergies between global and local ecosystem services Globally, simply ending the land use, passive restoration, has been shown to be more cost-effective than active restoration (Meli et al., 2017). However, in a densely populated region with complex social dynamics, protection of forest as carbon stock would be costly and ineffective (Skutsch et al., 2011). In both land use change scenarios, there is potential for developing forest carbon projects in the study area. Although on-site opportunity costs were low, social and indirect costs can be substantial (White et al., 2010). Most of the global forest carbon projects are financed as input-based projects, which often set a flat-rate payment per hectare under a contractual agreement of inputs to increase carbon stock (e.g., not cutting trees, tree planting or other	**5.3. Pertukaran dan sinergi antara jasa ekosistem global dan lokal** Secara global, hanya dengan mengakhiri penggunaan lahan, restorasi pasif, telah terbukti lebih hemat biaya daripada restorasi aktif (Meli et al., 2017). Namun, di wilayah padat penduduk dengan dinamika sosial yang kompleks, perlindungan hutan sebagai stok karbon akan mahal dan tidak efektif (Skutsch et al., 2011). Dalam kedua skenario perubahan penggunaan lahan, terdapat potensi untuk mengembangkan proyek karbon hutan di wilayah studi. Meskipun biaya peluang rendah, biaya sosial dan tidak langsung dapat menjadi substansial (White et al., 2010). Sebagian besar proyek karbon hutan global dibiayai sebagai proyek berbasis input, yang seringkali menetapkan pembayaran tarif tetap per hektar di bawah kesepakatan kontrak input untuk

management activities) (Wunder, 2008; Skutsch et al., 2011). Input-based carbon projects allow the inputs (e.g. agreed management actions) to be negotiated between project proponents and local communities, which makes the projects less politically contentious and allows broader management goals to be addressed (Skutch et al., 2011). However, input-based projects would likely generate fewer carbon credits overall while making it difficult to trace carbon to project activities (Skutch et al., 2011). Lack of reporting on actual performance of existing projects, in terms of carbon sequestration, poses a serious problem for the future of global carbon financing (Fischer et al., 2016).

We previously advocated for an input-based mechanism with readiness activities for capacity building of both institutions and communities in the study area (Kim et al., 2016). The results of this study show that simply increasing tree cover is not enough for enhancing ES at all scales. Reforestation to increase carbon stock without considering the landscape as a whole can have negative impacts on watershed services (e.g. reduced runoff, and concentrated pollutants downstream from the remaining agricultural lands). In addition, implementing reforestation projects without consideration for local livelihoods can be detrimental to forest-margin communities. Thus the details of agreed-upon management actions would dictate the nature of association among different ESs.

Previous studies argued that global forest carbon projects are unlikely to succeed without addressing food, energy and water provisions at the local level (Minang and van Noordwijk, 2013; van Noorwijk et al., 2016). Indeed, the findings from our community study demonstrate that local people obtain a wide range of benefits from forests. Mixed agroforestry systems can be a key strategy for increasing the multi-functionality of land uses (Minang et al., 2014) as well as enhancing the diversity of local communities' livelihood options (Hoang et al., 2014). Potential values of agroforestry systems for integrating forests into a multifunctional landscape have been recognized, although the benefits may vary depending on practices and landscape configurations (Table 9; Dewi et al., 2013; Prabhu et al., 2015). Impacts of agroforestry systems on the landscape's ability to provide watershed services also vary depending on species selection of crops and shade trees and different cultivation practices employed (Condon et al., 2002; Thierfelder et al., 2009), as well as density of tree cover (Ilstedt et al., 2016). Different tropical tree species have shown a wide range of production rates per cost of water

meningkatkan stok karbon (misalnya, tidak menebang pohon, penanaman pohon atau kegiatan pengelolaan lainnya) (Wunder, 2008; Skutsch et al., 2011). Proyek karbon berbasis input memungkinkan masukan (misalnya tindakan pengelolaan yang disepakati) untuk dinegosiasikan antara pemrakarsa proyek dan masyarakat lokal, yang membuat proyek tidak terlalu menimbulkan perdebatan politik dan memungkinkan tujuan pengelolaan yang lebih luas untuk ditangani (Skutch et al., 2011). Namun, proyek berbasis input kemungkinan akan menghasilkan lebih sedikit kredit karbon secara keseluruhan sementara membuatnya sulit untuk melacak karbon ke kegiatan proyek (Skutch et al., 2011). Kurangnya pelaporan tentang kinerja aktual proyek yang ada, dalam hal penyerapan karbon, menimbulkan masalah serius bagi masa depan pendanaan karbon global (Fischer et al., 2016).

Kami sebelumnya mengadvokasi mekanisme berbasis input dengan kegiatan peningkatan kapasitas lembaga dan masyarakat di wilayah studi (Kim et al., 2016). Hasil studi ini menunjukkan bahwa peningkatan tutupan pohon saja tidak cukup untuk meningkatkan ES di semua skala. Reboisasi untuk meningkatkan stok karbon tanpa mempertimbangkan lanskap secara keseluruhan dapat berdampak negatif pada jasa DAS (misalnya berkurangnya limpasan, dan polutan terkonsentrasi di hilir dari lahan pertanian yang tersisa). Selain itu, melaksanakan proyek reboisasi tanpa mempertimbangkan penghidupan lokal dapat merugikan masyarakat sekitar hutan. Dengan demikian, rincian tindakan pengelolaan yang disepakati akan menentukan sifat asosiasi di antara ES yang berbeda.

Studi sebelumnya menyatakan bahwa proyek karbon hutan global tidak mungkin berhasil tanpa menangani penyediaan pangan, energi dan air di tingkat lokal (Minang dan van Noordwijk, 2013; van Noorwijk et al., 2016). Memang, temuan dari studi komunitas kami menunjukkan bahwa masyarakat lokal memperoleh berbagai manfaat dari hutan. Sistem agroforestri campuran dapat menjadi strategi kunci untuk meningkatkan multi-fungsi penggunaan lahan (Minang et al., 2014) serta meningkatkan keragaman pilihan mata pencaharian masyarakat lokal (Hoang et al., 2014). Nilai potensial sistem agroforestry untuk mengintegrasikan hutan ke dalam lanskap multifungsi telah diakui, meskipun manfaatnya dapat bervariasi tergantung pada praktik dan konfigurasi lanskap (Tabel 9; Dewi dkk., 2013; Prabhu dkk., 2015). Dampak sistem agroforestry pada kemampuan lanskap untuk menyediakan jasa DAS juga bervariasi tergantung pada penerapan pemilihan spesies tanaman dan pohon pelindung dan praktik budidaya yang berbeda (Condon et al., 2002;

loss by transpiration (Cernusak et al., 2007) and different root depths for promoting soil infiltration of rainfall (Ghestem et al., 2011). Local communities that we surveyed also recognized specific "watershed trees" e.g. Beringin (Ficus benjamina), where soils underneath were observed to be more moist, compared to other fast growing species, e.g. Sengon (Albizia chinensis). Also the amount of water needed to produce different agroforestry crops varies greatly. For example, coffee and cacao tend to have high water footprint (about 22,900 m3 /ton for coffee and 9414 m3 /ton for cacao), compared to other crops (e.g. 514 m3 /ton for cassava) (Bulsink et al., 2009). Thus it is essential for forest carbon projects to consider the effects of increasing tree covers, along with species, size, and age distribution, on a range of ESs in the landscape and mitigate potential negative impacts. van Noorwijk et al. (2016) discussed several metrics for developing mitigation actions through agroforestry that can enhance different watershed services, including water yield, water flow and water quality, while improving local livelihoods. The plausible actions that can be incorporated into forest carbon projects include replacing fast growing tree plantations with low-evapotranspiration species and increasing presence of deep rooted trees while promoting litter layers and agricultural practices that increase infiltration and soil water content, enhancing sediment filter strips in fields and across landscape matrix, as well as protecting river banks, riparian zones and landslide-prone slopes, springs and sources of domestic water use. It is clear from the community surveys that the value of forest ESs to local communities is significant but vary by locations. Although it is difficult to fully untangle the underlying reasons for this, these differences are reflective of different designated functions of forest, suitability of land for agroforestry, and the security of land tenure. Community partnership scenario focused on recovery of secondary forests through agroforestry to provide food, energy and livelihood options for local communities. However, the synergy among global, landscape and local ESs can be created only if the clear accountability can be established for maintaining the threshold of forest covers (for carbon accounting) with specific species selection and agroforestry practices to increase soil infiltration and water use efficiency (for watershed services). Although the Forest Restoration scenario adds recovery of primary forests, local communities may lack motivation for restoration activities for ecological benefits alone. Global PES, such as REDD+, can help establishing technical guidelines for agroforestry practices that maximize carbon and watershed benefits, as well as developing community monitoring schemes, while	Thierfelder et al., 2009), serta kerapatan tutupan pohon (Ilstedt et al., 2016). Spesies pohon tropis yang berbeda telah menunjukkan kisaran yang luas dari tingkat produksi per biaya kehilangan air oleh transpirasi (Cernusak et al., 2007) dan kedalaman akar yang berbeda untuk mendorong infiltrasi curah hujan di tanah (Ghestem et al., 2011). Komunitas lokal yang kami survei juga mengenali "pohon daerah aliran sungai" tertentu, misalnya Beringin (Ficus benjamina), dimana tanah di bawahnya diamati lebih lembab, dibandingkan dengan spesies lain yang cepat tumbuh, misalnya Sengon (Albizia chinensis). Jumlah air yang dibutuhkan untuk menghasilkan tanaman agroforestry yang berbeda juga sangat bervariasi. Misalnya, kopi dan kakao cenderung memiliki jejak air yang tinggi (sekitar 22.900 m3 / ton untuk kopi dan 9414 m3 / ton untuk kakao), dibandingkan dengan tanaman lain (misalnya 514 m3 / ton untuk singkong) (Bulsink et al., 2009) . Oleh karena itu, penting bagi proyek karbon hutan untuk mempertimbangkan efek dari peningkatan tutupan pohon, bersama dengan spesies, ukuran, dan distribusi umur, pada berbagai ES dalam lanskap dan mengurangi potensi dampak negatif. van Noorwijk dkk. (2016) membahas beberapa metrik untuk mengembangkan aksi mitigasi melalui agroforestry yang dapat meningkatkan berbagai layanan DAS, termasuk hasil air, aliran air dan kualitas air, sekaligus meningkatkan mata pencaharian lokal. Tindakan masuk akal yang dapat dimasukkan ke dalam proyek karbon hutan termasuk mengganti hutan tanaman cepat tumbuh dengan spesies penguapan rendah dan meningkatkan keberadaan pohon berakar dalam sambil mempromosikan lapisan serasah dan praktik pertanian yang meningkatkan infiltrasi dan kandungan air tanah, meningkatkan lapisan filter sedimen di ladang. dan melintasi matriks lanskap, serta melindungi tepi sungai, zona riparian dan lereng rawan longsor, mata air dan sumber penggunaan air rumah tangga. Jelas dari survei komunitas bahwa nilai ES hutan bagi komunitas lokal adalah signifikan tetapi berbeda di setiap lokasi. Meskipun sulit untuk sepenuhnya menguraikan alasan yang mendasari hal ini, perbedaan ini mencerminkan fungsi hutan yang berbeda, kesesuaian lahan untuk agroforestry, dan jaminan kepemilikan lahan. Skenario kemitraan masyarakat difokuskan pada pemulihan hutan sekunder melalui agroforestry untuk menyediakan pangan, energi dan pilihan penghidupan bagi masyarakat lokal. Namun, sinergi antara ES global, lanskap dan lokal dapat tercipta hanya jika akuntabilitas yang jelas dapat ditetapkan untuk menjaga ambang tutupan hutan (untuk penghitungan karbon) dengan pemilihan spesies tertentu dan praktik agroforestri untuk meningkatkan infiltrasi tanah dan efisiensi penggunaan air (untuk jasa DAS).

promoting ecological restoration of primary forest with added carbon values under Forest Restoration scenario.	Meskipun skenario Restorasi Hutan menambahkan pemulihan hutan primer, masyarakat lokal mungkin kurang termotivasi untuk melakukan kegiatan restorasi demi manfaat ekologis saja. PES global, seperti REDD+, dapat membantu menetapkan pedoman teknis untuk praktik agroforestry yang memaksimalkan manfaat karbon dan daerah aliran sungai, serta mengembangkan skema pemantauan masyarakat, sambil mempromosikan restorasi ekologis hutan primer dengan nilai karbon tambahan di bawah skenario Restorasi Hutan.
6. Conclusions In this paper, we assessed realistic forest management scenarios for reforestation in eastern Indonesia and their effects on both global and local ES provisions. We have demonstrated that reforestation to increase carbon, i.e. global, ex-situ, ecosystem services, can have varying impacts on those ESs recognized locally. In particular, our results point to the significance of water regulation, agroforest products, and non-timber forest products to local communities. To create a sustainable local solution, we need to go beyond the zero-sum argument of livelihoods versus conservation. We demonstrated how global PES, such as REDD+, and landscape level PES, such as payment for watershed services, can help create, not dictate, such solution through agroforestry that meets global, landscape and local demands for ESs.	**6. Kesimpulan** Dalam artikel ini, kami menilai skenario pengelolaan hutan yang realistis untuk reboisasi di Indonesia bagian timur dan pengaruhnya terhadap ketentuan ES global dan lokal. Kami telah menunjukkan bahwa reboisasi untuk meningkatkan karbon, yaitu jasa ekosistem global, *ex-situ*, dapat memiliki dampak yang berbeda-beda pada ES yang diakui secara lokal. Secara khusus, hasil kami menunjukkan pentingnya regulasi air, produk agroforestry, dan produk hutan non-kayu bagi masyarakat lokal. Untuk menciptakan solusi lokal yang berkelanjutan, kita perlu melampaui argumen *zero-sum* dari penghidupan versus konservasi. Kami mendemonstrasikan bagaimana PES global, seperti REDD+, dan PES tingkat lanskap, seperti pembayaran untuk jasa DAS, dapat membantu menciptakan, bukan mendikte, solusi semacam itu melalui agroforestry yang memenuhi tuntutan global, lanskap, dan lokal untuk ES.
Footnotes [1] Reducing Emissions from Deforestation and Forest Degradation (REDD+) is an effort to offer financial incentives for developing countries to reduce emissions from forested lands. REDD+ projects include activities for (a) reducing emissions from deforestation, (b) reducing emissions from forest degradation, (c) while recognizing the role of conservation of forest carbon stocks, (d), sustainable management of forests, and (e) enhancement of forest carbon stocks (UN-REDD programme, 2017). [2] Primary forest in this study is defined as mature or intact forest, where standing stock has reached stability. The forest is generally of native tree species, there are no clear indications of human activities, and the ecological processes are not significantly disturbed. Secondary forest is regenerated forest that has been disturbed by human activities or natural disasters. Secondary forest may include a natural forest with timber extraction, retaining artificial gaps in the canopy to 50–60%. This kind of forest includes agroforestry and community forests. Shrubland refers to	**Catatan kaki** [1] Pengurangan Emisi dari Deforestasi dan Degradasi Hutan (REDD+) merupakan upaya menawarkan insentif finansial bagi negara berkembang untuk mengurangi emisi dari lahan berhutan. Proyek REDD+ mencakup kegiatan untuk (a) mengurangi emisi dari deforestasi, (b) mengurangi emisi dari degradasi hutan, (c) sambil mengakui peran konservasi stok karbon hutan, (d), pengelolaan hutan berkelanjutan, dan (e) peningkatan cadangan karbon hutan (program UN-REDD, 2017). [2] Hutan primer dalam studi ini didefinisikan sebagai hutan dewasa atau hutan utuh yang tegakannya telah mencapai stabilitas. Hutan pada umumnya merupakan jenis pohon asli, tidak ada indikasi jelas adanya aktivitas manusia, dan proses ekologis tidak terganggu secara signifikan. Hutan sekunder merupakan hutan hasil regenerasi yang telah dijamah manusia atau bencana alam. Hutan sekunder dapat mencakup hutan alam dengan ekstraksi kayu, mempertahankan celah buatan di kanopi hingga 50–60%. Jenis hutan ini termasuk agroforestry dan hutan

land with woody vegetation where the dominant woody elements are shrubs, bushes and young generation trees, generally less than 5 m in height. The latter appears usually after forest clear-cutting activities without crop cultivation. (Source: Bae et al. (2014)). [3] For carbon stock change, Verified Carbon Standard (VCS) guidelines state that the REDD+-related projects should account for the following carbon pools: above-ground living biomass of trees and non-trees, and wood products if harvested timbers are utilized to make long-lived wood products. Measuring and monitoring other carbon pools, such as living below-ground biomass and dead organic matter, are optional or not required. [4] Indonesian Law Number 41/1999 distinguishes "forest" as an ecosystem dominated by trees and "forest area" defined as a particular area designated by the government. Thus, these administrative designations may not necessarily represent actual forest cover and particular forest conditions (Bae et al., 2014) [5] The government of Indonesia declared a plan to dramatically increase community control of forests from 1.4 million hectares in 2014 up to 12.7 million hectares by 2019 and is currently identifying the areas suitable for community forests (Indonesia National Planning & Development Agency, 2015). [6] Carbon credits from REDD+ projects are based on different forms of avoided emission from planned (i.e. legally authorized and documented for conversion) and unplanned deforestation, as well as forest degradation (i.e. canopy cover remaining above the threshold for definition of forest and no change in land use) [7] Forests in the NTB province includes 20% production forest, 48% protection forest and 32%conservation forest.	kemasyarakatan. Perkebunan semak mengacu pada tanah dengan vegetasi berkayu dimana elemen kayu yang dominan adalah semak, semak dan pohon generasi muda, umumnya tingginya kurang dari 5 m. Yang terakhir ini biasanya muncul setelah kegiatan penebangan hutan tanpa penanaman tanaman. (Sumber: Bae et al. (2014)). [3] Untuk perubahan stok karbon, pedoman *Verified Carbon Standard* (VCS) menyatakan bahwa proyek-proyek terkait REDD+ harus memperhitungkan sumber karbon berikut: biomassa pohon dan non-pohon hidup di atas tanah, dan produk kayu jika kayu yang dipanen digunakan untuk menghasilkan produk kayu hidup. Mengukur dan memantau sumber karbon lainnya, seperti biomassa hidup di bawah tanah dan bahan organik mati, bersifat opsional atau tidak diperlukan. [4] Undang-Undang Nomor 41/1999 membedakan "hutan" sebagai ekosistem yang didominasi oleh pepohonan dan "kawasan hutan" yang didefinisikan sebagai kawasan tertentu yang ditetapkan oleh pemerintah. Dengan demikian, penetapan administratif ini mungkin tidak selalu mewakili tutupan hutan aktual dan kondisi hutan tertentu (Bae et al., 2014) [5] Pemerintah Indonesia mengumumkan rencana untuk secara dramatis meningkatkan penguasaan masyarakat atas hutan dari 1,4 juta hektar pada tahun 2014 menjadi 12,7 juta hektar pada tahun 2019 dan saat ini sedang mengidentifikasi kawasan yang cocok untuk hutan kemasyarakatan (BAPPENAS, 2015). [6] Kredit karbon dari proyek-proyek REDD+ didasarkan pada berbagai bentuk emisi yang terhindarkan dari yang direncanakan (yaitu diizinkan secara hukum dan didokumentasikan untuk konversi) dan deforestasi yang tidak direncanakan, serta degradasi hutan (yaitu tutupan kanopi yang tersisa di atas ambang batas untuk definisi hutan dan tidak ada perubahan pada lahan. menggunakan) [7] Hutan di Provinsi NTB meliputi 20% hutan produksi, 48% hutan lindung dan 32% hutan konservasi.

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