BASELINE ASSESSMENT REPORT ECONOMIC DEVELOPMENT AND LAND USE

Strategic Environmental Assessment of the Hydropower Sector in Myanmar

IN PARTNERSHIP WITH:

2121 Pennsylvania Avenue, N.W.
Washington, D.C. 20433
Internet: www.ifc.org

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ACKNOWLEDGEMENTS

The Strategic Environmental Assessment (SEA) for the Hydropower Sector in Myanmar would not have been possible without the leadership of the Ministry of Natural Resources and Environmental Conservation (MONREC) and Ministry of Electricity and Energy (MOEE), with support from the Australian government. Myanmar government focal points for this study including Daw Thandar Hlaing, U Htoo Aung Zaw, U Nay Lin Soe and U Sein Aung Min played a critical role at all stages of the SEA process. U Hla Maung Thein, Daw Mi Khaing, U Tint Lwin Oo and Dr. San Oo guided the work of the SEA and focal points. These individuals provided technical inputs and facilitated working relations.

International Centre for Environmental Management (ICEM) and Myanmar Institute for Integrated Development (MIID) prepared the SEA with IFC. ICEM's technical team included Jeremy Carew-Reid, Rory Hunter, Edvard Baardsen, Jens Grue Sjørslev, John Sawdon, Kyaw Moe Aung, Lina Sein Myint, Lois Koehnken, Lwin Wai, Mai Ky Vinh, Peter-John Meynell, Rick Gregory, Stephen Gray, Vuong Thu Huong, Win Myint, Yan Min Aung, and Yinn Mar Swe Hlaing.

The IFC team guiding the SEA included Kate Lazarus, Pablo Cardinale, Matt Corbett, Naung San Lin and Tiffany Noeske. Vikram Kumar, IFC Country Manager for Myanmar provided valuable inputs. We also recognize the ongoing support of IFC's Environmental and Social Governance Department and Infrastructure Department, as well as the feedback and collaboration received from colleagues at The World Bank.

We are thankful for the generous support from the Australian Government including John Dore, Rachel Jolly, Nick Cumpston, Dominique Vigie, Tim Vistarini, Ounheun Saiyasith and Thipphavone Chanthapaseuth.

We are grateful to the dedicated civil society organizations, NGOs, SEA Advisory and Expert Groups, and the Hydropower Developers' Working Group for contributing to this study and working to advance sustainability in Myanmar's hydropower sector.

ABBREVIATIONS

AAC	Annual Allowable Cut
ADB	Asian Development Bank
AIIB	Asian Infrastructure Investment Bank
ASEAN	Association of Southeast Asian Nations
BAU	Business As Usual
CSO	Civil Society Orgnisation
ECA	Export Credit Agency
EG	Expert Technical Group
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GoM	Government of Myanmar
HP	Hydropwer
HPP	Hydropower Project
ICEM	International Centre for Environmental Management
IFC	International Finance Corporation
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
LNG	Liquiefied Natural Gas
LPG	Liquiefied Petroleum Gas
MEMP	Myanmar Energy Master Plan
MOALI	Ministry of Agriculture, Livestock and Irrigation
MOECAF	Ministry of Environmental Conservation and Forestry
NTFP	Non-Timber Forest Product
O&MO	Operation and Maintenance
PDR	People's Democratic Republic
PPA	Power Purchase Agreement
PPP	Purchasing Power Parity
R&D	Research and Development
SEA	Strategic Environmental Assessment
T&D	Transmission and Distribution
UN	United Nations
USDA	Unites States Department of Agriculture

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EXECUTIVE SUMMARY

Hydropower development in Myanmar has potentially wide-ranging impacts. Hydropower development in Myanmar is taking place in the context of sustained and rapid economic growth over approximately the last two decades. This has been driven predominantly by growth in the industrial sector, although growth in the agricultural and service sectors has also been important. Extractive and natural-resourced based industries have been an important component of this growth with natural gas, minerals and timber comprising the lion's share of exports.

The economics baseline develops a broad strategic picture of relevant economic sectors, highlights development and environmental issues, identifies interactions with hydropower development and potential cumulative impacts of hydropower and other economic development. Based upon consultations throughout potentially hydropower affected areas of the country, five economic sectors were identified as having important linkages with hydropower that the SEA should investigate, these were i) the Power sector; ii) Agriculture; iii) Forestry; iv) Mining; and, v)Transportation.

Power sector - Hydropower has significant direct economic benefits. It represents an important part of grid-based electricity generation, accounting for around 3.5 GW of installed capacity and 72% of grid-based electricity generation in 2014. The value of the electricity generated per year is best estimated in terms of the value of alternative supply of electricity, which would make the approximately 6,920 GWh generated by hydropower in 2014 worth USD 735 million.[1]

Agriculture - agriculture has expended relatively rapidly since the 1990s with significant increases in land under cultivation, irrigable area and cropping intensity. The use of agricultural inputs has also grown rapidly with increases in the use of agricultural chemicals and mechanisation in particular. These changes have led to significant increases in agricultural productivity over the last two decades. However, in recent years value-added growth in the sector has been low. Significant interactions between hydropower and agriculture include:

- Reduced nutrient transport;
- Reduced deltaic stability;
- Increased erosion downstream of HP plants;
- Unseasonal changes in water flow or availability;
- Loss of riverbank gardens associated with changes in flow regime and/or sedimentation;
- Loss of agricultural land in area inundated by HP plants with a reservoir;
- Loss of access to land in watershed protection area;
- Reduced flooding of plants managed for flood reduction;
- Increased water availability for irrigation if plants managed for multiple use;
- Improved electricity supply;
- Deforestation and knock-on consequences for other sectors (such as flooding, erosion and soil degradation) and biodiversity loss;
- Increased pollution from agricultural run-off compounding reservoir water-quality issues; and,
- Increased soil degradation, erosion and sedimentation caused by agricultural practices.

Forestry - forestry represents a relatively small and declining share of GDP. Although value-added has grown considerably since the early 2000s, in recent years production in the sector has declined, in part due to policies banning the export of raw timber. Illegally exported timber, not accounted for in official statistics, is typically smuggled across the border to China, remains important. The key development and environmental issue associated with the forest sector is deforestation and unsustainable use of timber resources. Important interactions with hydropower development were identified as:

- Clearance of forest from inundation areas and transmission line corridors;
- Deforestation through better access to forests, through road and other infrastructure, including during the plant construction period; and
- Increased watershed erosion due to deforestation and sedimentation in reservoir.

[1] Deloitte, 2015, Myanmar Power Sector Financial Analysis and Viability Action Plan Inception Report.

Mining - Myanmar's complex geology means it has potentially large and varied mineral resources throughout the country, many of these resources have yet to be thoroughly explored. Mining remains one of Myanmar's most important productive sectors. Although like forestry the sector is plagued by informal and illegal practices meaning actual levels of production from the sector are likely much higher than official figures suggest, especially in the Jade mining sector. Important interactions between the development of the sector and hydropower development include:

- Changes in river flow cause by hydropower development may alter accessibility of fluvial deposits;
- Any improvement in the availability of electricity for mining operations due to hydropower would benefit productivity in the sector;
- Access to mineral deposits in developed hydropower watersheds could be curtailed;
- Increases in watershed erosion, sedimentation and disposal of waste from mining affect the long-term productivity of downstream hydropower plants;
- Water pollution from mining may compound issues with and reservoir water quality; and
- Mining related land degradation due to deforestation may compound existing issues.

Transportation - this is included as a key sector for consideration in the SEA due to potential interactions between the development of the sector and hydropower and the potential for cumulative environmental impacts stemming from the transportation sector development and hydropower. Myanmar has the rapid expansion and upgrading of the national road network over the last decade. However, the road sector still suffers from underinvestment, many roads are poor quality and the lack of provision of all-weather rural roads. Interaction with hydropower development include:

- Flooding of roads in inundation area;
- Increased erosion, sediment generation and land-slide risk from road development may negatively affect downstream hydropower developments; and
- Deforestation and land degradation associated with roads may compound forest loss due to hydropower.

Myanmar has over 9,600 Km of navigable rivers. The most important navigable waterways are those of the Ayeyarwady, Chindwin and the network of waterways in the Ayeyarwady delta. Despite the potential of the physical network, navigation is often difficult along the main rivers because of shallow water during the dry season, shifting river channels and the lack of adequate terminal facilities. The sector has declined in relative importance due to the development of road transport, but in absolute terms the sector has seen moderate growth. Development of the sector is still stymied by ineffective planning and a lack of investment. Interactions with hydropower include:

- Increased dry season flows due to regulation by large upstream hydropower plants, improving navigability;
- Conversely unpredictable changes in water level due to hydropower operations may pose a hazard to navigation;
- Unpredictable changes in river morphology due to hydropower may reduce navigability; and
- Hydropower plans may block linear navigation routes in upstream areas of catchments.

1 HYDROPOWER AND THE ECONOMIC SECTORS

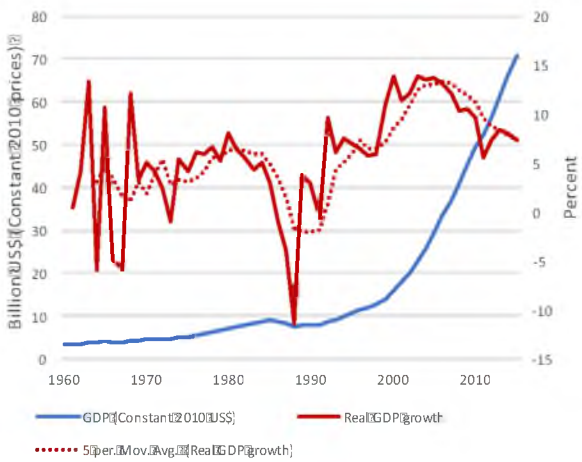
Hydropower development in Myanmar has potentially wide ranging impacts. Other sections of the SEA deal with the implications of hydropower development for bio-physical systems and communities. This section takes the first step in developing an investigation of the linkages between hydropower and the economy and the likely impacts of hydropower development on economic production.

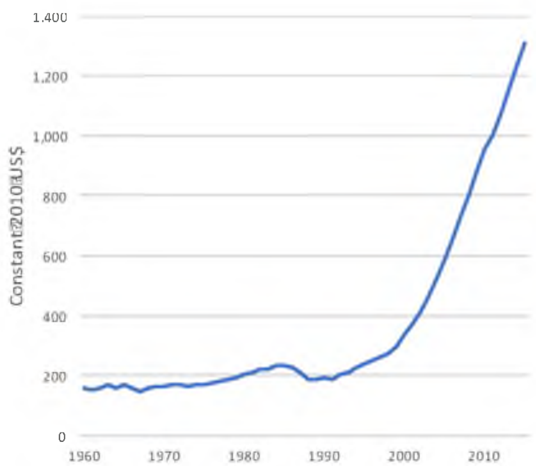
Following the SEA methodology, the economic sectors baseline seeks to develop a broad strategic picture of relevant economic sectors, highlight development and environmental issues, identify interactions with hydropower development and identify potential cumulative impacts of hydropower and other economic development. The first section of this report is a brief overview of the performance and structure of Myanmar's economy. This is followed by a summary of interactions between hydropower development and various economic sectors. This section also includes an identification of the most relevant economic sectors for consideration in the SEA. The rest of the report looks at the economic sectors in turn, namely section 2. Power; 3. Agriculture; 4. Forestry; 5. Mining; and, 6. Transportation (both road and navigation).

1.1 Myanmar's economic situation

Myanmar is entering a period of rapid and significant economic growth and structural change as it begins to develop a market economy. During the late 1990s and 2000s, Myanmar was the beneficiary of rapid growth in the broader region and the boom in demand for commodities as well as modest domestic reforms enabling some private sector development. This trend has continued into the 2010s as political and continuing economic liberalisation has enabled increased trade and foreign investment.[2] Between 2000-2010 average real economic growth ran at approximately 12% and between 2010-2015 about 8% (Figure 1.1). Similarly, growth in gross domestic product (GDP) per capita took off in the mid-1990s after a long period of stagnation. In 2015, per capita GDP stood at approximately USD 1,310 in constant 2010 prices or USD 4,930 at PPP[3] (constant 2011 USD).[4]

Figure 1.1: Real GDP growth (left) and GDP per capita (right) 1960 - 2015





Source: World Bank, 2017, World Development Indicators Database

That growth has been accompanied by rapid structural changes in the economy. As is typical of the growth pattern in developing Asia, over the last 10-15 years, growth has been driven largely by the

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[2] IMF, 2015

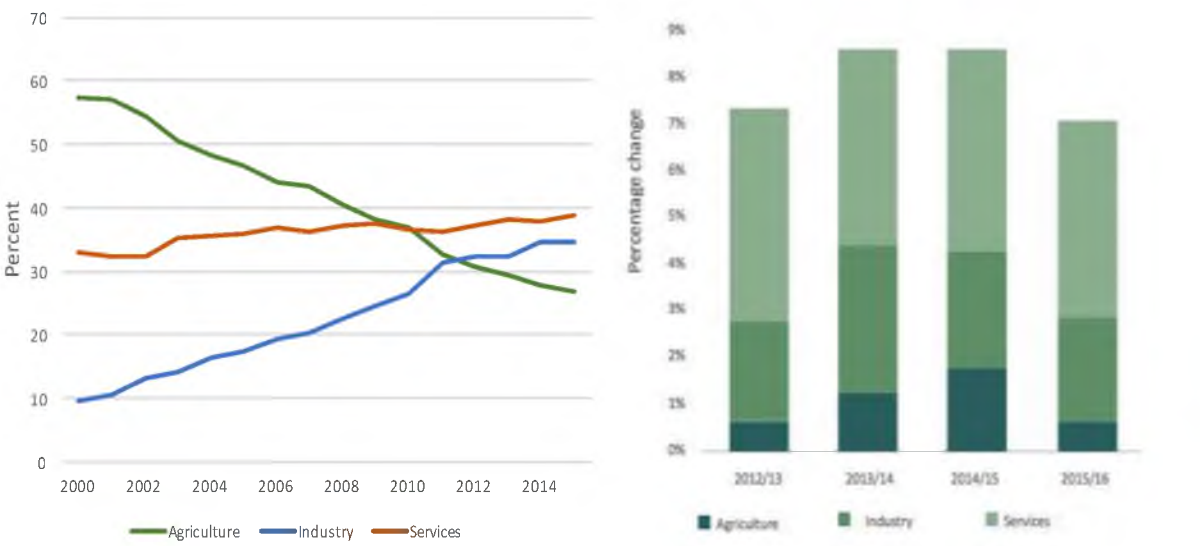
[3] There are two ways to measure GDP (total income of a country) of different countries and comparing them. One way, called GDP at exchange rate, is when the currencies of all countries are converted into USD. The second way is GDP (PPP) or GDP at Purchasing Power Parity (PPP). PPP compares different countries' currencies through a market "basket of goods" approach. According to this concept, two currencies are in equilibrium or at par when a market basket of goods is priced the same in both countries (taking into account the exchange rate).

[4] This compares to 2015 figures of USD 1,020 in Cambodia, USD 6,498 in China, USD 1,531 in Lao People's Democratic Republic (PDR), USD 3,834 in Indonesia, USD 2,640 in the Philippines, USD 5,775 Thailand and USD 1,685 in Vietnam.

industrial and services sectors, with growth rates of 21.4% and 12.5% respectively for 2000-2001 and 2014-2015 (Table 1.1). This industry/services driven growth contrasts with the broad agriculture sector which has seen much lower levels of growth in value added over the same period. Until 2010-2011, agriculture sector growth was around 9.6%. Since 2010 growth has stagnated (see discussion below).[5]

Agriculture's share of GDP has steadily declined from around 57% of GDP in 2000 to around 27% of GDP by 2015, whereas the shares attributable to the industrial and service sectors have increased (Figure 1.2 and Table 1.1).

Figure 1.2: Major sector share of GDP (left) GDP growth by sector contribution 2012/2013-2015/2016 (right)



Source: World Bank, 2017, World Development Indicators Database (left), World Bank, 2016, Myanmar Economic Monitor 2016 (right)

A privatisation and liberalisation process is underway and the government is actively promoting foreign investment in all sectors of the economy. Nevertheless, Myanmar remains a fragile state still emerging from over six decades of conflict and economic mismanagement. There remains a long way to go as state economic enterprises still dominate many traditional sectors of the economy (particularly in resource extraction and utilisation). The economy is plagued by a weak and underdeveloped legislative framework, poor institutions and limited governance capacity at the central and sub-national level and by endemic corruption. Indeed the World Bank's Doing-Business 2017 report ranks the country at 170 out of 190 countries, which ranks as the worst performance in Association of Southeast Asian Nations (ASEAN), alongside countries such as Afghanistan and Iraq.[6] Similarly, Transparency International's Corruption Perception Index ranks Myanmar 136 out of 176 countries.[7] These regulatory and institutional weaknesses are critical particularly in the natural resources sectors.

Table 1.1: Real value added by sector 2000/2001-2014/2015 (Billion Kyat, constant 2010 prices)

Sectors	GDP (Billion Kyat, constant 2010 prices)	AAGR	Trend

[5] Statistical data, particularly agricultural and socio-economic indicators are notoriously poor. Ware and Clarke for example note "Accurate statistical data for Myanmar is lacking, and what is available is of questionable validity. This is the result of several factors including the government having limited control over parts of the territory, limited resources for data gathering and analysis, and data being manipulated for internal and external consumption." (Ware, A. and Clark, M. 2009. Consequences of Sanctions: Are the MDGs Relevant in Myanmar? Paper presented at the MDG Update Conference, ACFID and La Trobe University, Melbourne, 30th November 2009.). See also Haggblade et al., 2013, A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar. Consultancy report for USAID Burma.

[6] World Bank, 2016, Doing-Business 2017. Economy Profile Myanmar. Retrieved from http://www.doingbusiness.org/~/media/wbg/doingbusiness/documents/profiles/country/mmr.pdf.

[7] Transparency International, 2016, Corruption Perceptions Index 2016. Retrieved from http://www.transparency.org/news/feature/corruption_perceptions_index_2016

	2000-2001	2005-2006	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2000/2001-2004/2005	
Agriculture	**5,884**	**10,974**	**14,659**	**13,649**	**13,790**	**14,436**	**14,761**	**6.3**	
Agriculture	5,016	9,027	11,108	10,079	9,982	10,377	10,412	5.0	
Livestock & Fishery	811	1,800	3,392	3,409	3,642	3,903	4,237	11.7	
Forestry	58	147	158	160	167	156	112	4.5	
Industry	**996**	**4,116**	**10,528**	**13,143**	**14,594**	**15,818**	**18,232**	**21.4**	
Energy	19	38	67	2,033	2,415	2,460	3,245	40.6	
Mining	41	133	299	426	368	461	634	20.0	
Processing & Manufacturing	737	3,009	7,900	8,283	9,058	9,735	10,550	19.4	
Electric Power	14	53	422	437	541	586	748	30.5	
Construction	185	883	1,839	1,964	2,213	2,576	3,055	20.5	
Services	**3,400**	**8,415**	**14,590**	**15,209**	**16,696**	**18,626**	**19,934**	**12.5**	
Transportation	589	2,455	4,595	4,999	5,376	5,836	6,073	16.8	
Communications	28	247	332	365	533	770	988	26.7	
Financial Institutions	11	20	38	59	75	96	110	16.8	
Social & Administrative Services	158	215	916	897	1,166	1,418	1,638	16.8	
Rental & Other services	141	376	738	801	964	1,115	1,243	15.6	
Trade	2,471	5,103	7,971	8,089	8,583	9,389	9,882	9.7	
Total GDP	**10,280**	**23,505**	**39,777**	**42,001**	**45,081**	**48,880**	**52,927**	**11.5**	

Source: Department of Planning 2016. World Bank, 2017, World Development Indicators Database (Note: GDP growth figures based upon Government of Myanmar (GoM) figures differ slightly from World Bank figures)

As is often the case with developing countries, Myanmar is running an increasingly significant current account deficit (Figure 1.3, left). This is not uncommon for an economy which is newly liberalising, but it can place national finances under strain and presents the question of how to finance the needed investment. The deficit has been exasperated in recent years due to falling demand for the commodities that still dominate Myanmar's exports (Figure 1.3, right), resulting in falling export prices and volumes. This serves to emphasise the continuing importance of the role played by natural resource sectors.[8]

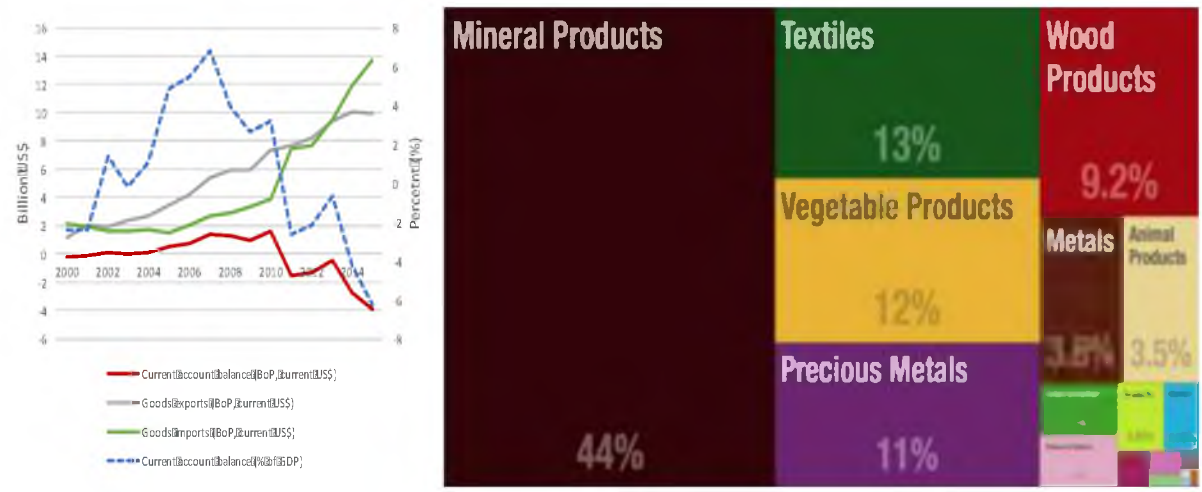
It should be borne in mind that the available official figures for exports reported here do not take into account the large illicit trade in precious stones (notably jade, see section on the mining sector below), narcotics (see section on the agricultural sector) and timber (see section on forestry sector), which are all reputedly significant export earners.

1.2 The relationship between hydropower development and economic development

As part of the SEA process the implications of hydropower development for other sectors are considered. Hydropower development can have important implications for development and long-term productivity of other economic sectors and sub-sectors. Similarly, there may be important impacts from the conduct of economic activities to the development and long term productivity of the hydropower sector. These interactions are often if not always realised through the changes to bio-physical systems they cause. Finally, together with hydropower the conduct of economic activities can contribute to broader, cumulative, changes to bio-physical systems. Part of the SEA is to understand these interactions at the strategic level.

Figure 1.3: Trade and current account balance 2000-2015 (left), composition of exports by category share 2014 (right)

[8] World Bank, 2016, Myanmar Economic Monitor, May 2016.



Source: World Bank, 2017, World Development Indicators Database (left), Simoes A., 2017, The Observatory of Economic Complexity[9]

Hydropower constitutes an important part of the electricity generation with around 3.5 GW of installed capacity accounting for 72% of grid-based electricity generation in 2014. From this perspective hydropower clearly provides an essential service to the national economy and is critical for future economic development. The value of the electricity generated per year is best estimated in terms of the value of alternative supply of electricity. In the case of Myanmar this would be gas fired generation at around 10.6 USc/KWh, which would make the approximately 6,920 GWh generated by hydropower in 2014 worth USD 735 million.[10] No figures on investment in the sector have been available. However, based upon the assumption that each MW of hydropower capacity costs around USD 2 million, the additional 2.3 GW of capacity installed between 2000-2001 and 2013-2014 imply an investment of around USD 4.6 billion or around USD 350 million per year.

Table 1.2 summarises the possible interactions between hydropower and the major economic sectors. These pathways have been identified through stakeholder consultations led by the SEA team with CSOs, government (national and sub-national), the private sector, international organisations and local communities in in Myanmar, inputs from expert technical groups (EGs), reviews of literature on hydropower in the region and globally and the experience of the project team. Details of the consultations which were held in the Thanlwin, Sittaung, Chindwin and Tanintharyi river basins, and were attended by a diverse range of stakeholders, are included in a separate report *Regional River Basin Consultations - Key Findings*. It should be noted that at this stage a very broad view was taken of potential economic development issues and their interaction with hydropower to ensure in-so-far-as-was-possible, all viewpoints were considered.

[9]Website. Retrieved from http://atlas.media.mit.edu/en/visualize/tree_map/hs92/export/mmr/all/show/2014/ on 28 February 2017.
[10]Deloitte, 2015, Myanmar Power Sector Financial Analysis and Viability Action Plan Inception Report.

Table 1.2: Potential interactions between hydropower and main economic activities

Sector	Potential strategic impacts		
	Potential for hydropower impact (i.e. affecting productivity of sector)	Potential for impact on hydropower (i.e. affecting productivity of hydropower)	Potential for cumulative environmental impact from activities in sector and hydropwer
1. Agriculture	• Reduced nutrient transport • Reduced flooding • Increased water availability for irrigation • Loss of land in inundation area/watershed protection area • Reduced sediment load to delta - reduced deltaic accretion • Loss of riverbank gardens (due to changes in flow regime) • Higher dry season flows reducing saline intrusion in river deltas • Availability of more reliable, cheaper grid based electricity	• Land clearance for agriculture in upstream watershed leading to increased erosion and sedimentation in hydropower reservoir • Loss of power production from management for multiple use • Reservoir water quality affected by agricultural run-off (sewage, fertilizers and pesticides)	• Land clearance and deforestation, land degradation (and known impacts on biodiversity, sedimentation etc.)
2. Fisheries	• Loss of migratory fish species • Loss of nutrients downstream leading to reduction in fisheries (freshwater and marine) • Increased potential for reservoir fisheries/aquaculture	N/A	N/A
3. Forestry	• Loss of forest in inundation area • Loss of forest in zone of influence around hydropwer plants • Loss of forest due to additional land clearance for agriculture to compensate losses in inundation areas and riverbank gardens	• Land clearance for agriculture in upstream watershed leading to increased erosion and sedimentation in hydropower reservoir • Logging and forest clearance in watershed causing increased sedimentation	• Land clearance and deforestation, land degradation (and known impacts on biodiversity, sedimentation etc.)
4. Mining	• Loss of access to mineral resources in inundation areas • Loss of easy access to gold bearing sediments on riverbanks due to changes in flow regimes • Availability of more reliable, cheaper grid-based electricity	• Mining activities upstream of hydropower plants may cause increased reservoir sedimentation • Mining activities upstream and uncontrolled emissions of pollutants may affect reservoir water quality and	• Land clearance and deforestation, land degradation (and known impacts on biodiversity, sedimentation etc.) • Influx of workers into forested areas putting pressure on NTFPs and fisheries • Public health issues and widespread

		lead to accumulation of toxins in reservoir sediments	drug use
5. Manufacturing	• Availability of more reliable, cheaper grid-based electricity	N/A	N/A
6. Tourism	• Availability of more reliable, grid-based electricity • Loss of tourism assets (cultural, historical, ecological) • Creation of tourism locations (reservoirs and dams) • Better access for tourism from access roads	N/A	N/A
7. Other services	• N/A	N/A	N/A
8. Transportation	• Inundation of roads in impoundment area • Increased erosion around bridges and other instream transportation infrastructure downstream • Barrier to navigation • Improved dry season navigation through changes in flow regime • Unpredictable variation in flow regime presents barrier for cross-river transport • Reduced riverine flooding and flood damage	• Improved transportation infrastructure from development of access roads • Loss of power production from management for multiple use	• Land clearance and deforestation, land degradation (and known impacts on biodiversity, sedimentation etc.)
9. Other infrastructure	• Increased erosion around instream infrastructure downstream • Reduced riverine flooding and flood damage	• Loss of power production from management for multiple use	• N/A

Based on the information from the regional river basin consultations through November and December 2016 and the baseline assessment workshops in January 2017 a scoring exercise was undertaken by the SEA team to focus on the areas of interaction between the sectors most important for economic development objectives. Table 1.3 gives the results of this scoring exercise and summarises a ranking of the potential significance of links between existing hydropower and other economic activities.

Table 1.3: Ranking the potential significance for interactions between existing hydropower and economic activities for the SEA

Sector	Sensitivity			Exposure (extent of potential impacts)[2]	Overall significance for HP development[3]
	Potential for HP impact[1]	Potential for impact on HP[1]	Potential for cumulative environmental impact[1]		
Agriculture	3	2	3	3	**24**
Fisheries	3	0	3	3	**18**
Forestry	3	2	3	3	**24**
Mining	2	2	3	2	**14**
Manufacturing	2	0	0	3	6
Tourism	2	0	0	1	2
Other services	0	0	0	0	0
Transportation	2	2	3	3	**21**
Other infrastructure	1	1	2	2	8

The scores were calculated as follows:

(i) The figures in the three sensitivity columns are scored from 0-3 depending on an assessment of the potential sensitivity of the sector to impacts from/to hydropower and potential cumulative impacts;

(ii) The figures in the exposure column score the potential extent of the impact for the sector (i.e. the scope of the impact) again giving a number from 0-3;

(iii) The final column gives the overall significance of the interactions between hydropower and the economic sector for economic development and the environment. It is calculated by adding the first three columns and multiplying the result by the fourth column, this gives a score between 0-27.

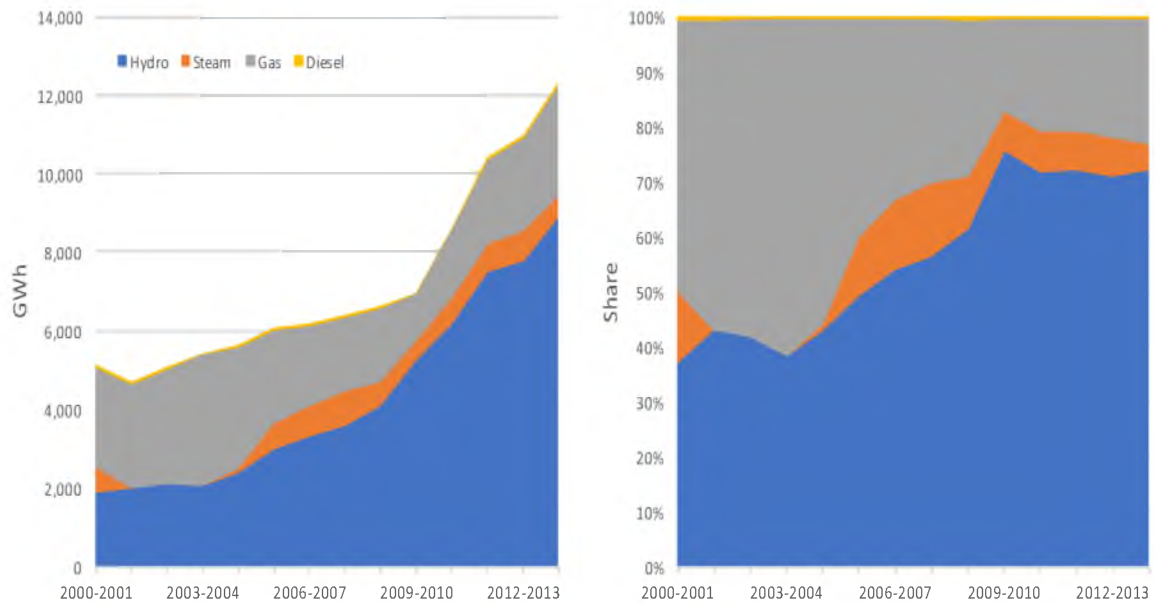
2 ENERGY

2.1 Power sector baseline

2.1.1 Power capacity and generation

Gross electricity generation has more than doubled over the last 13 years, from 5,118 GWh in 2000 - 2001 to about 12,278 GWh in 2013-2014, equivalent to an average annual growth rate of 6.5% (Figure 2.1). Around 97% of this increase in production has come from the expansion of hydropower. Its share of generation has increased over the same period from 37% in 2000-2001 to about 72% in 2013-2014. The remainder is made up largely of gas fired generation which has expanded from 2,500 GWh (49% of production) in 2000-2001 to around 2,800 GWh (23% of production) in 2013-2014.

Figure 2.1: Electricity production by generation technology 2000-2001 to 2013-2014



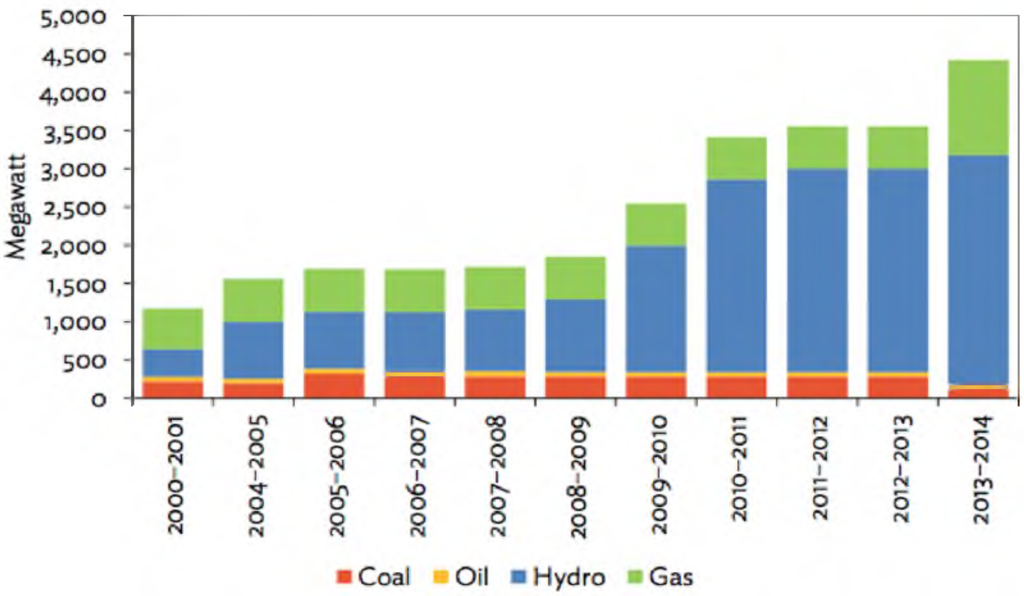
Source: NEMC, ADB, IES and MMIC, 2015, Myanmar Energy Master Plan 2016 to 2030

This pattern of increasing dominance of hydropower in the energy sector is reflected in the growth of installed capacity (Figure 2.2). Between 2000-2001 and 2013-2014 capacity additions have been dominated by FDI in hydropower, accounting for 2.3GW of new capacity. This includes the commissioning of several large hydropower projects including Paunglaung (280 MW) in 2005, Shweli (600 MW) in 2008, Yeywa (790 MW) in 2010 and Tapein (240 MW) in 2011. That growth compares to about 50 MW of new gas capacity and the 120 MW Tigyit coal plant commissioned up until 2013.[11] Investment in gas has since increased substantially with the commissioning of around 650 MW between 2013 and 2016. In 2015/2016 installed capacity stood at 5,235 MW.[12]

Figure 2.2: Installed capacity by generation technology 2000-2001 to 2013-2014

[11] Kee-Yung Nam,K.Y., Cham, M., and Halili, P.R., 2015, Power Sector Development in Myanmar. ADB Economics Working Paper Series. No. 460.

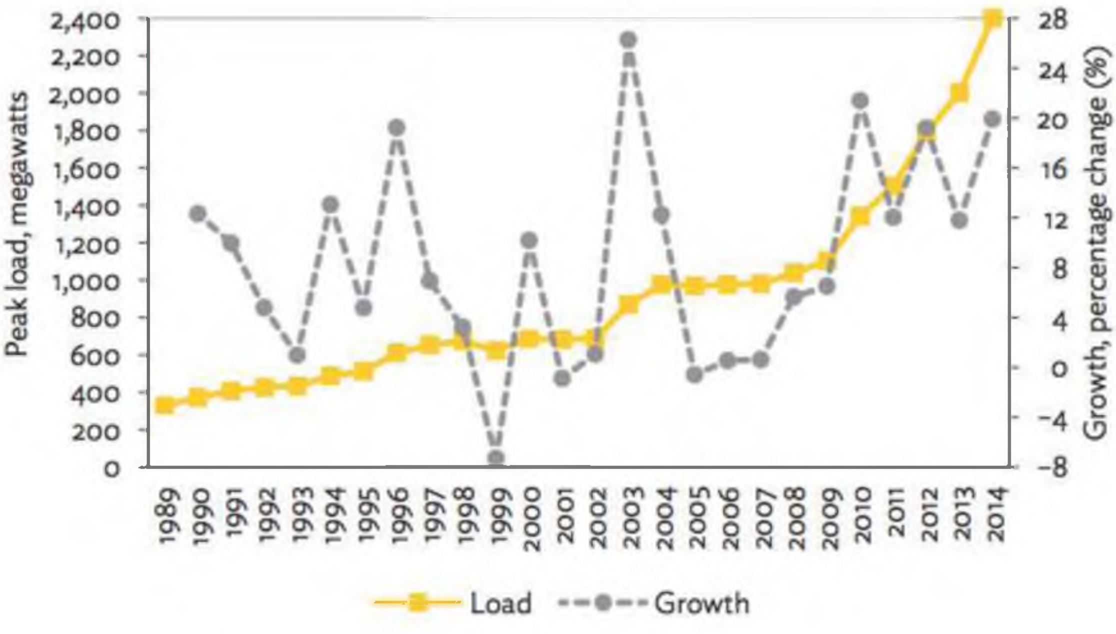
[12] Oxford Business Group, 2017, Myanmar 2017.



Source: Kee-Yung Nam,K.Y., Cham, M., and Halili, P.R., 2015, Power Sector Development in Myanmar. ADB Economics Working Paper Series. No. 460.

Peak load grew at around 6.5% between 2000-2008, growth accelerated between 2009-2014 to about 15% a year. Peak load in 2014 was an estimated 2,400 MW (Figure 2.3). Although peak load in 2013-2014 was only a little over half installed capacity of around 4.5 GW, electricity supplies have been dogged by load shedding and black-outs.[13,14]

Figure 2.3: Peak load growth 1989-2014



Source: Kee-Yung Nam,K.Y., Cham, M., and Halili, P.R., 2015, Power Sector Development in Myanmar. ADB Economics Working Paper Series. No. 460.

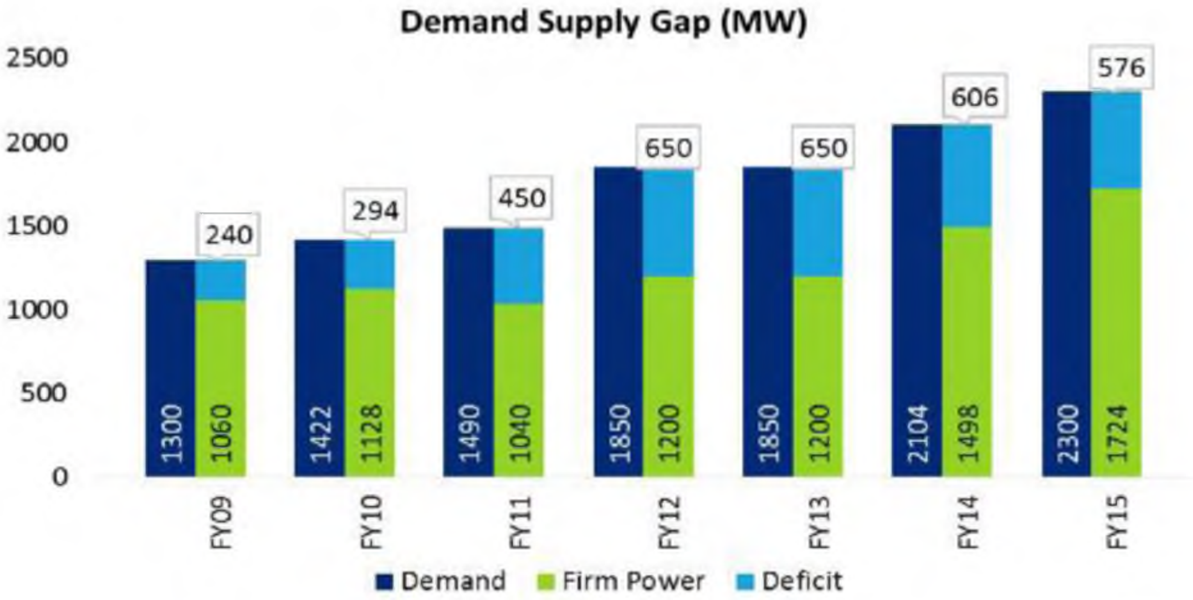
Figure 2.4 shows the demand supply gap over the last six years, at about a third in 2012 and 2013. The large and persistent gap between peak demand and firm power is due to the rapid growth in

[13] According to a recent World Bank report, due to load shedding "realised peak" was only around 2.1 GW. See World Bank, 2016, Electrifying Myanmar: Challenges and opportunities planning nation-wide access to electricity. Washington D.C.

[14] Posner-Ross, R., 2015, Myanmar's Path to Electrification. The Role of Distributed Energy Systems. Centre for Strategic and International Studies.

power demand over the last decade, the cumulative impact of delays in power sector infrastructure investment and an over-reliance on seasonally available hydropower. Low reliability, load shedding and blackouts remain a problem despite the recent additions in hydropower and gas capacity.[15]

Figure 2.4: Demand supply gap 2009 - 2015



Source: Deloitte, 2015, Myanmar Power Sector Financial Analysis and Viability Action Plan Inception Report. Consultancy Report for Myanmar Electric Power Enterprise.

Apart from shortfalls in generation capacity (from breakdowns and the seasonality of hydropower) underinvestment in transmission and distribution (T&D) infrastructure has led to large-scale transmission and distribution losses.[16] T&D losses have decreased from around 30% in 2000-2001 to around 20% in 2012-2014. Nevertheless these are still very high at around 2.4 TWh per year, of which around 70% take place in the distribution network, and the remainder on the transmission network.[17]

2.1.2 Power consumption

Following more than a decade of rapid growth, on-grid power consumption in 2013-2014 stood at around 9.6 TWh, almost three times the consumption in 2000-2001 of 3.3 TWh, growing at an average of 8.7% a year between 2000-2001 and 2013-2014. This growth has accelerated significantly between 2009-2010 and 2013-2014 to a rate of 13.6% (Figure 2.1).[18] Despite the rapid growth in consumption, grid-based electricity consumption at around 160 KWh/capita, around 5% of the world average in 2013-2014 remains low by international and regional standards.[19]

Moreover, those figures probably underestimate consumption. Firstly, some portion of T&D losses is likely to be due to non-technical losses (available data does not distinguish between technical and non-technical losses). Secondly, supply from isolated sources is likely to be significant. Micro and localized grids are common in rural areas, and in urban areas and at industrial facilities back-up generators are ubiquitous.[20] The World Bank estimates that 22% of households have access to off-

[15] World Bank, 2016, Electrifying Myanmar: Challenges and opportunities planning nation-wide access to electricity. Washington D.C.

[16] Posner-Ross, R., 2015, Myanmar's Path to Electrification. The Role of Distributed Energy Systems. Centre for Strategic and International Studies.

[17] NEMC, 2014, National Energy Policy.

[18] NEMC, ADB, IES and MMIC, 2015, Myanmar Energy Master Plan (MEMP).

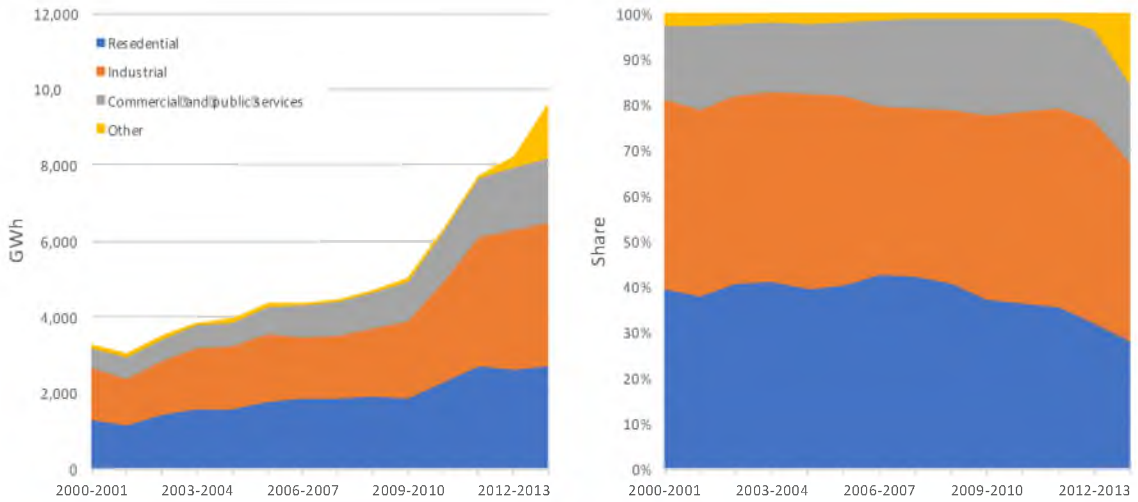
[19] World Bank, 2016, Electrifying Myanmar: Challenges and opportunities planning nation-wide access to electricity. Washington D.C.

[20] Figures from 2013 suggest that there was approximately 116 MW of off-grid or "isolated" capacity, of which 78 MW is diesel (see Win, U.T., 2015, Opportunities and Barriers of Power Development in Myanmar. Presentation). This seems an underestimate, as based upon a typical household generator rating of 20 kVA, this would mean there was only approximately 4,900 gensets in the country - this is low compared to estimates for Cambodia.

grid, high-cost, low-reliability electricity supply.[21] There are no figures on the number of back-up generators in the country.

All sectors have seen a rapid growth in the consumption of grid-based electricity. In 2012-2013 MEMP estimates final consumption by sector as 44% for the industrial sector, 32% for the residential sector and 20% for the commercial sector.[22] Consumption in all three sectors has grown rapidly over the last decade, although growth in industrial consumption accounts for the lion's share of consumption growth, followed by the residential sector and the commercial sector (Figure 2.5).

Figure 2.5: Electricity consumption by sector 2000-2001 to 2013-2014



Source: NEMC, ADB, IES and MMIC, 2015, Myanmar Energy Master Plan.

Given low levels of electrification and the reliance on isolated supply for off-grid supply and for grid-back-up, a considerable portion of demand for modern energy services is unmet through grid-based provision.

2.1.3 Exports

In recent years Myanmar has become a significant exporter of energy to China and Thailand. Off-shore natural gas fields (Shwe, Yadana and Yetagun in the Andaman Sea) are the most important official source of export revenues for the country, accounting for USD 3.71 billion in 2014-2015.[23] Most of this gas currently goes to Thailand (1.1 billion cu.ft) and China (300-400 million cu.ft), with the remainder (300-350 million cu.ft) being used domestically.[24] To develop its gas and oil resources Myanmar has relied upon production sharing contracts. As Myanmar shifts from the predominant pre-reform focus of generating foreign exchange earnings, to one of using domestic energy resources to support its own development, arrangements will have to allow for better serving domestic energy needs.[25]

Electricity exports from hydropower plants in Myanmar have also been developed over the last decade. Currently, Myanmar has capacity to export 520 MW to China. This consists of 221 MW from the Dapein 1 project and 300 MW from Shweli 1 (i.e. half of the six 100 MW units). Dapein 1 makes 8% of the capacity available to the Myanmar grid at no cost, and provides a royalty of 15% of revenues. Shweli 1 provides 50% of its capacity to the grid at no cost and pays a royalty of 10% of revenues.[26] This means that of the total installed hydropower capacity of about 3,150 MW, 2,630 MW

[21] World Bank, 2016, Electrifying Myanmar: Challenges and opportunities planning nation-wide access to electricity. Washington D.C.

[22] These figures do not account for the "other" category which remains unexplained.

[23] Kee-Yung Nam,K.Y., Cham, M., and Halili, P.R., 2015, Power Sector Development in Myamar. ADB Economics Working Paper Series. No. 460.

[24] Oxford Business Group, 2017, Myanmar 2017.

[25] Ibid.

[26] Deloitte, 2015, Myanmar Power Sector Financial Analysis and Viability Action Plan Inception Report. Consultancy Report for Myanmar Electric Power Enterprise.

serves domestic demand. More detail on the contents of these concessions or the Power Purchase Agreements (PPAs) for these projects have not been available.

2.1.4 Drivers of demand growth

Growth in demand for electricity is associated with rapid economic growth. In the commercial and industrial sectors expansion of production leads to greater demand. In particular, growth in more energy intensive sectors such as manufacturing has led to increased electricity demand. This is illustrated in Figure 2.5 by the increased share of industry in electricity consumption. Second, while the overall number of households connected to the national grid remains low it is increasing quickly. In 2010-2011 only 25% of households had a grid connection, by 2015-2016 the figure had increased to around 34% of households. This represents a growth in household connections of around 296,000 per year.[27] At the same time income growth and increased household consumption is increasing the demand for energy services and electricity per household (as ownership of air conditioners, refrigerators and other household goods increases). This has driven the rapid expansion of electricity demand in the residential sector.

Overall Myanmar is not only seeing increasing electricity demand due to general expansion of the economy, but, also an increase in the intensity of electricity use - in 2010 GDP per kWh was around USD 7.6 (2010 constant prices). In real terms this figure has shrunk to USD 5.2 by 2015 - representing an increase in electricity intensity of around 30%.[28]

2.1.5 Determinants of generation mix

Hydropower has accounted for most capacity additions over the last decade (Section 2.1.1 and Figure 2.2). This is due to the availability of good hydropower resources in Myanmar and the relatively low cost of hydropower. Domestic coal resources are limited and of low quality sub-bitumous coal or lignite (see section on mining). To date only the plant at Tigyit (120 MW) is in operation and this has been reportedly subject to technical problems.[29] Myanmar has significant gas reserves, but these have been developed by foreign companies and most current gas production is subject to long-term supply agreements with Thailand and China. Recent capacity additions through Independent Power Producer (IPP) plants and rental units have led to a significant increase in gas capacity. Thus far renewables have made little headway beyond the provision of off-grid electricity.

While immediate availability of resources has determined technology development, cost remains of utmost importance.

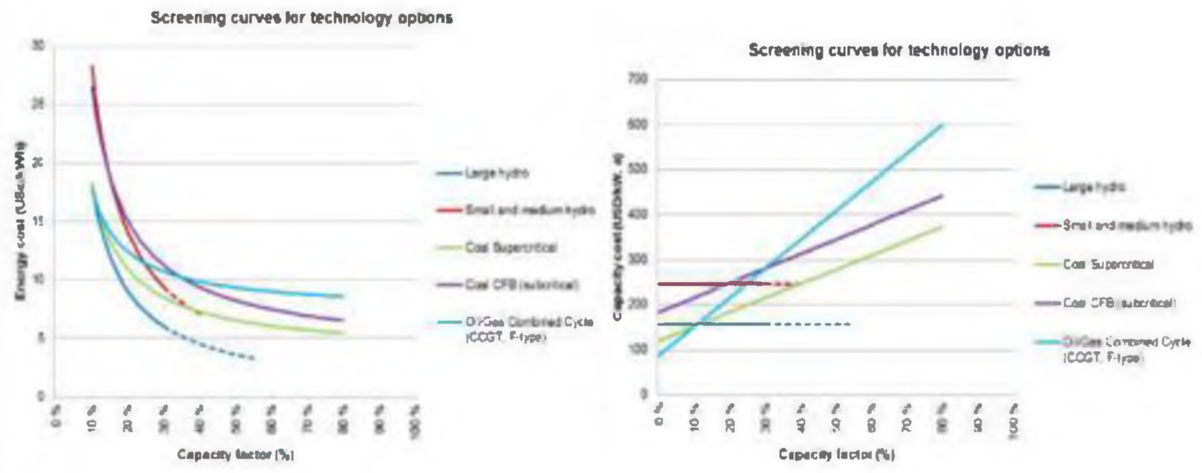
Figure 2.6 compares the basic cost characteristics of different technologies. In terms of both capacity cost and energy cost large hydropower has a clear cost advantage. For higher capacity factors small and medium scale hydropower also performs better than technologies other than supercritical coal. This explains the preference for hydropower in the generation mix.

[27] Wang, X., and Win, M., 2016, Myanmar: Towards Universal Access to Electricity by 2030. Presentation for ESMAP/World Bank. Bangkok, 21 June 2016.

[28] Based upon WDI GDP figures and MoEE power demand figures.

[29] Oxford Business Group, 2017, Myanmar 2017.

Figure 2.6: Comparing energy and capacity costs for generation technologies



Source: NEMC, ADB, IES and MMIC, 2015, Myanmar Energy Master Plan

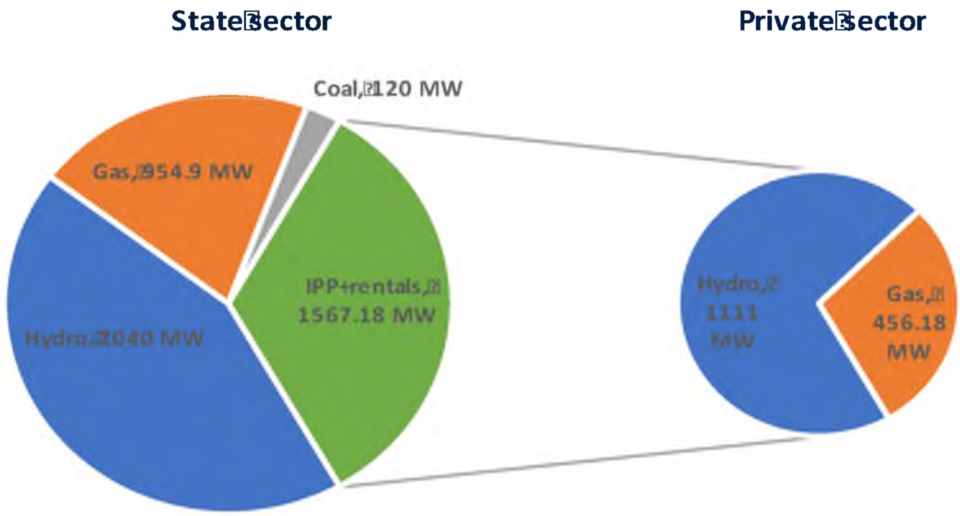
2.1.6 Financing power sector development

Myanmar's power sector is financially constrained. End-user tariffs fall below the long term marginal cost of supply, as a consequence the sector requires a subsidy of around USD 136 million per year.[30] Unless a more price reflective tariff is adopted the need for subsidies will only increase with increased electricity consumption. Subsidies put a strain on government finances, discourage potential energy efficiency investment and discourage private sector investors who are sensitive to the financial sustainability of the sector. What is more, given high demand growth in the sector there is an acute need for significantly expanded generation and T&D investment (see section 2). Investment needs for 2014-2030 were estimated to range between USD 15.2 billion and USD 29.6 billion[31], equivalent to between USD 0.95-1.85 billion per year or 1.5-3.0% of GDP in 2015.

Figure 2.7: Installed capacity by generation type and ownership 2015

[30] Kee-Yung Nam,K.Y., Cham, M., and Halili, P.R., 2015, Power Sector Development in Myamar. ADB Economics Working Paper Series. No. 460.

[31] Ibid. More recent estimates by some commentators suggest investment needs of up to US$37.5 billion between 2016 - 2030 (Oxford Business Group, 2017, Myanmar 2017.)



Source: Deloitte, 2015, Myanmar Power Sector Financial Analysis and Viability Action Plan Inception Report. Consultancy Report for Myanmar Electric Power Enterprise.

Much of the new investment in the power sector will have to come from the private sector (most of it FDI) with support from international donors. Indeed, a large increase in private sector involvement in the power sector indicate this trend is already apparent. While much of the capacity installed prior to 2010 was built and owned by the state (although more recently with support from Export Credit Agencies (ECAs) and bilateral donors), subsequently most investment have been led by the private sector, both foreign and domestic.[32] Figure 2.7 gives a breakdown of current capacity by fuel type and technology.

Although the investment climate may be challenging for some investors, there has been a significant increase in unsolicited private sector investment proposals in recent years. For gas-based plants this amounts to around 4,000 MW of capacity, for small and medium hydropower plants around 25,000 MW, and plans for around 20,000 MW of large (above 1,000 MW capacity), export oriented hydropower projects (with some capacity reserved for domestic use).[33]

2.2 Business As Usual (BAU) projection

2.2.1 Power demand

An official plan for power sector development has yet to be adopted. As noted by a recent study of the sector there have been a number of attempts by donors such as the United Nations (UN), World Bank, Asian Development Bank (ADB) and Japan International Cooperation Agency (JICA) to develop an acceptable sector plan, however at this stage the government has not adopted a coherent vision for the sector.[34] At the time of writing JICA is conducting a two-year technical assistance project to develop a comprehensive energy sector operations plan. Here we draw on recent available planning documents to determine key trends in the likely development of the sector to 2030.

Figure 2.8 gives medium demand projections for energy and peak load, suggesting the need to expand generation by around 440 MW per year between 2015-2030. In terms of increase in power consumption per capita this represents an increase from around 200 kWh/capita to 800 kWh/capita by 2030.[35] It should be noted these represent the medium demand growth scenario, projections of demand range between 41 TWh to 80.4 TWh and projections of peak load between 6,843 MW and 13,410 MW by 2030.[36]

[32] Deloitte, 2015, Myanmar Power Sector Financial Analysis and Viability Action Plan Inception Report. Consultancy Report for Myanmar Electric Power Enterprise.

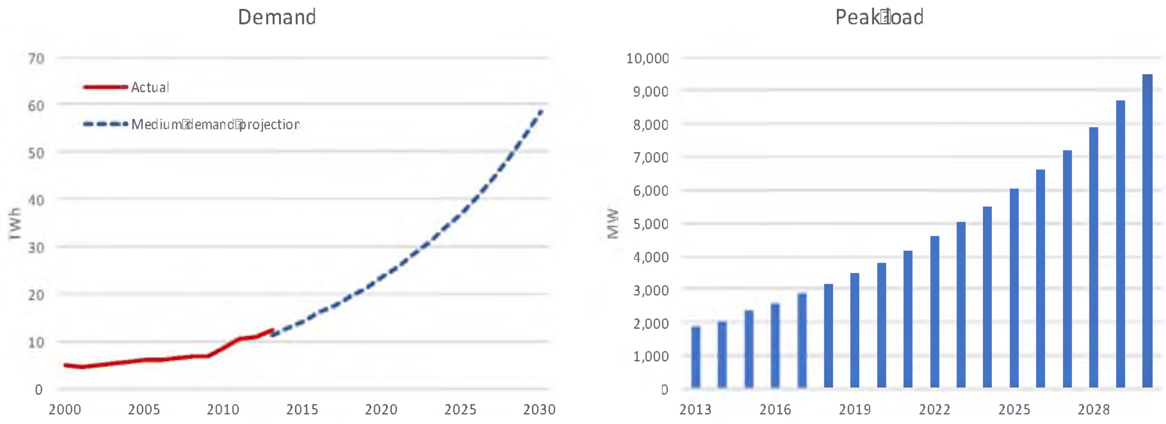
[33] Deloitte, 2015, Myanmar Power Sector Financial Analysis and Viability Action Plan Inception Report. Consultancy Report for Myanmar Electric Power Enterprise.

[34] Oxford Business Group, 2017, Myanmar 2017.

[35] NEMC, ADB, IES and MMIC, 2015, Myanmar Energy Master Plan

[36] Ibid.

Figure 2.8: Medium demand and peak load projections for Myanmar



Source: ADICA, 2015, National Power Expansion Plan

2.2.2 Projected generation mix

The generation mix for future power sector development is a particular point of contention in the plans for the sector. Coal was expected to play a major role in the sector but objections to coal plants have forced a rethink, with more recent planning documents emphasising the potential role of imported Liquiefied Petroleum Gas (LPG). Key considerations in determining the generation mix are as follows:

- **Coal** - cheap and relatively easy to build. As such coal was slated to provide around 7,940 MW of capacity. As domestic coal resources are limited in quality and quantity most of this capacity was expected to use imported coal. However, ambitions for coal have been reduced. Most international donors are reluctant to fund coal fired power plants (with the exceptions of Aisan Infrastructure Investment Bank (AIIB) and JICA), and local communities where coal plants were to be situated have been hostile. Although some foreign investors from Thailand and Indonesia still have an interest in pursuing investments in coal plants in Myanmar.[37]
- **Hydropower** - Likely to see a fall in its share of generation capacity and share of output. While cheap and available, seasonality, and social and environmental impacts remain a significant concern.
- **Gas** - Natural gas is more expensive than coal and available domestic supplies will not be sufficient to meet power generation needs, especially in the case where the share of coal is not increased. Imported Liquiefied Natural Gas (LNG) has been mooted as a potentially attractive option, if suitable facilities for storage and regasification can be developed. Moreover, LNG and natural gas generation units may be more attractive to private sector investors due to the lower environmental and construction risks, and the relatively short construction time needed[38].
- **Renewables** - Considerable potential for wind and especially solar in Myanmar. Currently around 670 MW of utility-scale solar is in the development pipeline, as well as a significant number of small scale micro-grid projects. Wind also has significant potential with 3,708 MW identified in feasibility studies in Chin, Rakhine, Ayeyarwady and Yangon.

Overall the process remains developer driven. While the government has solicited bids for a small number of energy and electricity related projects, the majority of projects in the development pipeline have been unsolicited. This pattern is typical of the region.

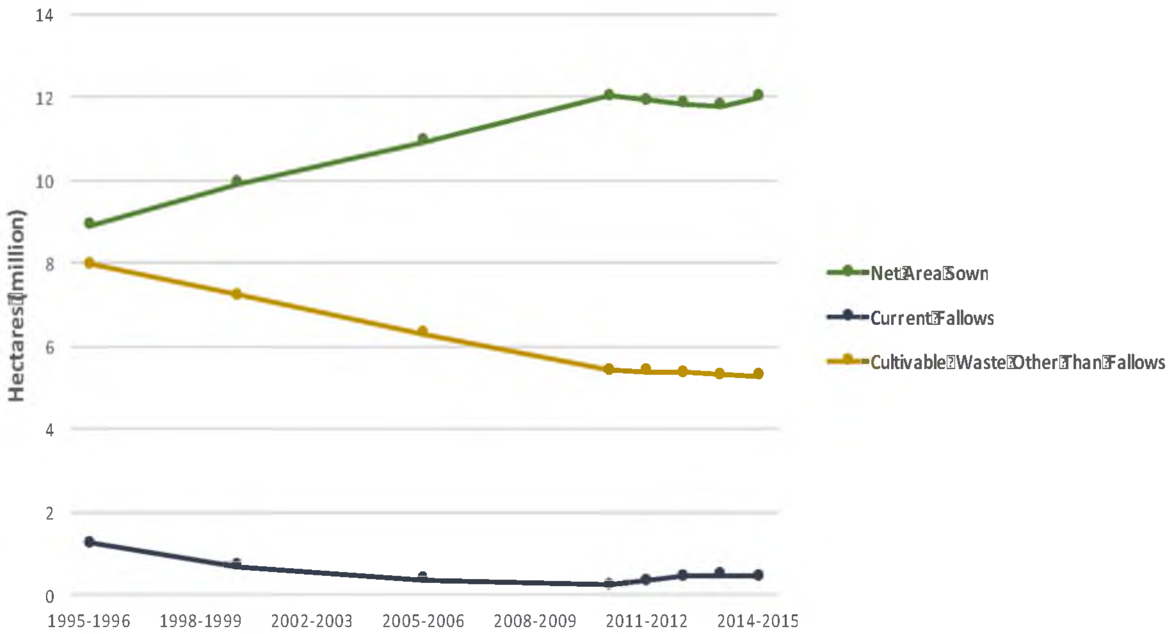
[37] Oxford Business Group, 2017, Myanmar 2017.
[38] Ibid.

3 AGRICULTURE

3.1 Resources

Myanmar is endowed with significant agricultural resource potential. In 2014-2015, of Myanmar's total land area of 67.7 million ha, around 12 million ha was cultivated, and a further 5.7 million ha which could be brought into agricultural production (consisting of 440,000 ha of fallow land and 5.27 million ha of cultivable wasteland) (Figure 3.1).[39] This suggests potential for additional expansion of agricultural land. Most of the remaining uncultivated areas are in the less populous regions of Chin, Kachin and Shan states.[40] The average landholding size in Myanmar at around 2.6 ha, is significantly larger than other countries in the region, reflecting the relative abundance of suitable agricultural land.[41]

Figure 3.1: Change in cultivable area 1995-1996 to 2014-2015



Source: Department of Agriculture and land Management Statistics, 2016

Myanmar has a diverse topography, geology and climate enabling the cultivation of a wide range of crops including cereals, pulses, horticultural production and fruits, as well as livestock.[42] The broad rainfall zones and soil types are indicated in Figure 3.2. For the purposes of this analysis, these can be further aggregated into **three main agro-ecological regions**. The **delta and coastal zone**, the **dry zone** and the **hill regions**, are each characterised by different types of agricultural systems.[43]

Delta and coastal zone - The densely populated deltaic (Ayeyarwady, Sittaung and Thanlwin deltas) and coastal regions have plentiful monsoonal rainfall, and good access to water, with alluvial and swampy soils. These areas are dominated by rice cultivation and aquaculture.

Dry Zone - The Dry Zone has significantly lower rainfall. Lying in the rain shadow of the upland areas to its west, this area has a semi-arid climate and long dry season. Population and agriculture in these areas are concentrated in the alluvial lowlands, along river valleys that offer access to water. Agricultural practices concentrate on rain-fed crops, and where water availability allows summer and monsoon rice.

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[39] Department of Agriculture and land Management Statistics, 2016

[40] Raitzer, D., Wong, L.C.Y., and Samson, J.N.G., 2015, Myanmar's Agriculture Sector: Unlocking The Potential For Inclusive Growth ADB Economics Working Paper Series No.470

[41] Ibid.

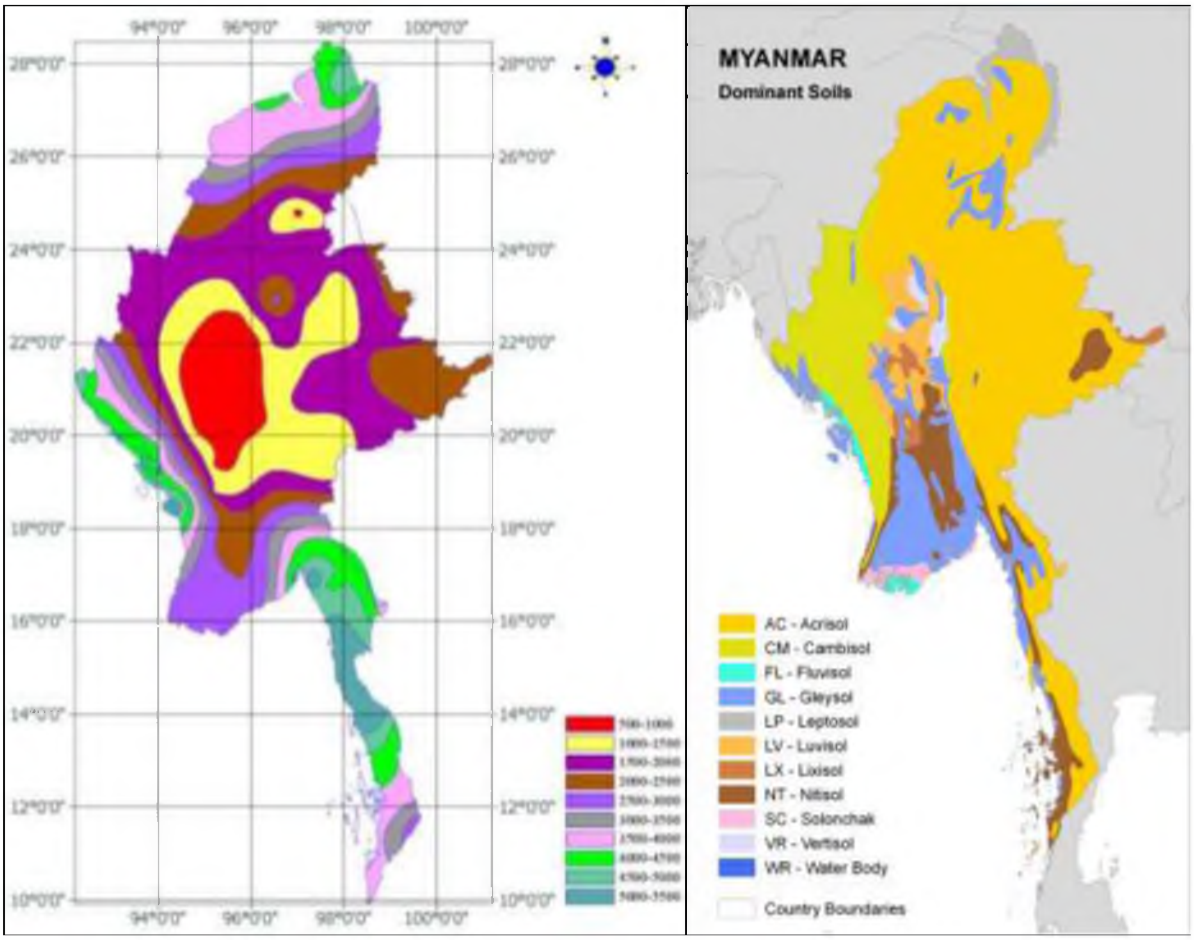
[42] Haggable, S., 2013, A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar. Report prepared for USAID Burma.

[43] Ibid.

Hill regions - The large hill regions have more temperate climates. They receive greater levels of rainfall than the Dry Zone. These regions in the main are still covered by forest. The Shan plateau in the east has significant area cleared of forest for agricultural purposes. Here the more temperate climate allows the cultivation of a wide range of mainly rainfed crops including fruit and other tree crops, vegetables and other horticultural products, as well as rice, maize and pulses. Upland areas are also home to swidden and other long-term fallow systems. Large upland areas in the east and west have degraded forest areas affected by shifting cultivation.

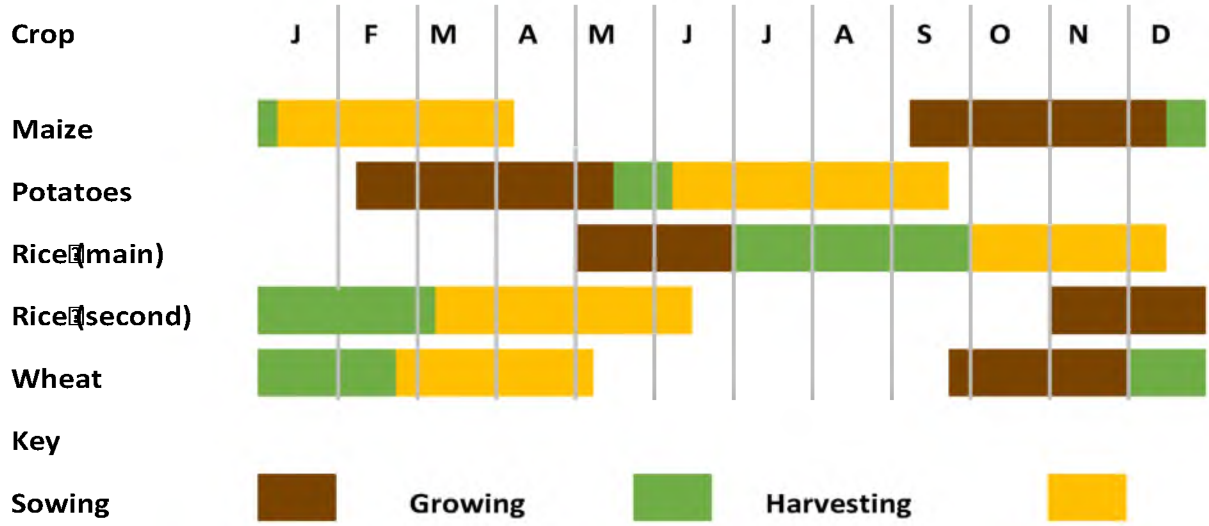
Myanmar has three seasons, giving still greater variation to cropping patterns (Figure 3.3). Most agricultural activity takes place during the monsoon which typically runs from May to October for most of the country. The following cool winter season runs until February when the weather starts to become warmer, this summer season typically lasts until the end of April. Agricultural production varies significantly depending on season and agro-ecological zone.

Figure 3.2: Myanmar's annual average rainfall by zone (mm) (left) and dominant soil types (right)



Source: FAO 2012

Figure 3.3: Crop calendar for main food crops



Source: Based on FAO and WFP, 2016, Special Report. FAO/WFP Crop and Food Security Assessment Mission to Myanmar

Myanmar also has the benefit of ample freshwater supplies, from significant groundwater resources and four major river systems - the Ayeyarwady-Chindwin, Thanlwin and Sittaung. Unlike other countries in the region it has the additional advantage that most of the catchments of its largest rivers lie within the country's territorial control. Myanmar's total renewable water resources amount to approximately 1,167,800 million m^3 $year^{-1}$.[44] Of this withdrawals only account for around 10%, and of this around 90% is used for irrigation (Figure 3.4). Most water use is from surface water, but some estimates suggest that there are substantial groundwater resources available in the Ayeyarwady River Basin.[45] Overall, renewable water resources per capita are amongst the largest in the region.[46]

Nevertheless, water availability presents a key constraint for agriculture because availability varies greatly between different locations (Figure 3.2) and between the seasons. Around 80% of water flows during the monsoon, with the remainder available during the dry winter and summer seasons. Seasonal water scarcity is particularly acute in Rakhine State and the central Dry Zone.[47]

Over the last 35 years the government has expanded the provision of irrigation considerably. Most of the expansion has been through the provision of dams (in some cases for both irrigation and hydropower), reservoirs and pumps. Estimates of current irrigation lie at around 16-20% of total sown area (Figure 3.4). Figures on irrigable area may also be misleading, for example, whereas around 25-30% of monsoon rice receives supplemental irrigation, the figure for dry season rice falls to 15%. Moreover, there is some evidence that only a small proportion of irrigation infrastructure is in use in areas such as the Dry Zone.

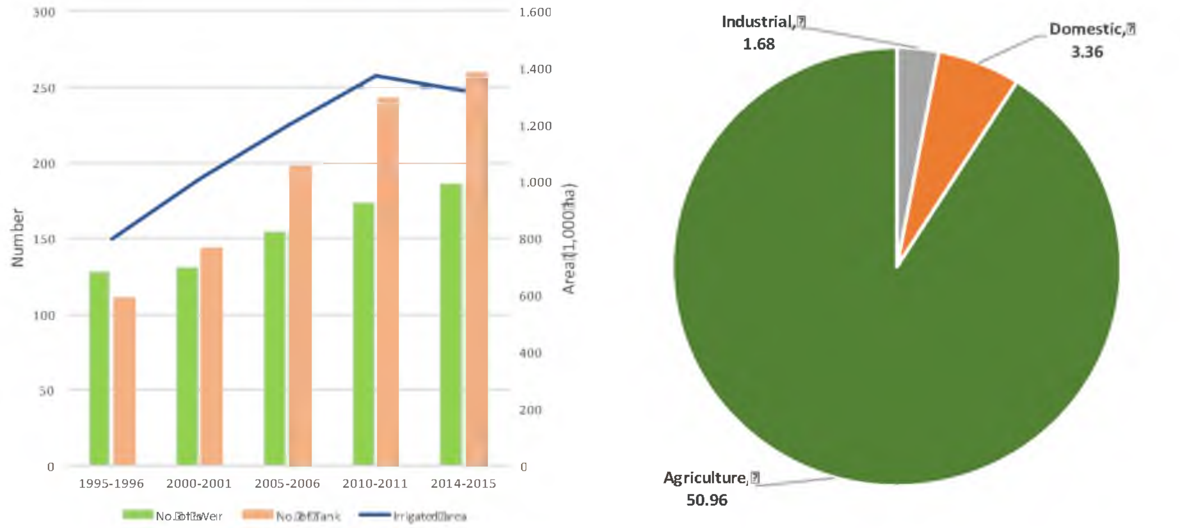
Figure 3.4: Irrigation infrastructure and irrigable area 1995 - 2015 (left) and annual water usage by sector (Km3) 2013 (right)

[44] FAO, 2011, Irrigation in Southern and Eastern Asia in Figures 2011. AQUASTAT.

[45] Len Drury – *The Group Water Resources of the Ayeyarwady Basin*, forthcoming report 2017; Naing M.M., 2005, Paddy field irrigation systems in Myanmar. *ftp://ftp.fao.org/docrep/fao/010/ai408e/ai408e01.pdf*

[46] Haggable, S., 2013, A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar. Report prepared for USAID Burma.

[47] Ibid.

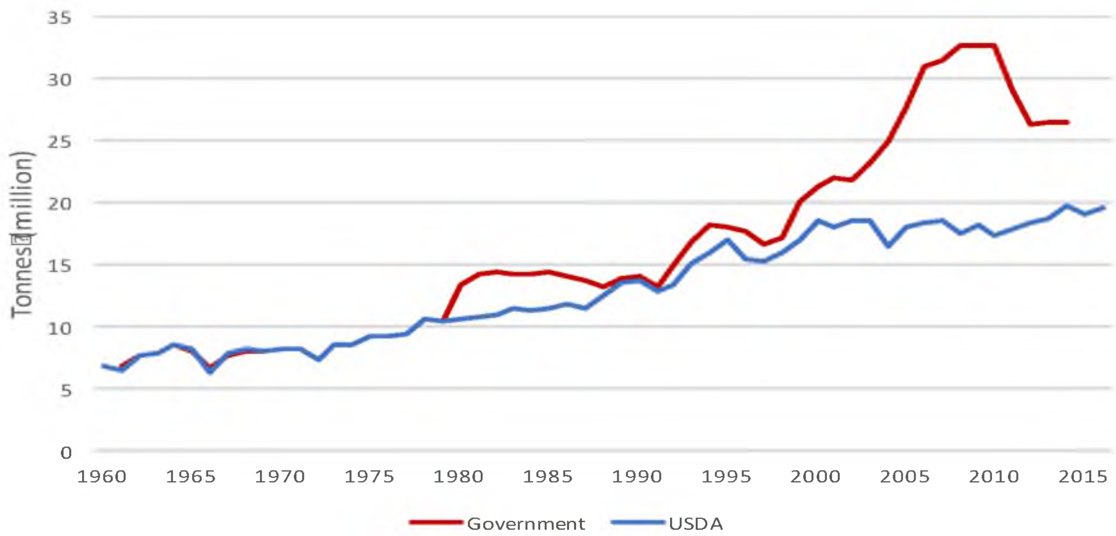


Source: Department of Land Management, Agriculture and Statistics 2015 (left), and New, H.O., 2014, Water Management for Agribusiness Development Myanmar. Presentation. Myanmar Agribusiness Development Summit. 21-22 January 2014, Yangon (right)

3.2 Agricultural production in Myanmar

There are serious questions regarding official agricultural statistics in Myanmar. A number of authors point out that estimates of paddy production from the United States Department of Agriculture (USDA) are around 35% lower than those of Myanmar's government (Figure 3.5), and that government figures significantly over-estimate rice production. Given the size and importance of the rice crop, it is likely that statistical uncertainties are greater for other crops. This paucity in the extent and quality of government figures should be borne in mind when considering the analysis provided here.[48]

Figure 3.5: Government and USDA rice production statistics in comparison 1960-2016



Source: FAOSTAT 2017 (government figures); USDA 2016.

Myanmar is experiencing a rapid decline in the relative importance of the agricultural sector as its growth is outstripped by that in the industrial and service sectors (Figure 1.2 and Table 1.2).

[48] Raitzer, D., Wong, L.C.Y., and Samson, J.N.G., 2015, Myanmar's Agriculture Sector: Unlocking the Potential For Inclusive Growth ADB Economics Working Paper Series No.470; and, Haggable, S., 2013, A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar. Report prepared for USAID Burma.

Nevertheless, agriculture still accounts for approximately 27% of GDP. It also remains a strategically important sector providing around 20% of export earnings, employing upwards of 60% of the labour force, supplying raw materials to the manufacturing sector, and important for food security and poverty reduction.

The sector has seen a significant slowdown in growth in recent years. After quite rapid growth in the sector of around 8.4% between 2000 and 2005, and around 6% between 2005 and 2010, growth has slowed dramatically since 2010 to an average of around 0.1% between 2010 and 2015 (Table 1.2).[49] Performance in the sector is related closely to performance in the food-crop sector which accounts for around 80% of agricultural production. Figure 3.5 illustrates this growth for some key crops.

Table 3.1 gives the main crops and production statistics. Despite the continued importance of rice cultivation, farming in Myanmar is already quite diversified. During the monsoon most farms plant rice but in other seasons crops other than rice are popular, including other cereals, pluses, and oil crops. Industrial crops like sugarcane, cotton, rubber, oil palm and tea are growing in importance. Myanmar also produces a range of vegetables (e.g. garlic, onion and potato), fruits (e.g. mango, banana, citrus fruits, durian, pineapple) and spices (e.g. chili, garlic, ginger, turmeric).[50]

Table 3.1: Main crops area sown and production 2013-2014

Crop	Area sown (million ha)	Yield (t/ha)	Production (million tonnes)
Paddy rice	7.28	3.9	28.32
Pulses	4.53	1.3	5.9
Maize	0.4	3.7	1.6
Groundnut	0.93	1.39	1.29
Sesame	1.62	0.29	0.46
Sunflower	0.48	1.7	0.82
Sugarcane	0.17	61.83	10.47
Cotton	0.3	1.7	0.51
Rubber	0.61	0.76	0.18
Oil Palm	0.15	3.28	0.14
Tea	0.09	1.2	0.1

Source: Lwin, A.K., 2015, Family farming: the case of Myanmar. Memorie di Scienze Fisiche e Naturali 133° (2015), Vol. XXXIX, Parte II, Tomo I, pp. 259-266

Increases in productivity have come from the expansion of the agricultural area, improved agricultural practices and the intensification of agricultural production. Expansion of the agricultural area is reflected in Figure 3.2. Expansion is also reflected in the growth of sown area for main crops (Figure 3.5), although this is also a result of higher cropping intensity - which has increased from around 119% in 1988-1989 to 180% in 2013-2014.[51] Farmers have also increased the intensity of input use (for example, of fertilizer, agricultural chemicals and machinery). In the case of rice production, it is estimated that around 58% of production gains have been due to an increase in sown area and 42% due to yield growth.[52]

Productivity growth for most crops has slowed significantly in recent years (rice and maize). The reasons for this are not clear although suggestions have included soil degradation, availability of fertilizer and a changing climate, as well as institutional constraints.[53] Whatever the reasons, agricultural productivity in Myanmar remains low in comparison to other countries in the region.[54]

[49] Consultants estimates based upon Department of Land Management, Agriculture and Statistics 2015

[50] World Bank, 2016, Myanmar: Analysis of Farm Production Economics. Economic and Sector Work Report No. 100066-MM

[51] Kywe, M., 2016, Overview of Myanmar Agriculture. Presentation.

[52] Raitzer, D., Wong, L.C.Y., and Samson, J.N.G., 2015, Myanmar's Agriculture Sector: Unlocking the Potential For Inclusive Growth ADB Economics Working Paper Series No.470

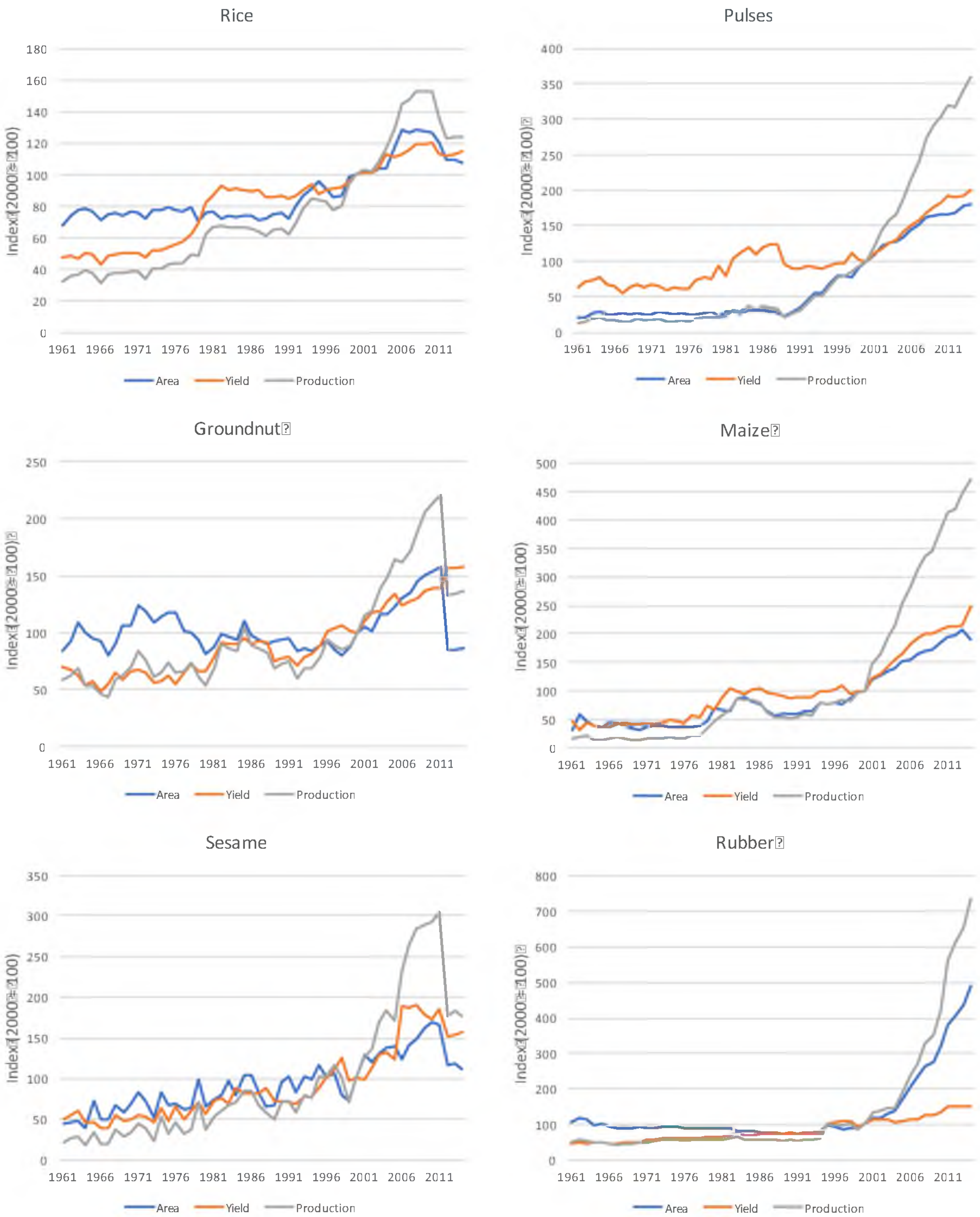
[53] Baroang, K., 2013, Background Paper No.1 Myanmar Bio-Physical Characterization: *Summary Findings and Issues to Explore. USAID.*

[54] Raitzer, D., Wong, L.C.Y., and Samson, J.N.G., 2015, Myanmar's Agriculture Sector: Unlocking the Potential For Inclusive Growth ADB Economics Working Paper Series No.470; and, World Bank, 2016, Myanmar: Analysis of Farm Production Economics. Economic and Sector Work Report No. 100066-MM

Figure 3.5 also indicates the expansion of rubber. Similar patterns of expansion also apply to other plantation crops including sugar cane and palm oil. This expansion has been implicated in land conflicts and deforestation.

Myanmar is the largest producer and exporter of pulses such as black gram, green gram, pigeon pea butter bean, cowpea, kidney bean and chickpea) in ASEAN. Pulse production was liberalized in 1988, subsequently production of pulses surged, with output quadrupling between 1991 and 2014. As a result pluses became an important export earner, second only to gas and oil in official statistics. Sesame and groundnut production also increased significantly over the last 20 years, with the area of planted sesame increasing about 86% and that of groundnut 20%, and both crops seeing a tripling in production (Figure 3.5).

Figure 3.6: Change in area, yield and production for main crops in Myanmar 1961-2014



Source: FAOSTAT, 2017

3.3 Shift from subsistence to commercial agriculture

Agriculture in Myanmar is changing rapidly. While traditional, subsistence farming systems and approaches still prevail they are increasing existing alongside more modern commercial approaches. Commercial approaches to agriculture are characterised by higher levels of inputs (including extensive use of agro-chemicals), mechanisation, the increased use of wage labour, and the consolidation of land holdings. Commercialisation has been developing amongst smaller farmers as better productivity enable the generation of crops surplus to subsistence needs and the development of

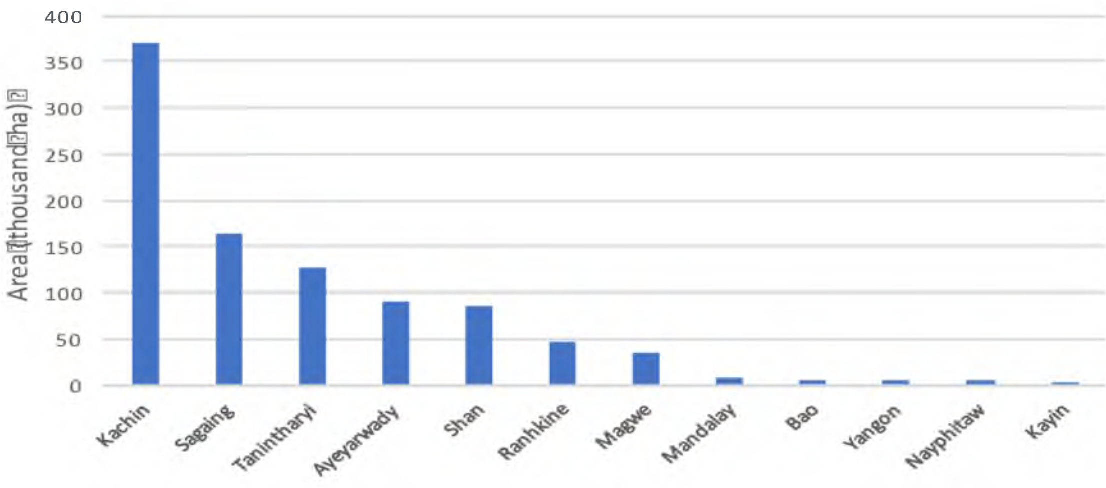
infrastructure and growth in urban populations provides access to large markets for this surplus. At the same time other forms of commercialisation, such as agribusiness concessions and contract farming have also been developing rapidly (Figure 3.6).[55]

Figure 3.7: Large areas cleared for plantation Kachin state 2012

Source: Google Earth 2017

As of 2014 around 940,000 ha had been granted to private companies in Myanmar for large scale agricultural concessions by Ministry of Agriculture, Livestock and Irrigation (MOALI). These figures exclude concessions granted by sub-national authorities and by the former Ministry of Environmental Conservation and Forestry (MOECAF) and probably significantly underestimate the actual extent. This represents a rapid expansion of concessions. Most of these have been granted in more sparsely populated border areas including Sagaing, Kachin, Shan, and Tanintharyi (Figure 3.7). Concessions are typically developed for rubber, oil palm (Tanintharyi) and rice, although other crops include sugar, cassava and jatropha.[56]

Figure 3.8: Area of concessions granted to domestic companies March 2014



Source: MOALI figures from Oxfam, 2017, Whose Crops, At What Price? Agricultural investment in Myanmar. Oxfam Discussion Papers

Contract farming is also an increasingly common form of commercialisation that is transforming agricultural systems in some parts for the country. For example, contract maize farming in Shan State to supply the Chinese poultry industry has resulted in the rapid commercialisation of agriculture in

[55] Ibid.

[56] Oxfam, 2017, Whose Crops, At What Price? Agricultural investment in Myanmar. Oxfam Discussion Papers.

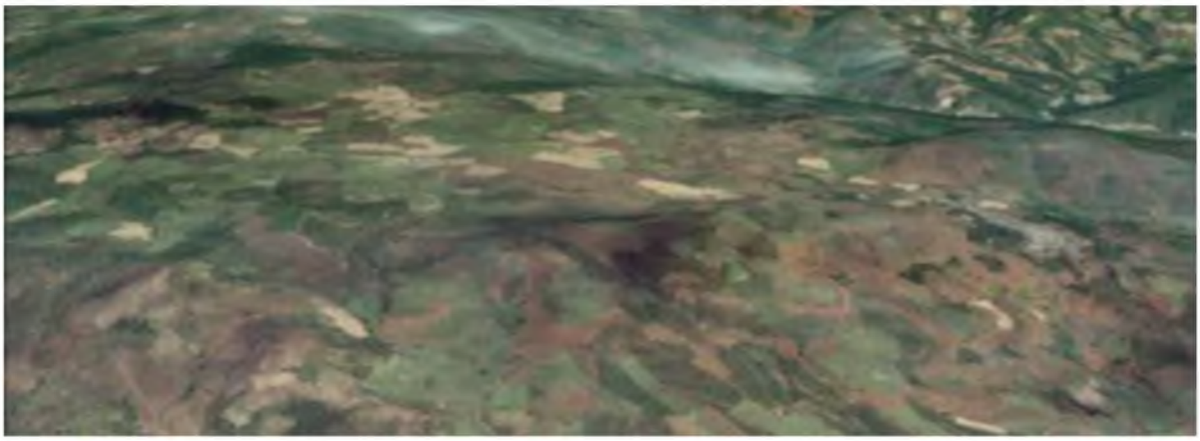
some areas of Shan State (Figure 3.8).[57] With better transportation links and greater access to markets within Myanmar contract farming is likely to increase and be an important driver of agricultural commercialisation.[58]

3.4 Swidden cultivation

Swidden or shifting cultivation is still common in upland, hilly and remote areas in Myanmar, with this farming system most common in Kachin, Kayah, Kayin, Chin and Shan states. Swidden systems are diverse, complex and dynamic which are often difficult to define, categorise, measure and regulate.[59] For these reasons estimates of the extent of swidden agriculture are sketchy.

Recent figures from the Department of Agriculture give the net swidden sown area as around 270,000 ha in 2014/2015 (approximately 2% of net sown area or 0.4% of total land area). These figures are likely to be an underestimate of the significance and impact of swidden systems. First, these figures only take into account the area under cultivation that year. Land is typically rested and left fallow in a swidden rotation for anything from 3-20 years. The area of land under swidden systems could therefore be anything from 3-20 times the area currently cultivated. Second, these figures are net of "squatters", that is they do not include unofficial land users. This may make up the majority of swidden cultivation. Figures from the Forest Department of Myanmar dating from 1993 suggest that around 15 million ha (22.8% of total land area) was affected by shifting cultivation, these figures are likely to be inclusive of fallows and unofficial land use, these estimates are supported by sources cited in a recent paper by Andersen,[60] given a figure of 15.5 million Ha. Other sources from the last two decades estimate figures from 0.29 million ha to 10.18 million ha.[61] Figures for households dependent upon swidden agriculture are similarly vague, although Forestry Department figures estimated that between 1.5 million and 2 million households practiced swidden agriculture in 1995. Nevertheless, it is clear that swidden systems remain an extremely important agricultural system and livelihood strategy in many upland areas in Myanmar.

Figure 3.9: Intensively farmed area in Northern Shan State 2015



Source: Google Earth 2017

Given the paucity of data it is not possible to arrive at determinate trends relating to the extent of swidden agriculture. Nevertheless, the experience of countries elsewhere in the region, corroborated by small scale studies conducted in Myanmar over recent years do suggest a number of important trends. First, swidden cycles are shortening, often due to increasing local population pressure, the cultivation of more marginal land, and possibly the declining availability of land. For example, in

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57 Woods, K., 2015, CP maize contract farming in Shan State, Myanmar: A regional case of a place-based corporate agro-feed system. BRICS Initiative for Critical Agrarian Studies.

58 Oxfam, 2017, Whose Crops, At What Price? Agricultural investment in Myanmar. Oxfam Discussion Papers.

59 Padoch,C., Coffey, Mertz, O., Leisz, S.J., Fox, J., and Wadley R.L., 2007, The Demise of Swidden in Southeast Asia? Local Realities and Regional Ambiguities. Geografisk Tidsskrift, Danish Journal of Geography 107(1)

60 Andersen, K.E., 2015, Study of Upland Customary Communal Tenure in Chin and Shan States. Outline of a Pilot Approach towards Cadastral Registration of Cutomary Communal Land Tenure in Myanmar. Land Core Group.

61Schmidt-Vogt, D., Leisz, S.J., Mertz, O. et al., 2009, An Assessment of Trends in the Extent of Swidden in Southeast Asia, Hum Ecol (2009) 37: 269.

Western Chin State a decline form 15 years to 6-9 year has been documented[62], in Shan State reports suggests swidden cycles as short as 3-5 years (Figure 3.9).[63]

Figure 3.10: Swidden mosaic in Eastern Shan State 2016

Source: Google Earth 2017

Secondly, there has been a decline in swidden cultivation due to increases in other types of land use. Other types of land use include the intensification of swidden cycles, introduction of terracing[64], permanent more intensive cultivation practices, the more widespread cultivation of industrial crops, and related to this, the development of large scale agri-business concessions.[65] A reason often given for the increased intensity of swidden agriculture is the increase in population. However, some reports suggest a decline in swidden area due to outmigration and declining population.[66] It is likely that these factors are highly localised and vary from area to area. Thirdly, the expansion of other types of agricultural system does not necessarily entail the abandonment of swidden cultivation as short fallow swidden is often maintained alongside other intensive farming practices.[67]

3.5 Riverbank gardens

In Myanmar, as elsewhere in Southeast Asia, the cultivation of riverbanks, islands and other seasonally available in-stream structures during dry season represents an important source of agricultural production for riparian communities. Riverbank gardens become available for cultivation as the water level recedes in the dry season and are used for the cultivation of a range of subsistence and cash crops. They are particularly attractive for cultivation because, i) The fertility of the soil is replenished every year by nutrients attached to sediments deposited during wet season; ii) Seasonal flooding also means areas are largely free of weeds; iv) These areas have easy and reliable access to water[68]; and iv) They provide a reliable source of production to households during the dry season.

[62]Thien, U.S., 2012, Study on the Evolution of the Farming Systems and Livelihoods Dynamics in Northern Chin State. GRET/LIFT

[63] Win, S., 2004, Investigation on Shifting Cultivation Practices Conducted by the Hill Tribes for the Development of Suitable Agroforestry Techniques In Myanmar.

[64] Chan, N., and Takeda, S., 2016, The Transition Away from Swidden Agriculture and Trends in Biomass Accumulation in Fallow Forests Case Studies in the Southern Chin Hills of Myanmar

[65]Ziegler, A.D., Bruun, T.B.,Guardiola-Claramonte, M., Giambelluca, T.D., Lawrence, D., Lam, N.T., 2009, Environmental Consequences of the Demise in Swidden Cultivation in Montane Mainland Southeast Asia: Hydrology and Geomorphology. Hum Ecol. 37:361–373.

[66]Chan, N., and Takeda, S., 2016, The Transition Away from Swidden Agriculture and Trends in Biomass Accumulation in Fallow Forests Case Studies in the Southern Chin Hills of Myanmar

[67]Schmidt-Vogt, D., Leisz, S.J., Mertz, O. et al., 2009, An Assessment of Trends in the Extent of Swidden in Southeast Asia, Hum Ecol (2009) 37: 269.

[68]Kiguchi, Y., undated, 2-8. Riverside Agriculture in the Mekong Basin: An Uncertain Future for Environmentally Friendly Agriculture

Riverbank gardens can be substantial with large areas of alluvial deposits forming seasonal islands and sandbanks which may also be cultivated in a similar manner. Anecdotal and observation data suggests that riverbank gardens are as ubiquitous in Myanmar as elsewhere in the region. However, there are no available estimates of their likely extent.[69]

3.6 Employment and livelihoods

Agriculture remains the critical sector for employment and poverty reduction. Current estimates suggest that the agricultural sector accounts for 60-70% of employment. It shuld be noted that households which may be predominantly reliant on agriculture typically have a diversified income stream, for example relying on income from wage labour, fuelwood, NTFPs, aquatic products and remittances. While this has declined it is expected to be the major source of employment for the foreseeable future. Similarly, agriculture is critical in addressing poverty. Rural poverty rates stand at 36%. Amongst the rural poor around 70% of income is spent on food.[70] Myanmar has high levels of landlessness, with around 30% of the rural poor classed as landless. Agricultural labour is critical for this group. A shortage of agricultural labour and low wages (linked to poor labour productivity in the sector) are reportedly an increasing problem in the sector.[71]

3.7 Development issues in the agricultural sector

Despite the significant potential of agriculture in Myanmar and recent improvements in the sector, it lags well behind other countries in the region in terms of practically all performance metrics. Key issues identified in recent reports include:[72]

- **Inadequate availability of input markets** - markets for quality seed, fertilizer and pesticides have not been developed;
- **Inadequate water infrastructure** - farmland is vulnerable to flooding and drought in some places. There is considerable scope for improving productivity through the extension of irrigation (drylands) and drainage (delta), and flood protection infrastructure;
- **Weak tenure rights** - land holders suffer from insecure land tenure which discourages investment and hampers the commercial development of the sector. While weak tenure rights are an issue throughout the country, expropriation of land by various state and non-state actors is a critical issue in upland areas. It is often associated with the development of planations and infrastructure.
- **Limited government support for farmers** - limited extension services, restrictive policy environment, low level of spending on agricultural research and development (R&D); and
- **Limited infrastructure provision** - poor electricity supply and transportation links hamper value addition, transportation costs due to inadequate transportation infrastructure and antiquated ports add considerable costs.

3.8 Environmental issues in the agricultural sector

Given its close reliance on the natural resource base and its role in modifying natural systems to improve agricultural productivity, there are many significant environmental issues associated with activities in the sector:

[69] If a very conservative estimate of a recessional area suitable for the cultivation of riverbank gardens of 10 m either side of the river is assumed for the whole length of the Ayeyarwady this suggests a total of 4,340 ha of riverbank gardens in the mainstream alone, excluding other in-channel structures such as sand bars and seasonally inundated islands. Land classified as Kaing (alluvial land/island) by the Department of Land Management and Statistics amounted to approximately 546.3 thousand ha in 2014-1015 - this may be seasonally inundated riverine land although this is not clear from the statistics.

[70] Haggable, S., 2013, A Strategic Agricultural Sector and Food Security Diagnostic for Myanmar. Report prepared for USAID Burma.

[71] World Bank, 2016, Myanmar: Analysis of Farm Production Economics. Economic and Sector Work Report No. 100066-MM

[72] See Raitzer, D., Wong, L.C.Y., and Samson, J.N.G., 2015; and, Haggable, S., 2013.

- **Deforestation** - Agricultural practices are heavily implicated in forest loss. Clear cutting trees for agribusiness plantations has also been a key cause of forest loss in recent years - including both intact forest and degraded forest (which is often part of swidden cycles). Upland areas are most affected by this such as the Bago Hills, Kachin State, Sagaing region, Chin State, Rakhine, Tanintharyi and Shan state. Deforestation due to agricultural encroachment may also be a problem in the coastal mangrove forests which have also seen rapid declines over recent years;
- **Land degradation** (water erosion) - Cultivation of steeply sloping land and higher intensity agricultural practices (the shortening of the swidden cycle in particular) has in some circumstances lead to higher instances of soil erosion from water. This degrades soils and causes increases in sediment loads. In serious cases this can result in loss of slope stability and land-slides, or the localized loss of soil altogether. This is common a problem throughout the country in and near hilly areas in particular.[73]
- **Desertification** - Deforestation, erosion (from water and wind) and salinization of soils in the Dry Zone contribute to increased problems with desertification. Dry Zone soils[74] are sensitive to degradation due to low natural levels of fertility, high salinity, low organic content, exposure to brief periods of intense rainfall, and overall low annual rainfall totals[75].
- **Salinization** (Dry Zone) - In Dry Zone areas salinization is associated with the evapotranspiration of saline ground water or irrigation water leaving a salt crust on the soil surface. In Dry Zone areas this can accumulate over years and rainfall can be insufficient to flush the salt concentration from the soil.
- **Salinization** (coastal areas) - In coastal areas salinization occurs due to (i) Ingress of salt water in estuarine areas and up rivers; (ii) Storm surges and tides; and (iii) Infiltration via groundwater. This can be a problem for farmers during the dry season in coastal areas preventing the cultivation of some crops. For example, in southern areas of the Ayeyarwady delta from January onwards until the onset of the monsoon.[76] But this also likely affects other coastal areas such as the Sittaung delta, and the coastal plains in Rakhine State and Tanintharyi.[77]
- **Drought and irregular rainfall** - Variability of rainfall and to a lesser extent droughts pose a problem for farmers in the Dry Zone. Variability in the onset of seasonal rainfall is a particular problem.[78]
- **Flooding** - Myanmar is susceptible to seasonal flooding damaging agricultural infrastructure, crops and livestock. In upland areas and the narrow coastal plains of Rakhine State and Tanintharyi region rapid onset flooding is a problem. This issue has probably been exasperated by continuing deforestation. Slower onset, riverine flooding can affect large areas to the north of the Ayeyarwady delta as well as areas in the Dry Zone, the confluence of the Ayeyarwady and the Chindwin is particularly prone to flooding. Production is susceptible to flooding. Coastal areas are susceptible to flooding due to extreme weather events such as cyclones, in which intense rainfall is often combined with a storm-surge.[79]
- **Water pollution** - While there is limited documentation of instances of water pollution and declines in water quality due to agricultural practices in Myanmar, as elsewhere in the region it is likely to be an increasingly important issue. Increasing agricultural intensity, meaning greater use of fertilizers and agricultural chemicals, more intensive livestock production increasing the issue of high concentrations of animal waste entering waterbodies and less

[73] See appendix to this section for erosion map.
[74] It is estimated that 72% of the Dry Zone is affected by land degradation of some sort (see Yee, K., 2014, Land Degradation Assessment in the Dry Lands of Myanmar. Presentation. MOAI.
[75] Vaughan, E., and Levine, E., 2015, The Dry Zone of Myanmar A strategic resilience assessment of farming communities. Mercy Corps.
[76] LIFT, 2014, Learning Together in the Ayeyarwady Delta. Lessons and Good Practice from LIFT's Delta Programme 2011 – 2014.
[77] Some estimates suggest saline soils including saline gleysols, mangrove forest soils and saline tidal alluvium soils cover up to 1.25 million ha. See Boje-Klein, G., 1986, Problem Soils as Potential Areas for Adverse Soil-Tolerant Rice Varieties in South and South East Asia. IRRI Research Paper Series Number 119. This paper notes that some of these soils, if not classified as saline, would be acid sulphate soils - suggesting if salinity control infrastructure and management practices were introduced into some of these areas, then the issue of acidification would become more important (similar to the situation on the Mekong delta).
[78] IWMI, 2013, Improving water management in Myanmar's Dry Zone for food security, livelihoods and health
[79] See FAO/WFP, 2016, Special Report. Crop and Food Security Assessment Mission to Myanmar.

sustainable cultivation practices leading to increased sedimentation are all likely to affect water quality. Large scale mono-crop plantaions in particulat have been implicated in increased pollution loads from agricultural chemicals.

3.9 Agricultural and associated environmental issues by river basin

3.9.1 Ayeyarwady

The Ayeyarwady River Basin is central to Myanmar's agricultural production. Importantly, the delta accounts for a large proportion of the county's rice, pulses and oil crop production. Key issues for agriculture in the basin are varied. In the upper reaches of the catchment in Kachin, Sagaing, and some areas of Shan State, deforestation due to clearing for various agricultural activities is important. Connected to this increased incidence and intensity of agriculture on sloping land is a growing issue. Both deforestation and the expansion of agriculture on sloping land increase issues of erosion, land degradation and flooding. Lower in the catchment in the Dry Zone, agricultural issues relate to variability in water availability and soil erosion. Riverine flooding is an important constraint on agriculture in some Dry Zone areas. The coastal and estuarine areas face issues with saline intrusion, as well as riverine and coastal flooding. These risks are increased through the loss of mangrove forest.

3.9.2 Chindwin

The Chindwin basin is dominated by forest cover and more intensive agriculture is practiced where conditions allow in valley bottoms and other flat areas, where wet rice and other crops can be cultivated. However, swidden agriculture dominates and much of the forest is already degraded. There is anecdotal evidence that swidden cycles have shortened in this river basin, and there is evidence of a change to sedentary agriculture - for example through the development of terrace systems in Chin State. Key issues are likely to be rapid onset flooding, a lack of infrastructure to support agriculture (such as roads and irrigation infrastructure) and continuing forest degradation and loss. Landslides and soil erosion is also likely to be an issue in hill areas of the basin.

3.9.3 Thanlwin

The Thanlwin River basin has seen the development of plantation and permanent agricultural area in areas bordering on China and Thailand. Permanent intensive agriculture is common in some areas of Shan State. Swidden systems are common in the basin on sloping and degraded forest land. Rice cultivation is more common in lowland and coastal areas of the basin. Issues include rapid onset flooding and landslide risk in upland areas. Erosion and land degradation is also an issue in intensively farmed upland areas. Rapid onset flooding is also likely to be a risk in the coastal plain. Lack of agricultural infrastructure (irrigation and transport in particular).

3.9.4 Sittaung

This basin and in particular, the deltaic region is an important location for rice cultivation. Hill and mountainous areas have seen extensive swidden cultivation. Hill and flood plain areas are prone to rapid onset flooding. Riverine areas also suffer from slow onset flooding. Deltaic areas face the familiar issues of saline intrusion and vulnerability to coastal flooding from storm surges.

3.9.5 Mekong

This area is dominated by swidden systems and plantations. Like the Chindwin basin, this area is remote and lacking in the development of support infrastructure. Little information is available on issues with this region, although land degradation due to agricultural intensification (of swidden and other systems), soil erosion, land slide and rapid onset flood risk are likely to be an issue. The expansion of plantations and associated issues are also likely to be important in the region.

3.9.6 Tanintharyi

Most agricultural activity is centered on the narrow coastal strip in this region. This area is prone to rapid onset flooding in the monsoon. Coastal areas are also vulnerable to flooding from storm surges, these risks are increased by the rapid loss of mangrove forests. Tanintharyi region has seen rapid

expansion of oil palm plantations and concomitant forest loss in upland areas mainly bordering on existing agricultural areas. Swidden agriculture is also common in upland areas and is associated with forest degradation, soil erosion, increased flooding risks and increased land slide risk.

3.9.7 Rakhine

Rice cultivation is important in the narrow coastal plain, although most of the region is forested. Deforestation due to agricultural encroachment (from swidden and plantations) is important with high levels of forest loss. The coastal plain has also seen the widespread loss of mangroves - although this has in the main been due to consumptive use of the timber rather than agricultural encroachment. Loss of mangroves, however, increases other risks. The area is at risk of rapid onset flooding due to high levels of wet season rainfall and the proximity of hills to the coastal plain. Coastal flooding associated with storm surges is also an issue, these risks are increased by the loss of mangrove forests.

3.10 Potential interactions between hydropower and the agricultural sector

Table 3.2 summaries the potential interactions between the hydropower sector and the agricultural sector. It describes the potential impact of hydropower development on the agricultural sector, the impact of agricultural activities on hydropower and potential cumulative impacts.

Table 3.2: Potential interactions between hydropower and agricultural production

Impact	Narrative
Of hydropower on agriculture	
Reduced nutrient transport	Nutrients are typically attached to sediment particles in suspension. These may drop out of the water as water slows down in the reservoir area. This may mean that nutrients are trapped along with sediments in reservoirs, disrupting the supply to nutrients to downstream farmland.
Reduced deltaic stability	Reduction in sediment load reaching the delta due to sediment trapping in hydropower reservoirs. Leading to reduced deltaic accretion and threatening long term deltaic stability with knock-on implications for agriculture in these areas.
Increased downstream erosion	Reduction in sediment load due to sediment trapping in hydropower reservoirs. Leading to increased downstream erosion affecting riverbank stability and agriculture on and near these areas. In-stream agricultural infrastructure (such as weirs and water intakes) could also be affected.
Unseasonal changes in water flows/availability	HP plants may alter the seasonal pattern of water flows in a river. In-stream irrigation intakes may need adjustment to account for changes in flow regime.
Loss of riverbank gardens	Aside from increased erosion and the risks of peaking operations, HP development may affect viability of riverbank gardens through changing seasonal patterns of water flow and river level in an unpredictable manner, thus inundating riverbanks or other in-stream cultivated areas.
Loss of land in inundation area	Fertile land in the valley bottom will be inundated and unavailable for agricultural production.
Loss of land in watershed protection area	Watershed protection provisions in HP catchments may preclude the use of these areas for agriculture.
Reduced flooding	HP reservoirs may in some circumstances be managed to reduce flooding.
Increased water availability for irrigation	Close to the project, hydropower reservoirs may be managed for multiple use and irrigation provision. Larger dams or the combined influence of a number of dams may improve dry season flows improving the potential for irrigation.
Improved electricity supply	HP development may increase the availability of affordable electricity to agricultural areas allowing increases in productivity through reliably

Impact	Narrative
	powering irrigation pumps and technology for post-harvest processing.
Of agriculture on hydropower	
Impacts of deforestation and land degradation due to agriculture	Deforestation resulting from unsustainable forestry practices can result in the loss of land cover in watersheds up-steam of hydropower plants. This may increase erosion and reservoir sedimentation and result in the loss of productivity at the hydropower plant, as well as potentially increased wear and tear on the plant implying higher O&M costs.
Increased pollution from agricultural run-off	Greater use of chemicals, fertilizers and more intensively raised livestock may increase agricultural run-off into reservoirs compounding reservoir water quality issues.
Water use for irrigation	Any management of HP projects for multiple use including irrigation will reduce the amount of water that can be used for power generation.
Cumulative impacts	
Deforestation and biodiversity loss	Agricultural expansion is the main driver of deforestation, especially in areas of degraded forests. This compounds deforestation pressures from other sources such as HP development, transport, mining and logging.
Soil degradation, erosion, sedimentation	Increased intensity of farming, especially on sloping land is an important factor in land degradation, erosion and soil loss. Compounding influences from logging, mining and infrastructure development.
Flooding	Increased run-off due to agriculture-induced deforestation could result in some circumstances to an increased risk of flooding, this will add to impacts from climate change, infrastructure development, mining and logging in upland areas.

3.11 Business As Usual (BAU) projection/projected baseline

Although agricultural productivity growth has stalled in the last few years, in the longer term the sector is expected to return to growth. New policy is currently under discussion. Under the new government there seems to be a change in policy emphasis towards the prioritisation of food security, and farm income, through a focus on enhancing the productivity of small farmers. At the same time policy is shifting towards the promotion of a more diversified sector with less focus on rice production.[80] New targets have yet to be developed, those in previous policy documents focus on extensification and internsification of rice cultivation.

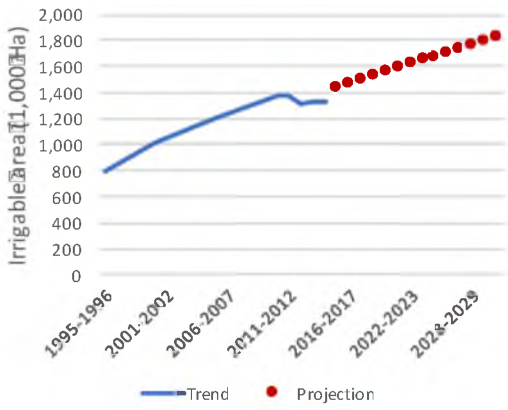
With a new policy direction in the offing developing a BAU projection for the sector is challenging, let alone determining the spatial distribuition of such changes. However, given limited government capacity, and important governance and institutional issues in the sector (such as those realting to land tenure and input markets) BAU projections are based only on the projection of established trends in the agricultural sector. The assumption being that there is no significant change in the trajectory of the sector. This implies:

- Continuing conversion of forest and unused land to agricultural uses (including small scale conversion and conversion of forested land at a large scale for agro-forestry plantations);
- Continuing commercailisation of agriculture, including increasingly concentrated land holdings, increased mechanisation, increased use of chemical inputs; and
- Gradually improving productivity - through provision of better support infrastructure and ammenties, high levels of inputs and better agricultural practices.

More concretely, Figures xx and xx project established trends in land use and irrigation forward to 2030-2031. And Figure xx projects establish trends in rice production to 2030-2031.

Figure 3.11. Irrigable area and net sown area, 1995-1996 to 2030-2031

[80] Agricultural Development Strategy and Investment Plan. Preliminary Formulation. Draft 1 - 4 November 2016.



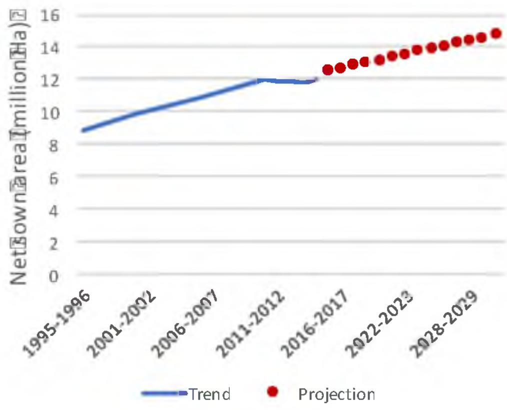
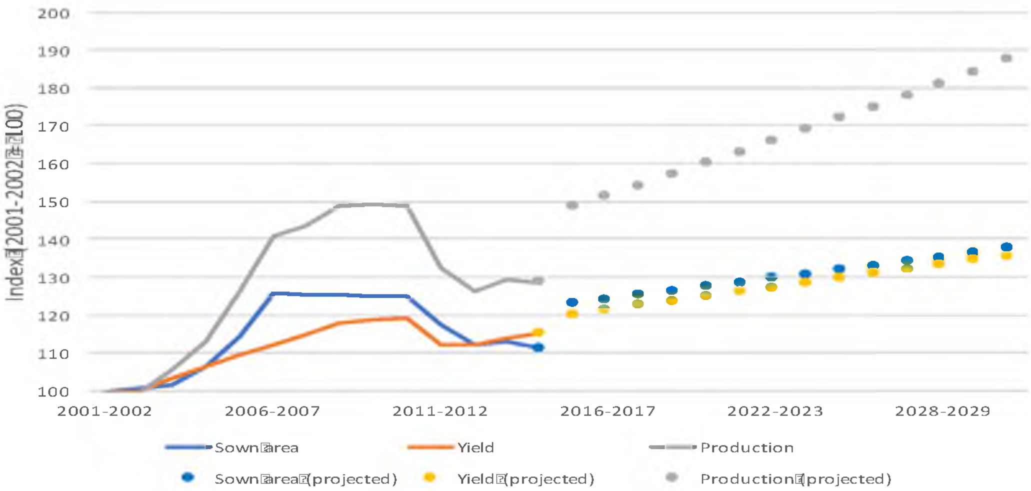


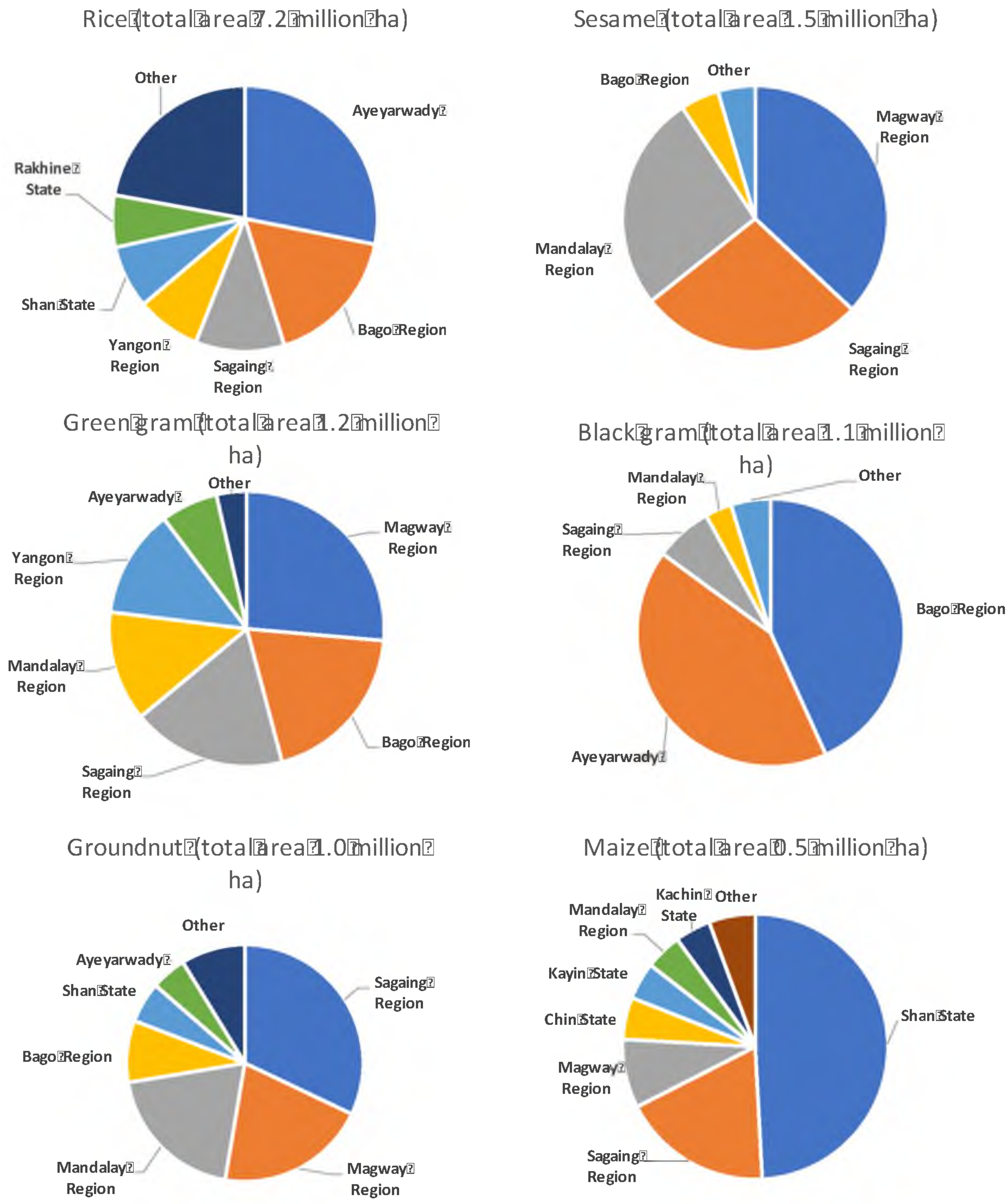
Figure 3.12. Sown area, yield and production for rice to 2001-2031



Based upon an assumption of the continuance of currently established trends in the sector, projctions suggest a 22% increase in irrigable area and a 37% increase in sown area. This implies a similar increase in water extraction for irrigation of around 25,700 million m^3 $year^{-1}$. This also implies an increase in sown area of around 2.2 milion Ha. While some of this would come from intensification of cropping patterns and multi-cropping, further conversion of forest land and land under swidden cycles to more or less permanent agricultural use is likely.

3.12 ANNEX to agriculture section

Distribution of sown area by main crops 2014-2015

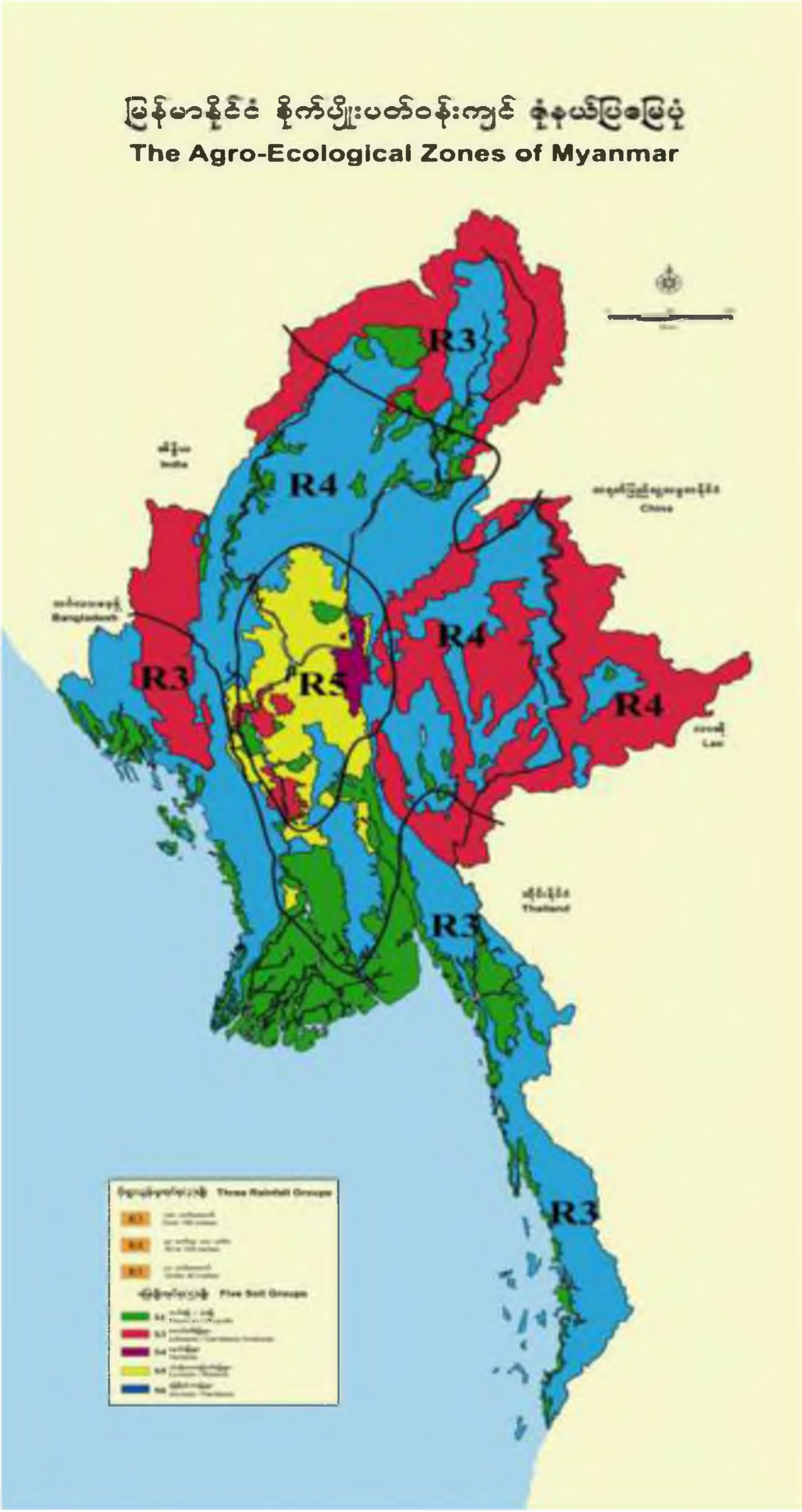


Source: Department of Agricultural Land Management and Statistics

Soil erosion risk

Source: Yee, K., 2014, Land Degradation Assessment in the Dry Lands of Myanmar. Presentation. MOAI.

Agro ecological zones



Source: Yee, K., 2014, Land Degradation Assessment in the Dry Lands of Myanmar. Presentation. MOAI.

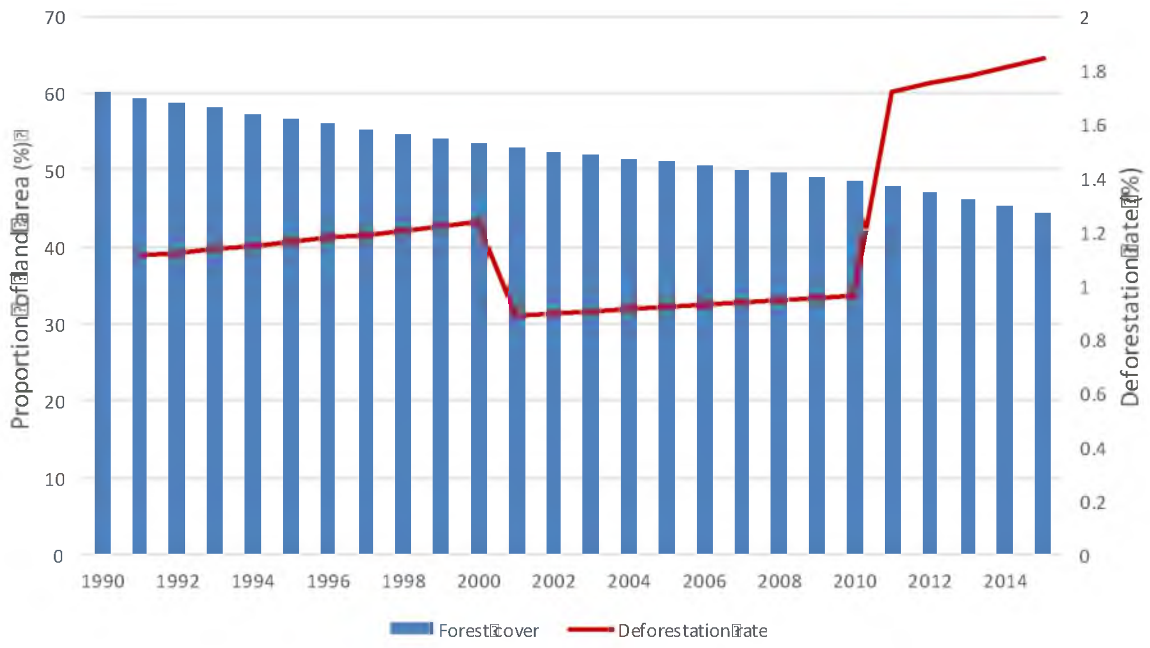
4 FORESTRY

4.1 Resources

Myanmar has significant forest resources. Figures differ between sources but generally accepted Food and Agriculture Organization (FAO) of the United Nations figures suggest that in 2015 around 44.5% of the land area of Myanmar or over 290,000 km^2 was covered by forest.[81] Despite the significant remaining extent of its forested area Myanmar is experiencing rapid rates of deforestation. Between 1990 and 2015 Myanmar saw forest cover decline by approximately 26%, from about 392,000 km^2 to 290,000 km^2 - an average of 678,500 ha a year (Figure 4.1). Figures suggest a significant increase in the rate of deforestation over the last five years. The decline has been dramatic particularly for dense forest which declined from 45.6% of land coverage in 1990 to 19.9% by 2011.[82]

The causes of this decline include land conversion for agriculture, plantations and infrastructure, and unsustainable levels of extraction for timber and fuelwood. These are discussed in greater detail below.

Figure 4.1: Forest cover in Myanmar 1990-2015 and deforestation rate 1991-2015



Source: World Bank, 2017, World Development Indicators Database (FAO statistics)

Myanmar's diverse geography, with varied topography, soils and climates give rise to a wide variation in ecosystems. This is reflected in the variety of forest types across the country. These are typically categorized into the seven major types given in Figure 4.2 and Table 4.1 below. Each type provides a range of different products including fuelwood, timber and non-timber forest products (NTFPs). Most of Myanmar's remaining forests are composed of mixed deciduous forests (approximately 38%). This is seen as the most economically important, containing valuable timber species such as teak (*Tectona grandis*), rosewood *(Dalbergia spp.),* pyinkado (*Xylia dolabriformis*), and padauk (*Pterocarpus macrocarpus*).[83, 84] Although, other types of forests also have economic

[81] Defined as "Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens." FAO.

[82] Tint, K., Springate-Baginski, O., and Gyi, M.K.K., 2011, Community Forestry in Myanmar: Progress & Potentials

[83] Tint, K., Springate-Baginski, O., and Gyi, M.K.K., 2011, Community Forestry in Myanmar: Progress & Potentials

[84] EIA, 2014, Myanmar's Rosewood Crisis. Why key species and forests must be protected through CITES

importance and are critical for the supply or fuelwood, locally used building materials and NTFPs - as well numerous ecosystem goods and services.[85]

Figure 4.2: Main forest ecosystems in Myanmar

Source: A Checklist of the Trees, Shrubs, Herbs, and Climbers of Myanmar. Contributions from the United States National Herbarium. Volume 45: 1-590

Teak is of particular importance to the forestry sector. Myanmar accounts for an estimated 80% of the world's teak reserves, it still has the world's largest natural teak forests - approximately 50% of the global figure or 14.5 million ha - as well as the third largest area of planted teak in the world (approximately 390,000 ha).[86]

Table 4.1: Forest resources in Myanmar by forest type 2010 (left) and legal classification (right)

Forest type	Area (ha)	Proportion of forested area (%)	Legal classification	Area (ha)	Proportion of total land area (%)
Mangrove	467,330	1.5	**Permanent forest estate**	15,694,976	23.2
Hill and temperate evergreen	8,541,190	26.9	***Of which:***		
Tropical evergreen	5,470,600	17.2	***Reserved forest***	*12,184,291*	*18.0*
Mixed deciduous	12,157,300	38.3	***Protected Area System***	*3,510,685*	*5.2*
Deciduous Dipterocarp	1,321,870	4.2	**Protected Public Forest**	4,094,960	6.1
Dry	3,114,710	9.8			
Scrub land	700,000	2.2			

[85] Springate-Baginski, O., Treue, T., and Htun, K., 2016. Legally and illegally logged out. The status of Myanmar's timber sector and options for reform.

[86] FAO, 2017, Global Teak Trade In The Aftermath Of Myanmar's Log Export Ban. Planted Forests and Trees Working Paper Series No. 49

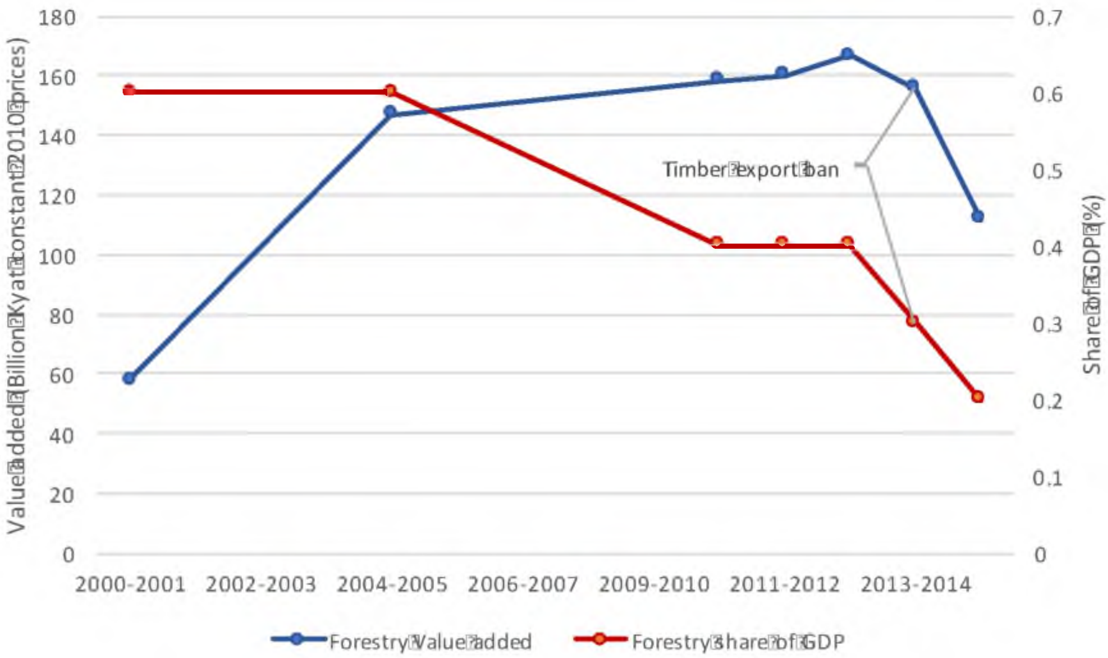
Total	31,773,000	47.0[a]	**Total**	19,789,936	29.2
Total land area	67,659,380	100	**Total land area**	67,659,380	100.0

Source: FAO, 2010, Forest Resource Assessment (left); Planning and Statistics Division, Forestry Department (right). a - proportion of total land area

4.2 Production and economic significance

Forestry accounts for a small and declining share of GDP. This is, in part, due to very high growth in the industrial and service sectors, and in part due to declining productivity of the remaining forest, and recent legislative changes including the ban on the export of unprocessed timber in force since 31 March 2014 (Figure 4.2).[87] This ban, however, has had no impact on the large illegal trade of timber across the border to Yunnan.[88]

Figure 4.3: Forestry value added and share of national GDP 2001/2002 - 2013/2014



Source: Department of Planning, Consultants own calculations based upon World Bank, 2017, World Development Indicators

The importance of timber exports as a source of revenue has diminished with the development of other revenue sources (including energy, manufacturing and mining sector projects). However, timber and wood products maintain a sizable share in export revenues (Figure 4.3) and remain an important source of foreign exchange earnings. Figure 4.4 shows the rapid increase in the value of timber exports to over USD 1.6 billion in 2013, which has more than trebled since the early 2000s. These figures are derived from customs statistics from importing countries as these are deemed to be a better guide than Myanmar's own production and export statistics which miss out large portions of illegally exported wood.[89]

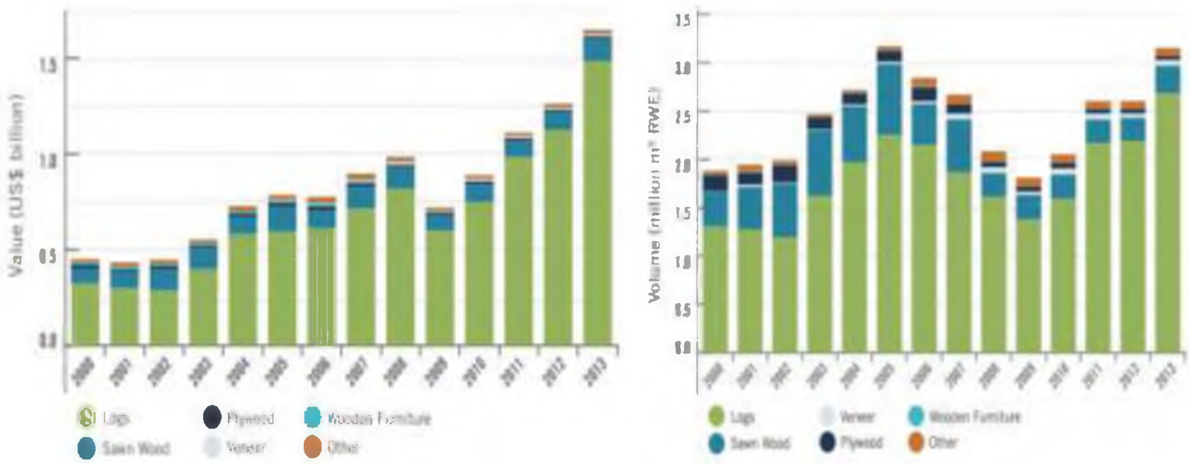
[87] According to FAO research, this ban has caused a dramatic rise in the price of high quality teak in China which sources 80% of this timber from Myanmar, from USD 750 m^3 at the end of 2013, to USD 2,000 m^3 in January 2014. FAO, 2015, Global teak trade in the aftermath of Myanmar's log export ban by Kollert, W. & Walotek, P.J. Planted Forests and Trees Working Paper FP/49/E. Rome, Italy (available at http://www.fao.org/forestry/plantedforests/67508@170537/en/)

[88] EIA, 2015, Organised Chaos. The illicit overland timber trade between Myanmar and China.

[89] In official figures the export of Timber products was worth almost US$ 950 million in 2013-2014, almost 60% below the value of exports from Myanmar reported by importing countries. This also fails to account for smuggled timber.

Teak reportedly accounted for 70-80% of this value, although in recent years a boom in demand for rosewood in China has led to a significant increase in the importance of this trade.[90] Reported export volumes peaked in 2005 and were again approaching those levels in 2013. Recent years have also seen an increase in the share of raw timber in exports, as export priorities have overridden considerations of the development of domestic productivity.[91] This trend has been reversed somewhat with the implementation of the 2014 timber export ban.

Figure 4.4: Timber exports by value (left) and volume (round-wood equivalent) (right) 2000-2013



Source: Woods, K., 2015, Commercial Agriculture Expansion in Myanmar: Links to Deforestation, Conversion Timber, and Land Conflicts. Forest Trends Report Series Forest Trade and Finance

Figures for timber production by region/state are given in Figure 4.5. Again, it is important to note that these do not take account of illegally extracted timber or wastage which may be substantial.[92] Key sources of timber production over the last decade have been Mandalay, Sagaing, Shan, and Bago for teak, and Sagaing, Mandalay, Bago and Tanintharyi for other hardwoods. Again, the recent export ban is reflected in the decline in production in 2014-2015. In terms of illegal logging, Sagaing and Kachin remain an important source of timber for the Chinese market.[93] In the absence of effective governance, the ban on official exports (and consequent timber price increases) increases the incentive for this illegal trade.

Fuelwood and charcoal production also represent a critical economic function of the forestry sector. Fuelwood and charcoal remain by a large margin the most import source of household energy supply, representing an estimated 90% of biomass energy consumption.[94] Average annual household consumption of fuel wood is estimated to be around 2.5 tons for rural households and 1.4 tons for urban residents.[95]

Figure 4.5: Timber production by region teak (left) and other hardwoods (right) 1995-2015

[90] Treanor, N.B., 2015, China's *Hongmu* Consumption Boom: Analysis of the Chinese Rosewood Trade and Links to Illegal Activity in Tropical Forested Countries. Forest Trends Report Series, Forest Trade and Finance.

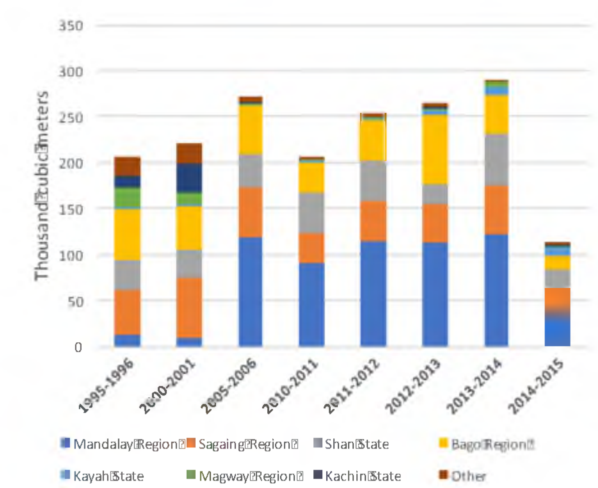
[91] Woods, K., and Canby, K., 2011, BASELINE STUDY 4, MYANMAR, Overview of Forest Law Enforcement, Governance and Trade. Forest Trends for FLEGT Asia Regional Programme August 2011.

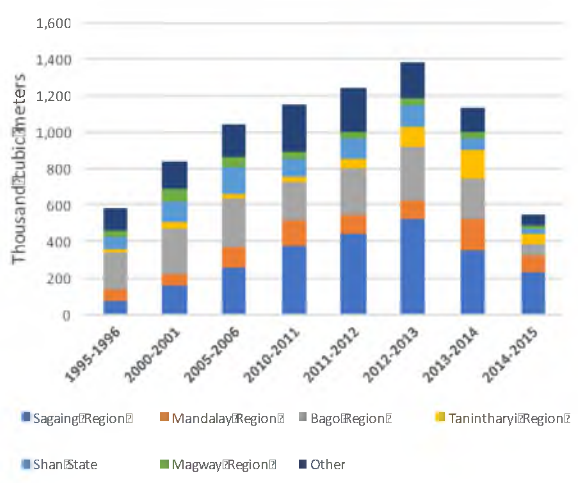
[92] See Springate-Baginski, O., Treue, T., and Htun, K., 2016. Legally and illegally logged out. The status of Myanmar's timber sector and options for reform, and Woods, K., 2015, Commercial Agriculture Expansion in Myanmar: Links to Deforestation, Conversion Timber, and Land Conflicts.

[93] EIA, 2015, Organised Chaos. The illicit overland timber trade between Myanmar and China

[94] Kissinger, G. 2017, Background report for identifying the drivers of deforestation and forest degradation in Myanmar. UN-REDD and MONREC.

[95] Ibid., ADB, IES and MMIC, 2015, Myanmar Energy Master Plan





Source: Myanmar Timber Enterprise 2016

Estimates of overall fuelwood use are uncertain however, there seems to be consensus in the literature that for approximately that last decade fuelwood consumption has been around 20 million tonnes.[96, 97] It is unclear if these figures include charcoal production for domestic use, estimated to be between 94,000 tons and 207,000 tons per anum.[98] The figures do not seem to account for the growing charcoal export trade to China, which has grown from virtually nothing before 2007 to representing about 32% of China's timber imports from Myanmar by volume by 2013 (500,000 m^3).[99]

Aside from fuelwood and charcoal, a broader range of NTFPs are harvested at a commercial scale from forests. These include bamboo, rattan, barks, resins and oils, honey, beeswax, bat-guano, orchids, edible birds' nets and lac as well as a wide range of wildlife species (much of it taken illegally). Most of these products also used to support subsistence livelihoods, along with wild foods and natural medicines amongst other things. A recent valuation study suggested that the economic value of NTFPs in 2012 was approximately USD 487 million and USD 20 million.[100]

4.3 Employment and livelihoods

Approximately 36,000 people were directly employed in the forestry sector in 2011, and broader estimates from 2009 including unreported, informal and indirect employment suggest up to 500,000 people are dependent upon the forestry sector for employment.[101] In 2012 around 520,000 forest adjacent households were likely to depend on forestry resources for their livelihoods.[102] Although the relative importance of this has likely declined with rapid expansion of the services and industrial sectors, the sector remains a significant source of employment in rural areas.

Forestry is also important for rural livelihoods. Many communities are dependent upon forested areas for fuelwood, small timber for construction and provision of farm implements, as well as a wide range of NTFPs. Forest land is also utilised in a pattern of shifting cultivation which accounts for an estimated 15% of forested land mainly in Kachin, Kayah, Kayin, Chin and Shan states.[103]

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[96] Ibid.

[97] 48 million m^3 based on a conversion factor of 2.4m^3/tonne and 36 million m^3, based upon a conversion factor of 1.8m^3/tonne. Emerton and Yan (2013) estimate the figure at 50 million m^3

[98] Based on ADB, IES and MMIC, 2015, Myanmar Energy Master Plan and Bailis, R., Drigo, R., Ghilardi, A., & Masera, O. (2015) The carbon footprint of traditional woodfuels. Nature Climate Change, 5, 266-272. doi: 10.1038/nclimate2491

[98] Forest Trends, 2014, Analysis of the Myanmar-China Timber Trade. Policy Brief

[99] Forest Trends, 2014, Analysis of the Myanmar-China Timber Trade. Policy Brief.

[100] Emerton, L. and Yan Ming Aung. 2013. The Economic Value of Forest Ecosystem Services in Myanmar and Options for Sustainable Financing. International Management Group, Yangon.

[101] Woods, K., and Canby, K., 2011, BASELINE STUDY 4, MYANMAR, Overview of Forest Law Enforcement, Governance and Trade. Forest Trends for FLEGT Asia Regional Programme August 2011.

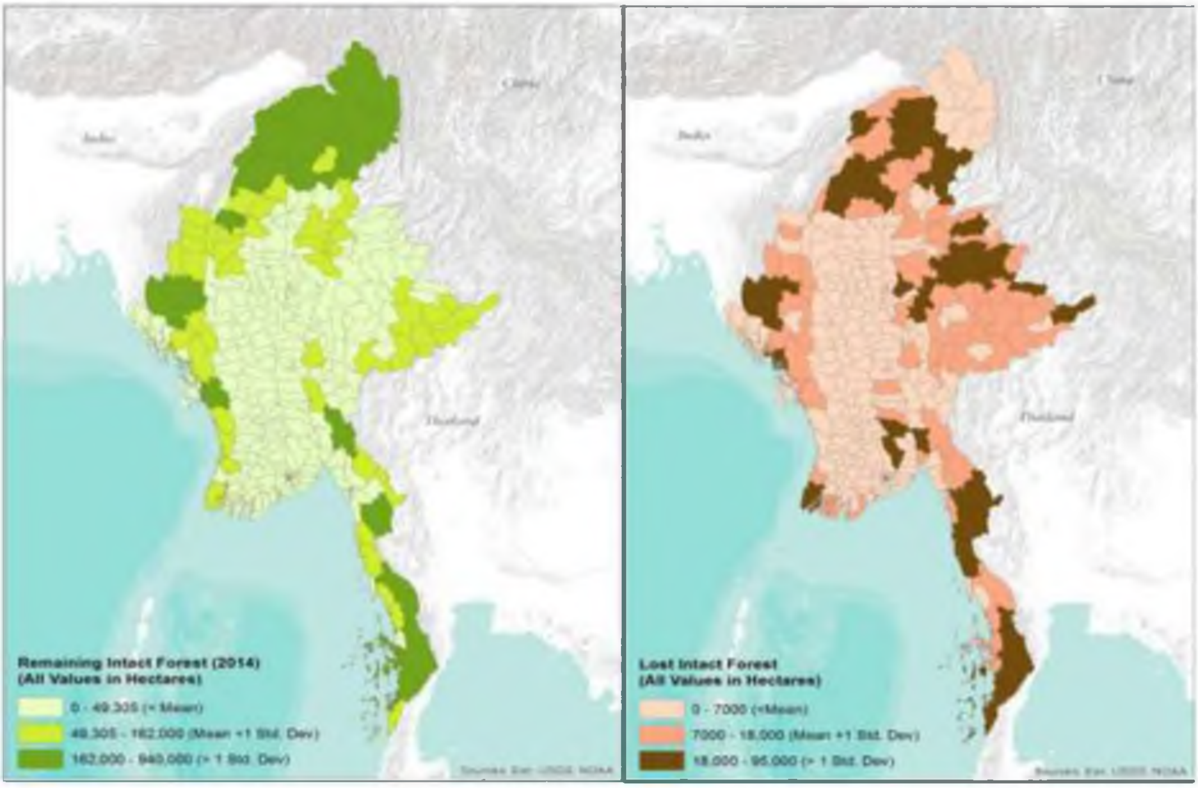
[102] Emerton, L. and Yan Ming Aung. 2013. The Economic Value of Forest Ecosystem Services in Myanmar and Options for Sustainable Financing. International Management Group, Yangon.

[103] Naw, E.E.M., 2014, Shifting cultivation in Myanmar. Presentation.

4.4 Key issues in the forestry sector

There is no clear delineation between key development issues in the forestry sector and key environmental issues as the single most important concern for the sector is the unsustainable use of forest resources and deforestation. There have been dramatic declines in the forested area in Myanmar (Figure 4.6) shows how deforestation in the last decade has been concentrated in and near locations with the largest areas of surviving intact forest in Kachin, Sagaing, Tanintharyi, Shan and Chin. The highest forest losses have been experienced in Shan and Sagaing, significant declines have also been experienced in other mountainous areas including Kachin and Tanintharyi.[104]

Figure 4.6: Townships showing remaining intact forest 2014 (left) and areas showing most forest loss 2002-2014 (right)



Source: Bhagwat, T. et al, 2016, Myanmar Forest Cover Change 2002-2014

The forest loss not only presents concerns for the long-term sustainability of the sector itself, but entails broader environmental consequences, including land degradation, erosion and soil loss, sedimentation, increased flooding, loss of biodiversity, local and global climatic change.

There are multiple causes of deforestation in Myanmar, the most important of these are logging for commercial timber extraction, extraction of timber for fuelwood, and other subsistence uses (construction etc.), mining, infrastructure development, conversion to permanent agricultural use and the expansion and/or intensification of swidden agriculture. These causal factors are often present together at the same location.

It should also be noted that informal, weak or otherwise ambigious land tenure arrangements in much of the country, and in particular in upland areas serve to enable land expropriation and timber extraction. As such it represents an important institutional factor in understanding these drivers of

[104] Note these figures come from a recent paper estimating land cover change using the analysis of satellite imagery. As such this may overestimate the level of forest cover overall. Nevertheless, it does present an internally consistent means of identifying areas of land cover change. Bhagwat, T. *et al*, 2016, Myanmar Forest Cover Change 2002-2014.

deforestation. The allocation of land for plantations and logging concessions in particular frequently effectively entails 'land-grabbing'.[105]

Fuelwood and charcoal - As noted above estimates of fuelwood consumption are at about 36-48 million m^3 per year. This alone is roughly twice the estimated renewable fuelwood supply of 24 million m^3. Given the high rate of deforestation in the intervening decade it is likely that this significantly over-estimates the current level of sustainable fuelwood extraction. In addition to fuelwood use, charcoal production is estimated at an annual rate of 1.4 million m^3 which implies the additional extraction of around 3.2 million m^3 of fuelwood. This means that fuelwood extraction is likely to be a major cause of deforestation in some areas, although as a recent survey of the drivers of deforestation points out, the degree to which fuelwood extraction is a driver of deforestation is likely to vary significantly between different regions.[106]

Logging for commercial timber extraction - An important cause of deforestation is unsustainable levels of timber extraction for commercial use. As noted above this trade consists primarily of commercially valuable species including teak and other hardwoods. Table 4.2 summarizes the main sources of timber, geographical region, the actors in the timber trade, and sustainability and legal characteristics of timber production from these areas.

First, more sustainably managed forest resources (community forests and forest plantations) are not significant contributors to the commercial timber trade.

[105] Kissinger, G. 2017, Background report for identifying the drivers of deforestation and forest degradation in Myanmar. UN-REDD and MONREC

[106] Kissinger, G. 2017, Background report for identifying the drivers of deforestation and forest degradation in Myanmar. UN-REDD and MONREC

Table 4.2: Characteristics of the timber trade from different sources

	Community Forests	Tree plantation	State-managed forest	Natural Forest	
				Log concessions	Land conversion
Relative Volumes of Harvest	N/A	Low	Medium	High	High
Geographic distribution	Throughout country; varying degrees used as resistance to land grabs	Predominantly Burmese central low lands	Predominantly Burma central lowlands up to northern and down to southern Myanmar	Predominantly in ethnic conflict areas	Predominantly in ethnic conflict areas but also non-ethnic states (e.g. Sagaing and Tanintharyi Regions)
Permits	Forest Department	Forest Department	MTE	National and regional Myanmar military, MTE, Para-militaries, Non-state armed groups	National and regional Myanmar military, Ministry of Agriculture & Irrigation, MTE, National Burmese Military, Para-militaries, Non-state armed groups
Harvesting and Trading	Local community	Domestic company or state	MTE, "Crony" Companies	Para-militaries, Non-state armed groups, "Crony" companies, Cross-border companies (in ethnic border areas), Local political-economic elites	Para-militaries, Non-state armed groups, "Crony" companies, Local political- economic elites
Market	Subsistence allowed only	Mostly domestic	Mostly export via Yangon	Mostly export via Yangon & cross border	Export of valuable timber, less valuable for domestic
Legality	N/A	Strong	Strong	Medium-low	Medium
Sustainability	High	High	Medium-low	Low	None
Local land rights	Medium-high	None	None	None	None

Source: Woods, K., 2013, Timber Trade Flows and Actors in Myanmar: The Political Economy of Myanmar's Timber Trade. Forest Trends Report Series

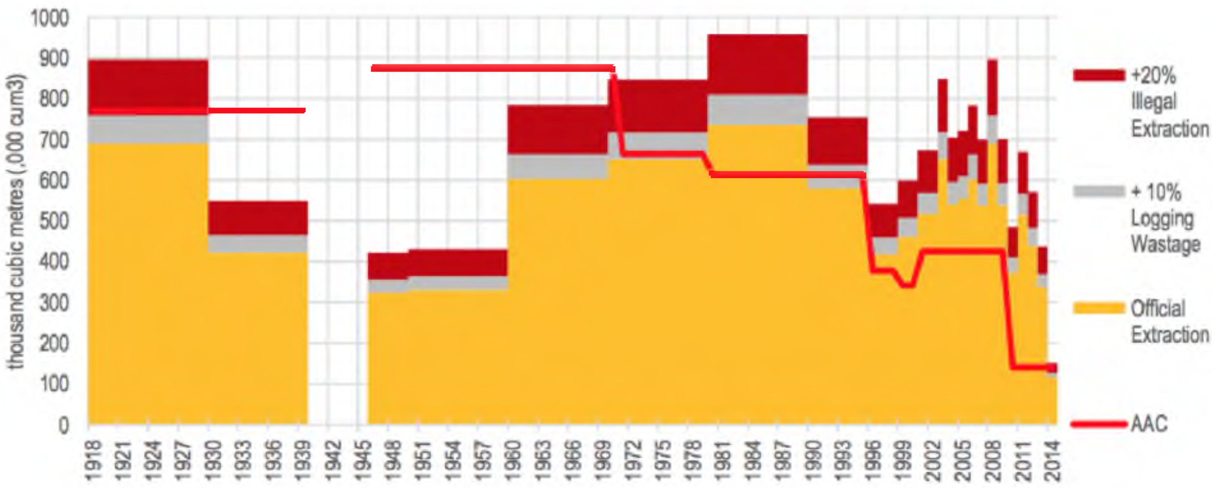
Second, even when considering legally harvested timber from state managed forests, official logging levels have consistently exceeded sustainable levels.[107] Figure 4.7 and Figure 4.8 compare the annual allowable cut (AAC)[108] to the actual levels of extraction including conservative estimates of wastage

[107] Springate-Baginski, O., Treue, T., and Htun, K., 2016. Legally and illegally logged out. The status of Myanmar's timber sector and options for reform.

[108] The Annual Allowable Cut is the upper limit for sustainable extraction. Less than or equal to the annual increment of timber in a given forest area.

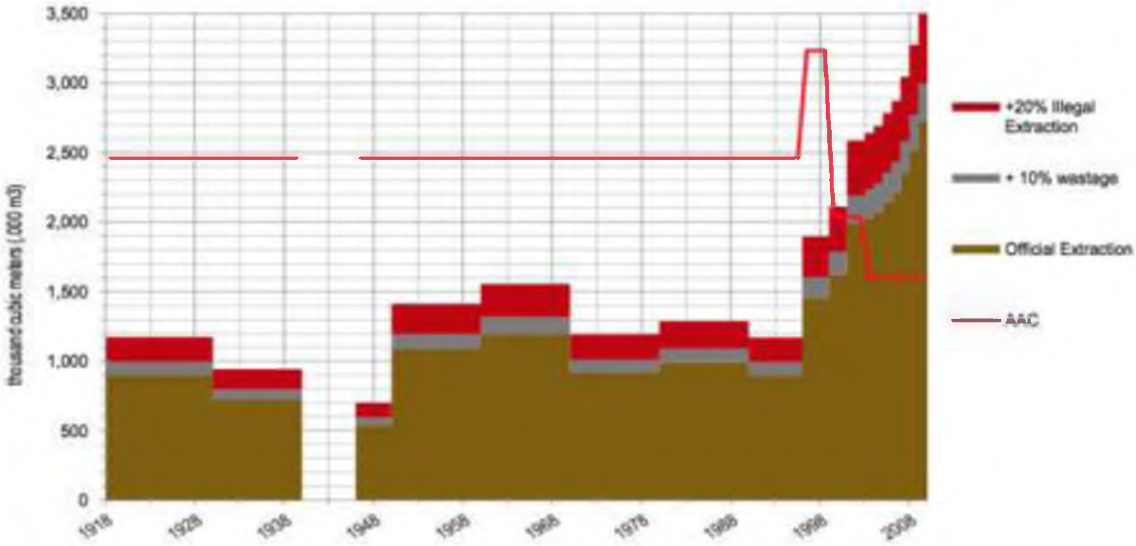
and illegal extraction. These patterns have continued, in the year leading up to the ban on exports, official teak extraction in Sagaing alone exceeded the national AAC in 2013-2014.[109]

Figure 4.7: Teak AAC and production plus estimated wastage and illegal extraction



Source: Springate-Baginski, O., Treue, T., and Htun, K., 2016. Legally and illegally logged out. The status of Myanmar's timber sector and options for reform

Figure 4.8: Other hardwood AAC and production plus estimated wastage and illegal extraction



Source: Springate-Baginski, O., Treue, T., and Htun, K., 2016. Legally and illegally logged out. The status of Myanmar's timber sector and options for reform

Third, in recent years "conversion timber", from the clearance of forests in areas designated for infrastructure development (including roads and hydropower), and agro-forestry plantations (for example, oil palm, rubber and bio-fuels) has been a major source of timber exports. In particular, large scale land acquisitions for agricultural concessions have increased 170% between 2010 and 2013. That does not include concessions granted by sub-national government or local militias. There is some evidence that these concessions are used to enable the extraction of timber rather than to develop plantation as by the end of the period only about 25% of the land was planted with crops. This pattern is illustrated in Figure 4.9.[110]

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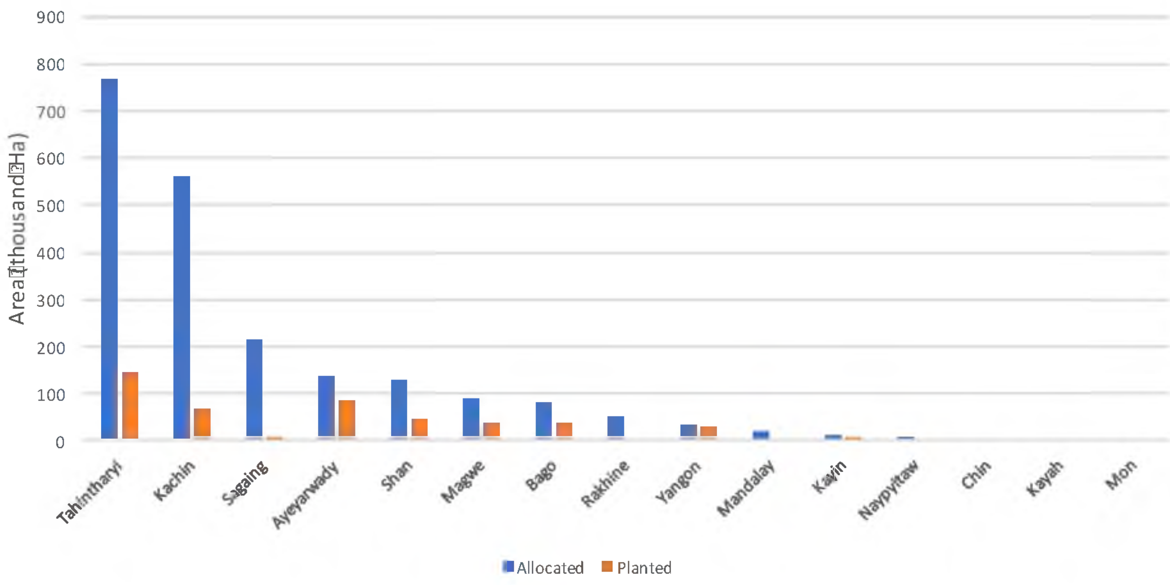
[109] Ibid.

[110] Woods, K., 2015, Commercial Agriculture Expansion in Myanmar: Links to Deforestation, Conversion Timber, and Land Conflicts. Forest Trends Report Series.

Figure 4.9: Area allocated for agribusiness concessions and area planted 2012-2013



Source: Figures from Woods, K., 2015, Commercial Agriculture Expansion in Myanmar: Links to Deforestation, Conversion Timber, and Land Conflicts. Forest Trends Report Series.

A significant proportion of these concessions have been granted in de-gazetted forest reserves, including some areas of high conservation value forest. Data is not collected on timber production from these sources so it is difficult to gauge the extent of timber extracted from these areas.[111] Furthermore, the legality of the timber produced from these areas is unclear.

Figure 4.10 illustrates the extent of the development of plantations in areas in Tanintharyi and in Sagaing regions.

There is a significant trade in illegally logged timber. In principle, all timber extraction that is not approved by the Myanmar Timber Enterprise (MTE) is illegal (Table 3.1). MTE does not administer most logging concessions granted in natural forests. These are typically granted in ethnic areas often under the control of ethnic armed groups. Logging concessions are controlled by local elites (be they local Burmese military and state officials, ethnic armed groups and local ethnic leaders).[112] Much of the timber is illegally exported across the land borders with China and Thailand, although the provenance of the timber exported by MTE through Yangon can be uncertain and may come from illegal sources.[113] Given the nature of the trade figures on the scale of the trade are unavailable. The illegal border trade with China was reputedly at a level of 1 million m^3 in the early 2000s, but

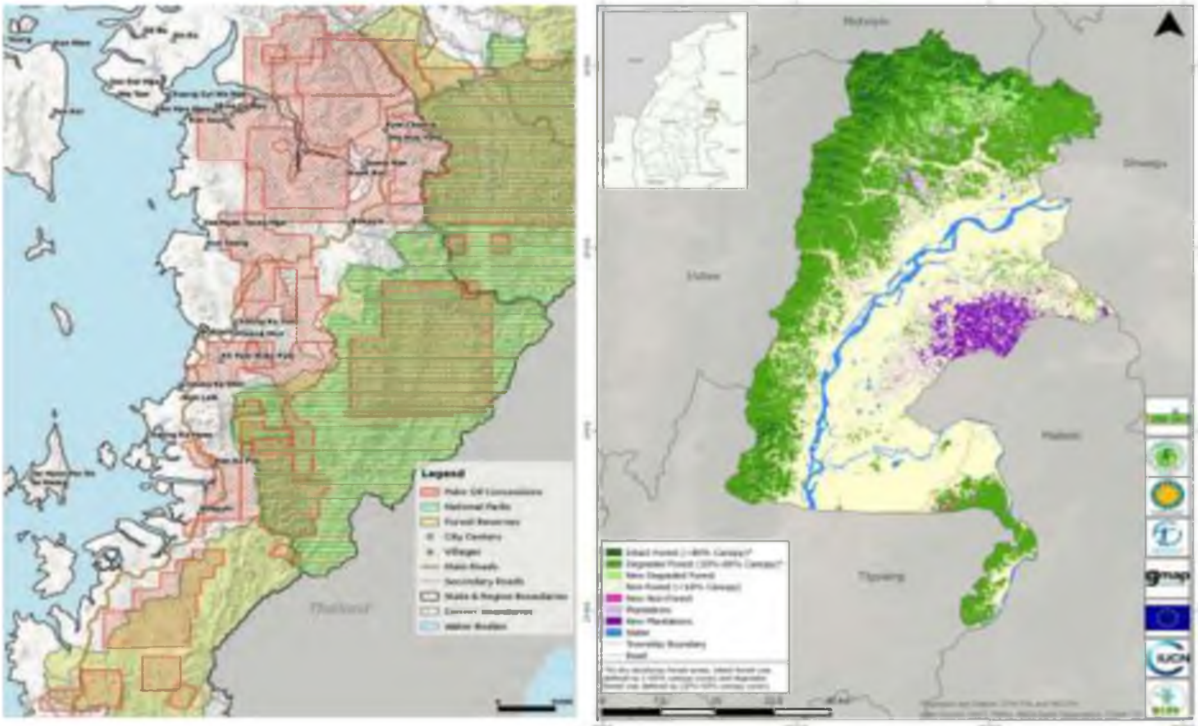
[111] Ibid.

[112] EIA, 2015, Organised Chaos. The illicit overland timber trade between Myanmar and China

[113] Woods, K., 2013, Timber Trade Flows and Actors in Myanmar: The Political Economy of Myanmar's Timber Trade. Forest Trends Report Series

declined following a crackdown by the Myanmar and Chinese authorities. In recent years, reports suggest that the trade is again reaching these levels.[114]

Figure 4.10: Palm oil concessions granted in Southern Tanintharyi region 2013 (left), landcover change Katha Township Sagaing region 2002-2014 (right)



Source: Woods, K., 2015, Commercial Agriculture Expansion in Myanmar: Links to Deforestation, Conversion Timber, and Land Conflicts. Forest Trends Report Series (left), Bhagwat, T. et al, 2016, Myanmar Forest Cover Change 2002-2014 (right)

Mining - As noted in the mining section, the development of mining activities is associated with deforestation. This is caused in part through ground clearance for mining to allow access to mineral deposits. Areas around mines are also likely to be subject to more intensive use as they supply wood used for fuel and construction at mining camps. An example of forest loss due to mining activity is shown in Figure 4.11.

Figure 4.11: Forest loss due to mining 2002-2014 Homalin Township, Sagaing region (left), Satellite image of Homalin Township 2012, showing mining activity along the Uyu river (right)

[114] EIA, 2015, Organised Chaos. The illicit overland timber trade between Myanmar and China

Source: Bhagwat, T. et al, 2016, Myanmar Forest Cover Change 2002-2014 (left), Goggle Earth Image (right)

Transport and other infrastructure development - Infrastructure provision is directly and indirectly related to deforestation in a number of ways. Currently a range of infrastructure developments are taking place in forest areas across the country including the development of transport infrastructure, power generation infrastructure (hydropower plants in particular) and power transmission and distribution infrastructure. Firstly, as with conversion to other land use types new infrastructure implies the clearance of timber. Secondly, the development of infrastructure in forested areas usually implies the development of better access and better enables the extraction of timber, fuelwood and other NTFPs (illegally or otherwise).[115] Thirdly, infrastructure development may imply the displacement of people, if resettled households are moved to forested areas this too can be a cause of additional deforestation and forest degradation. Finally, civil works projects typically employ a large number of constriction workers which live on site for the duration of the project, as with mining camps this influx of workers, can lead to increased demand for forest resources and unsustainable resource use.

Other contributory factors to deforestation may include the conversion of land for small scale, generally household, agricultural production, and the extension and/or intensification of swidden agriculture. However, these factors seem to be of secondary consideration for the forestry sector because they generally take place in areas where forest resources are *already degraded and of limited commercial value*. Furthermore, there seems little available data on the extent of this type of land conversion.[116] Indeed, a recent report on the drivers of deforestation and forest degredation in Myanmar found that there was insufficient information to determine whether or not swidden cultivation was a contributory factor to deforestation in Myanmar.[117]

4.5 Forestry resources, production and known issues by basin[118]

4.5.1 Ayeyarwady

Deforestation and degradation of existing forests remain a critical issue in Kachin and Sagaing. This seems to be due in the main to illegal and legal timber extraction, facilitated through the development

[115] For example see Laurance, W.F., Goosem, M., and Laurance, S.G.W., 2009, Impacts of roads and linear clearings on tropical forests. Trends in Ecology and Evolution. Volume 4, Issue 12. P659-669; and, Dasgupta, S., and Wheeler, D., 2016, Minimizing Ecological Damage from Road Improvement in Tropical Forests. Policy Research Working Paper 7826. World Bank, Washington D.C.

[116] Costenbader, J., Varns, T., Vidal, A., Stanley, L., and Broadhead, J., 2015,
Drivers of Forest Change in the Greater Mekong Subregion. Regional Report. USAID LEAF Programme and FAO.

[117] Kissinger, G. 2017, Background report for identifying the drivers of deforestation and forest degradation in Myanmar. UN-REDD and MONREC.

[118] Much of this analysis is based upon a recent report on forest cover change in Myanmar between 2004 and 2012, this remains the only consistent sufficiently detailed analysis available to enable a description of forest cover change by river basin. See Bhagwat, T. *et al*, 2016, Myanmar Forest Cover Change 2002-2014

of areas cleared for plantation and extensive mining activities. Other regions in the river basin have seen moderate levels of forest loss, particularly in Shan state, although the reasons for this are unclear as mostly in forest areas that are already degraded so is unlikely to be driven by the extraction of valuable timber. A more likely explanation is the continued over exploitation for fuelwood and charcoal, as well as expansion of plantations and agriculture. In the delta deforestation has been driven by the development of plantations but also use of forests for fuelwood and construction materials. It is unclear how much if any forest loss has been due to conversion of land to rice or aquacultural use.

4.5.2 Chindwin

In the Chindwin river basin, high levels of forest loss have taken place due to mining activities, timber extraction and plantation development. The intact forests of Sagaing region, in particular, have seen high levels of forest loss and degradation. The Uyu river basin has seen extensive mining activity which has likely been a cause of considerable forest loss in this area.

4.5.3 Thanlwin

The Thanlwin river basin has seen considerable deforestation along the border areas with Thailand and China. As with other border areas, much of this is likely to have been driven by the illicit border trade. Lowland deforestation has been driven by the development of plantations on the edge of existing agricultural areas.

4.5.4 Sittaung

In the west of the basin in Bago region the development of irrigation reservoirs has been a significant driver of intact forest loss. More generally, forest cover in the basin has been lost to the development of plantations and the encroachment of agricultural land.

4.5.5 Mekong

Significant forest loss particularly in boader areas likely due to the expansion of plantations in these areas, as well as the trade in timber and charcoal.

4.5.6 Tanintharyi

Tanintharyi region has seen forest loss due to the development of plantations and particularly oil palm plantations. Most forest loss has been to the west with the forests on the Thai border remaining relatively intact.

4.5.7 Rakhine

The western most townships of Chin state have seen considerable deforestation although the reasons for this are unclear, given the degraded state of much of the forest in this area most of this change is likely to be driven by fuelwood extraction and conversion to agricultural uses. In the coastal areas of Rakhine state the significant loss of mangrove forests is probably driven by extraction for fuelwood and other subsistence purposes.

4.6 Potential Interactions between hydropower and the forestry sector

Table 4.3 summaries the existing and potential interaction between the hydropower sector and the forestry sector. It describes actual and potential impact of hydropower development on the forestry sector, and the impact of forestry sector activities on hydropower development and potential cumulative impacts.

Table 4.3: Potential interactions between hydropower and forestry

Impact	Narrative

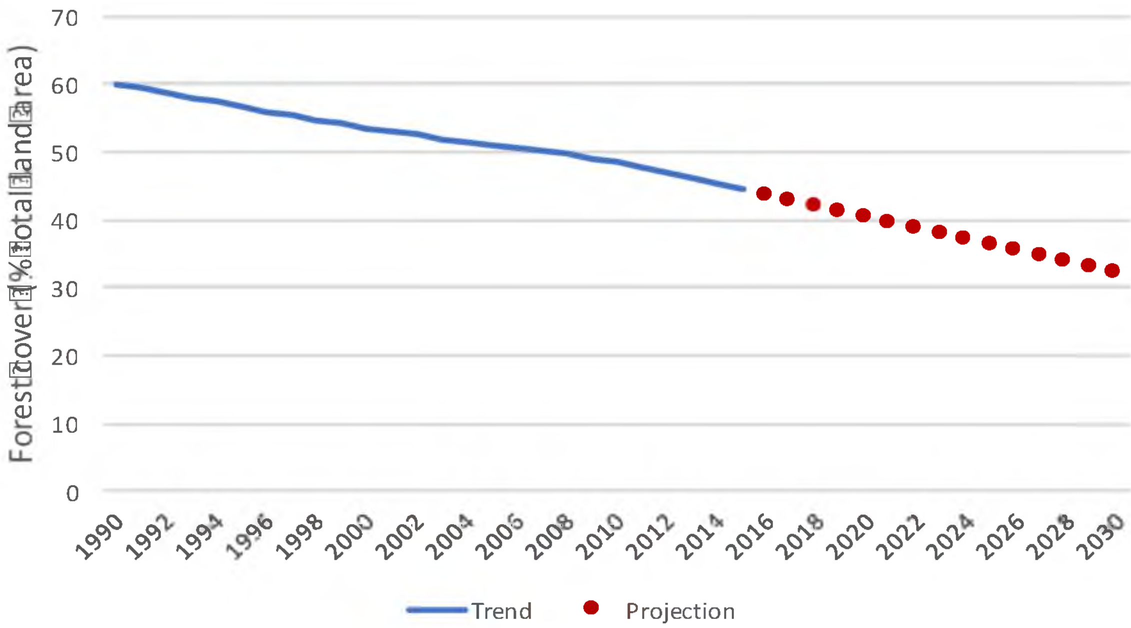
Impact	Narrative
Of hydropower on forestry	
Clearance of forest from inundation areas	Most biomass is typically removed from impoundment areas. This typically involves the clear-cutting of remaining timber on the basis of logging concessions. This typically provides a one-off short term boost to production in the sector. On the other hand, the potential removal forest areas diminishes the productive forest area and to that extent the potential of the sector. Given the lack management of forest resources the legally legitimate extraction of timber from impoundment areas, can be used for cover to launder illegally extracted timber. Finally, if concessions are granted through a transparent, competitive and fair manner they may serve to further entrench problematic patronage networks.
Clearance of forest for transmission lines	Forest will need to be cleared form the path of any transmission lines. Aside from the direct impact in terms of forest loss, similar concerns arise as to those for timber from impoundment areas, i.e. relating to the laundering of illegal timber.
Unsustainable use of forest resources curing construction period	Timber is likely to be extracted from the local area in large quantities to be used in the construction of HP projects. Moreover, workers encampments are likely to require timber for some construction purposes. Workers will use fuelwood and NTFPs from the surrounding area putting further pressure on forest resources.
Deforestation through better access to forests	HP development may improve access to hitherto inaccessible or less accessible forests. Increased access may come through i) the development of access roads; ii) development of transmission lines; iii) the influx of workers over the construction period of the HP plant.
Displacement of agricultural activities through resettlement	Resettlement from hydropower development areas may cause additional pressure on forest resources elsewhere as households are moved into new areas.
Establishment of watershed protection forest	Hydropower development may bring sustainable management of forest resources in the watershed area as a means of protecting the watershed of the hydropower reservoir (see impacts from forestry below).
Of forestry on hydropower	
Watershed erosion and sedimentation	Deforestation resulting from unsustainable forestry practices can result in the loss of land cover in watersheds up-steam of hydropower plants. This may increase erosion and reservoir sedimentation and result in the loss of productivity at the hydropower plant, as well as potentially increased wear and tear on the plant implying higher O&M costs.
Increase in run-off and flood risk	Lower forest cover resulting from unsustainable forestry practices may result in increased levels of run-off and flood risk. This may be particularly acute in catchments that are prone to flash floods. This may mean higher risks of flood damage to HP plants and pose problems for HP plant management.
Cumulative impacts	
Deforestation and biodiversity loss	Unsustainable use of forest resources will compound impacts from other sectors on forest resources. This will lead to a further loss of terrestrial and aquatic biodiversity.

Impact	Narrative
Soil degradation, erosion, sedimentation	Loss and degradation of forest cover in some locations could compound this issue. Other sector exasperating this issue include mining, agriculture and infrastructure development.
Flooding	Increased run-off due to deforestation could result in some circumstances to an increased risk of flooding, this will add to impacts from climate change, infrastructure development, mining and agriculture in upland areas.

4.7 Business As Usual (BAU) projection

Given the dynamic nature of Myanmar's current economic and policy environment, the focus for recent policy changes that the forest sector has become it is difficult to assess the likely trajectory of the sector. However, given institutional and govrnance weaknesses in the sector, alluded to above, compounded both by conlict and the fragmentation of state authority over forestry resoruces, unless there is a significant change in demand pressures (from China, for fuelwood or elsewhere), or pressures from other land uses, current trends in deforestation are unlikely to be reversed. More specifically, a BAU projection through to 2030-2031 would be driven by:

- Contnuing small scale agricultural encroachment;
- Continuing development of plantations and clear cutting;
- Continuing forest degradation on and close to mining and infrastructure development;
- Some declines in fuelwood demand can be expected with better modern energy provision, but charcoal and fuelwood demand are expected to remain important and likely at unsustainable levels;
- Continuing unsustainable timber extraction - both legal and illegal, concentrated in areas of HCV forest which still host significant quantitied of valuable hard woods.



It is difficult to quantify these trends. If pressures remain at similar levels one would expect to see an increasingly rapid decline in forest cover as a smaller and smaller forestry resoure faces the same level of demand pressure. Projections were therefore based upon an assessment of the average area of forest loss over the last five years for which there is data (2011-2015), at arounf 5,460 km^2 $year^{-1}$. It was assumed that forest loss continues at this level. This implies a total forest loss between 2015 and

2030 of 84,600 Km^2 between 2015 and 2030, or 28% of the remaining forest area in 2015. This is equivalent to a deline in forest cover from around 45% in 2015 to 32% by 2030.

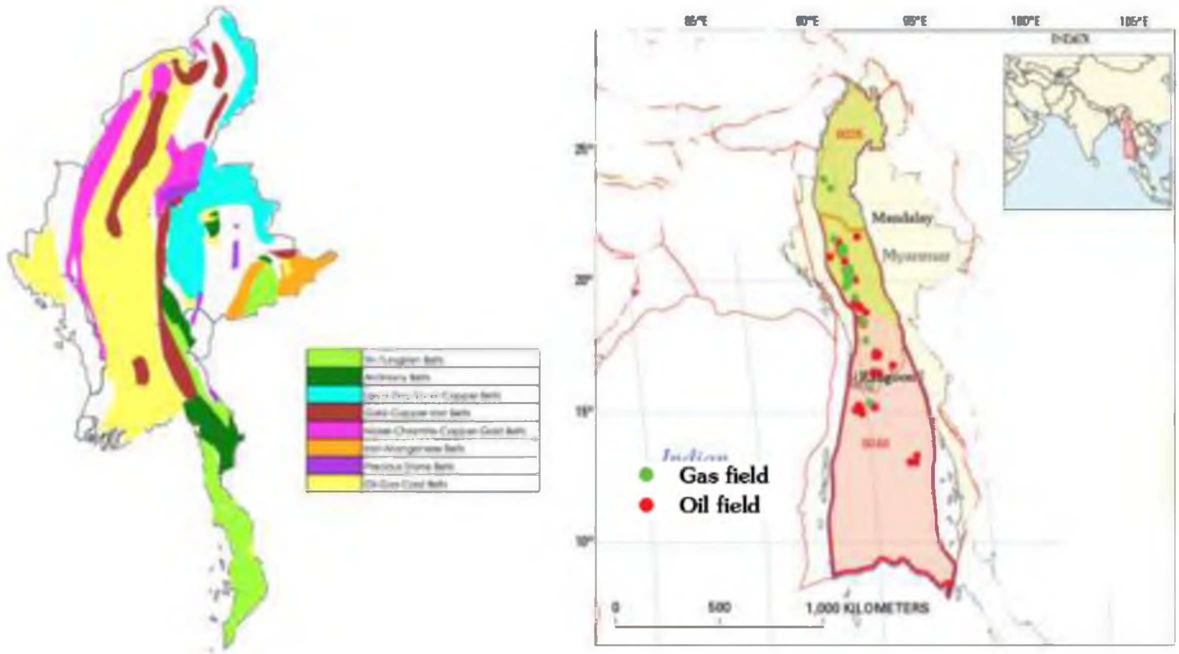
Not clear wht this might mean for timber production, clearly with unsustainable levels of timber extraction it must reach an inflection point at which a large scale timber extraction industry will no longer be viable. This is in contrast to fuelwood and charcoal production which can utilise much less mature forest resources.

5 MINING

5.1 Resources

Myanmar's complex geology means it has potentially large and varied mineral resources throughout the country, many of these resources have yet to be thoroughly explored.[119] A recent study on Myanmar's geological potential notes: "Myanmar comprises one of the most diverse and richly endowed collections of natural resources in Southeast Asia, and as a country retains huge potential for the growth of its mining industry - both through the rehabilitation of old workings, and by the discovery of new ore deposits".[120] Resources include, gemstones, mineral fuels (coal, natural gas and oil), metals (iron, manganese, chromium, nickel, molybdenum), precious metals (gold, platinum and silver), base and non-ferrous minerals (lead, zinc, copper, tin, tungsten, antimony), chemical fertilizer minerals (barite, fluorite, gypsum and rock salt), ceramic and refractory minerals (clay, limestone, dolomite, feldspar and quartz) and construction materials (granite, limestone and sand). Figure 5.1 shows the broad mineral producing areas of Myanmar (left) and the major oil and gas producing areas (right).

Figure 5.1: Major mineral resources (left) and oil and gas fields (right)



Source: IES and MMIC 2015 (left), Ministry of Mines 2013(right)

Myanmar hosts mineral deposits of global significance at Badwin (Lead-Zinc-Silver), Monywa (copper) and Mawchi (tin-tungsten).[121] Despite the undoubted potential commercial significance of these deposits, in general proven reserves are small relative to reserve levels in countries that dominate the markets for these minerals.[122] Table 5.1 highlights the estimated extent of major mineral resources in Myanmar. Given the underdeveloped nature of the most of the estimates of resource potential remain speculative. Estimates of the resource potential for Jade and other precious stones have not been available.

Table 5.1: Estimated major mineral reserves in Myanmar

[119] Htun, K. 2014, Sustainable Mining in Myanmar. Applied Environmental Research: 36 (1): 25-35.

[120] Gardiner,N.J., Robb, L.J., and Searle, M.P., 2014, Review. The metallogenic provinces of Myanmar. Applied Earth Science. Volume 123, No. 1.

[121] Gardiner, N.J., 2014, Burma's Rising Star. The Geologist. Retrieved from https://www.geolsoc.org.uk/Geoscientist/Archive/February-2015/Burmas-rising-star

[122] IES, MMIC and ADB, 2015, Myanmar Energy Master Plan.

Mineral	No. of occurrences	Resource estimate (mmt, possible)	Notes
Lead - Zinc	291	44	Zinc ores of 0.3 - 36% Lead-Zinc ores of 1.06 - 5 %
Lead-Zinc-Silver	>100	-	Major deposits at Bawdwin
Tin Tungsten	480	40	Major deposits at Mawchi and Heinda, Hermingyi
Copper	50	1,583	Copper content 0.4 - 1.5% (Largest deposit at Letpadaung 1,478 mmt at 0.4%)
Gold	341	66	Gold content 1.4 - 27 ppm Main mining operations at Kyaukpahto
Iron	393	495	Iron content 28-66%
Manganese	52	9	Manganese content 6.6-27%
Nickel	14	76	Tagaung Taung lateritic nickel deposit 40 Mt at 2%, Mwetaung lateritic nickel deposit 36 Mt at 1.5%
Chromite	43	-	-
Coal	300	480	Mainly sub-bitumous

Source: Swe, Y.M , 2016, Geology and Mineral Resources of Myanmar. Presentation 28 January 2016.

5.2 Production and economic significance

In terms of production, Table 5.2 shows the major mineral products in Myanmar for the years 2009 - 2013. Myanmar produces a number of mineral commodities including non-ferrous metals such as copper, gold, lead, tin, tungsten and zinc, precious and semi-precious stones (including jade, diamonds, rubies and sapphires), as well as oil, natural gas and coal.[123] Myanmar produced 70% of the world's Jadite and 90% of the world diamonds. The country also produces significant amounts of construction materials such as cement, sand and limestone (Table 5.2) for domestic use.

Figure 5.2 illustrates the main mining locations for different minerals in the country.

Table 5.2: Production of selected minerals in Myanmar 2009 - 2013

Commodity	Unit	2009	2010	2011	2012	2013
Metals						
Antimony	Tonnes	3,700	5,900	7,000	7,400	9,000
Copper (mine output)	Tonnes	3,500	9,000	9,000	19,000	25,000
Gold, refined	Kg	NA	NA	NA	787	893
Lead (mine output)	Tonnes	5,000	7,000	8,700	9,800	11,700
Manganese (mine output)	Tonnes	242,000	299,000	234,400	157,000	160,000
Nickle (mine output)	Tonnes	10	-	800	5,000	9,300
Silver (mine output)	Kg	249	-	-	-	-
Tin (mine output)	Tonnes	1,000	4,000	11,000	10,600	45,200
Tungsten (mine output)	Tonnes	87	163	140	130	130

[123] USGS 2013, USGS Minerals Yearbook. Burma.

Commodity	Unit	2009	2010	2011	2012	2013
Zinc (mine output)	Tonnes	6,000	8,975	30,000	21,539	31,295
Industrial minerals						
Barite	Tonnes	7,623	8,975	30,000	21,539	313,295
Cement, hydralic	Tonnes	669,941	534,034	538,000	600,000	600,000
Gypsum	Tonnes	97,518	81,051	50,000	64,079	60,510
Precious and semiprecious stones:						
Jade	Kg	25,427,237	38,990,035	45,000,000	19,080,442	12,768,000
Ruby	do.	1,674,579	1,612,070	870,000	852,033	395,711
Sapphire	do.	795,228	1,311,327	1,500,000	1,351,916	1,059,559
Spinel	do.	296,956	618,730	620,000	514,052	417,441
Crude, rock salt	Tonnes	NA	NA	NA	207,261	210,000
Stone:						
Dolomite	Tonnes	4,390	3,119	2,000	170	400
Limestone, crushed and broken	1,000 tonnes	4,000	3,200	3,200	428	667
Mineral fuels and related materials						
Coal, lignite	Tonnes	245,418	217,650	300,000	471,022	380,272
Gas, natural marketed	million cumec	11,555	12,425	12,500	12,577	12,894
Crude	bbl	6,881	6,806	6,400	6,197	5,857

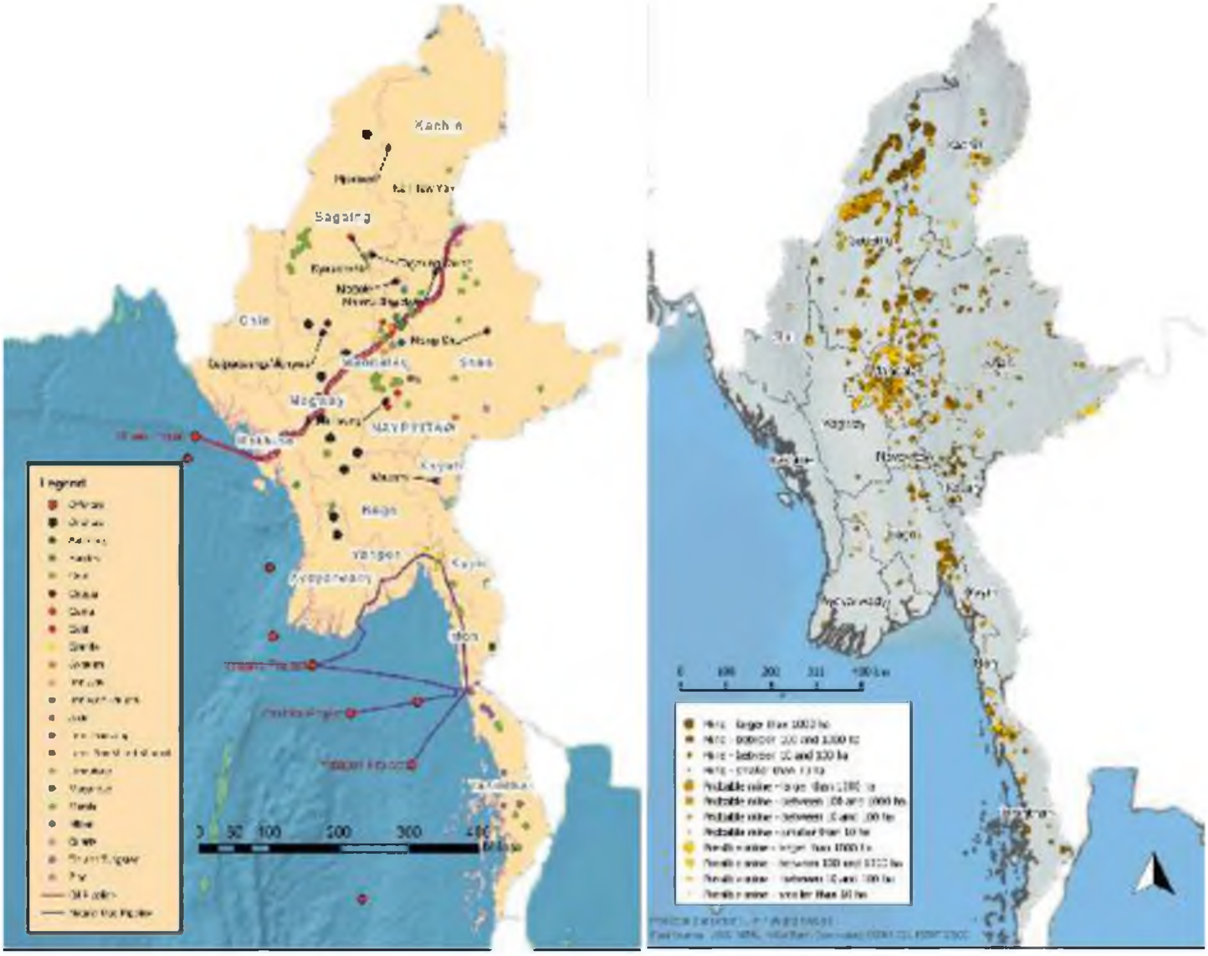
Source: USGS, 2013, 2013 Minerals Yearbook, Burma [Advance Release]

According to official figures mining activities, excluding oil and gas extraction, accounted for 1.2% of GDP or around Kyat 634 billion (constant 2010 prices) in 2014-2015. This represents significant growth in the sector, with average real growth rate in value added running at approximately 20% per year for the last 15 years. The mining sector is an important source of export earnings accounting for around 12% of exports by value in 2014-2015. Jade exports accounted for approximately 8% of this figure.[124] It should be noted that official figures on the trade in Jade have shown a decline in 2015 and 2016. The reasons for this are not clear but may point to a reduction in production due to renewed conflict in Jade producing areas and reduced demand in China.[125]

Considering the potential of the sector, mining has attracted relatively little foreign investment. Between 1988 (when foreign investment was enabled by new legislation) and 2015, only US$2.87 billion was invested in the sector, less than 5% of all FDI. This remains relatively low with the sector attracting only US$ 6.26 million in 2014-2015 out of a total across all sectors of US$ 8 billion. Concerns about the investment climate for mining activities, and especially high risk exploration activities are preventing higher levels of investment (see below).

[124] World Bank, 2016, Myanmar Economic Monitor. October 2015.
[125] Ibid.

Figure 5.2: Mineral extraction activities in Myanmar 2016 (left) estimated ground disturbance due to mining activities 2014 (right)



Source: Bauer, A., Shortell, P. and Delesgues, L., 2016. Sharing The Wealth: A Roadmap for Distributing Myanmar's Natural Resource Revenues. Natural Resource Governance Institute (left), Connette et al., 2016, Assessment of Mining Extent and Expansion in Myanmar Based on Freely-Available Satellite Imagery. Remote Sensing. 8, 912

5.3 Data accuracy

Many commentators have noted that figures on mining and mineral extraction activities are highly unreliable. Production and export figures do not, by and large, take into account in-country stockpiling, illegal and quasi-legal mining operations and a large black market.[126]

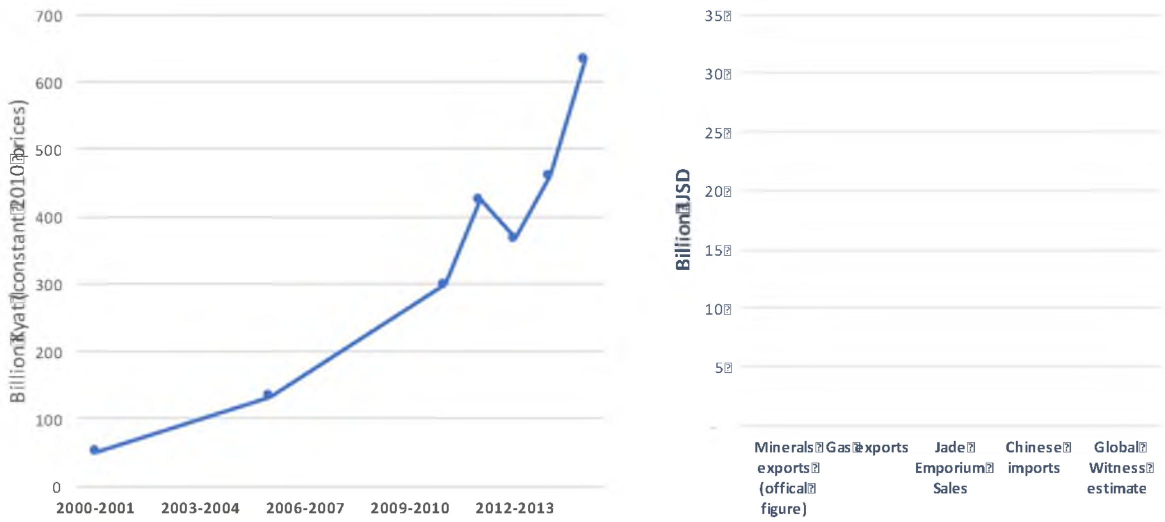
The Jade sector in particular is subject to significant problems relating to illegal activities resulting in the significant under reporting of the value of the sector. While official figures for 2013-2014 showed total mineral exports worth US$ 1.15 billion, estimates from the Myanmar Gem Emporium[127] indicate sales of US$ 3.4 billion in the same year.[128] Higher estimates based upon Chinese imports suggest the trade in Jade was worth US$ 12.3 billion. Global Witness provides a higher estimate of over US$ 30 billion in 2013-2014 based upon estimates of Jade quality and the extent of smuggling across the Chinese border. These estimates are shown in Figure 5.3 (right) alongside the value of gas exports and total national GDP estimates for comparison. As the figures suggest, the value of the mining sector to the economy is likely to be massively underestimated by official figures.

[126] Global Witness,

[127] The government owned trading company which controls the official Jade trade in Myanmar.

[128] Global Witness, 2015,

Figure 5.3: Mining sector value-added (left) and differing estimates of value of Jade exports in 2013-2014 context (right)



Source: Department of Planning, World Development Indicators, IMF 2015, Global Witness 2015

5.4 Employment and livelihoods

Estimates of employment in the mining industry vary markedly between sources. Statistics from the Ministry of Mines (

Figure 5.4) show remarkable fluctuation in the number of employees over the last 15 years. With employment growing from around 14,000 in 1995, to at its peak, over 71,000 in 2010, and dropping dramatically to around 18,500 by 2014. These figures probably show employment in state owned mining enterprises under the remit of the Ministry of Mines and foreign invested mines, and do not take account of private sector and wide-spread artisanal mining. Alternative data gained from the 2014 census suggests employment in the mining industry stood at around 168,000. The census figures probably better represent the importance of employment in mining. In the case of a significant proportion of artisanal miners this is likely to be a secondary and/or seasonal occupation, something which may not be picked up in the census data.[129] Some press reports suggest that the figure for employment in Jade mining alone could be 300,000.[130] Moreover, official figures aside, it is likely that employment in mining has grown over recent years with increases in production of most minerals (Table 5.2).

The census figures indicate that 80% of this mining employment is in rural areas. The breakdown by state and region also illustrates locations where mining activity is concentrated, with Mandalay, Sagaing, Kachin and Magway representing the main Jade, Ruby, Gold and Copper producing areas which accounted for around 75% percent of employment in the sector. In terms of the importance of the mining sector to employment in different areas, almost 6% of the workforce in Kachin state worked in mining, followed by Kayah (3%), and Sagaing and Mandalay (2%). In all other areas mining accounted for less than 1% of employment.[131]

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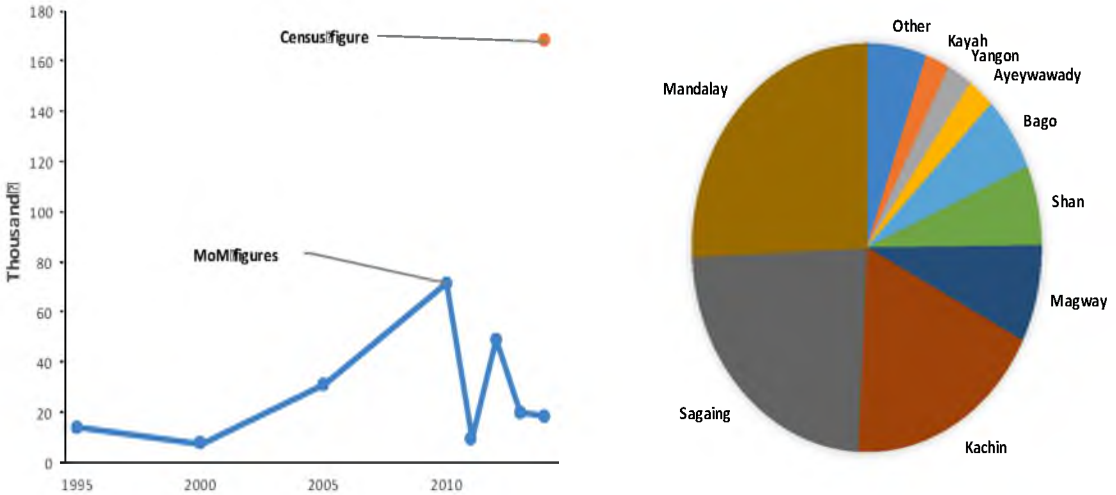
[129] Hentschel, T., Hruschla, F., and Priester, M., 2003, Artisanal and Small Scale Mining. Challenges and Opportunities. IIED and World Business Council for Sustainable Development.

[130] Myanmar Now, 26 May 2016, Dreams of riches and risk of death - a jade miner's life. Retrieved from http://www.myanmar-now.org/news/i/?id=df5e65ef-c61e-43cd-a53d-71aba14403ed

[131] 2014 Census

Figure 5.4: National employment in mining sector 1995-2014 (left) share of employment by region/state 2014 (right)



Source: Ministry of Mines (left), 2014 Census (right)

Mining is physically difficult and dangerous work, but provides considerable livelihood opportunities. It generally generates higher incomes than other employment activities in rural areas such as small scale farming, fishing, and forestry. It also offers the potential for livelihood diversification, allowing farmers to pursue the activity during the dry season when demand for agricultural labour is low. There is some evidence that farmers are forced to take up the activity when they are forced off their land, whether this is through loss of land to infrastructure or plantation development, loss of land to mining or pollution from mines operating in the area.[132]

5.5 Development issues in the mining sector

Despite recent growth in production in the mining sector in Myanmar, the resource base remains underexplored, production is underdeveloped and the sector is largely unregulated. Foreign investment in the sector remains relatively low and further development is constrained by a range of institutional, political and infrastructural factors.

Investors complain that the government has little understanding of the incentive structure facing investors in exploration and mining. This is coupled with unrealistic expectations of the value of mineral deposits, current regulations (including production sharing contracts, high dead-rents and signature bonuses) that are unfavorable to exploration risk investment, complex procedures and over lapping central and sub-national government remits, and a poor business environment. Other risks include complex governance arrangements with multiple stakeholders (for example, central government, sub-national government, different ministries, the military and other armed groups).[133]

The perception of uncontrolled political risk in the sector arising from unresolved conflict, risk of complicity in human rights violations (in particular, related to the expropriation of land) and political uncertainty, also discourage foreign investment in the sector.[134] In addition to these barriers, investors also cite the lack of infrastructure including access to electricity for mining operations, poor roads and communications infrastructure, and continuing conflict in some locations.[135] As such the sector

[132] IHRB, Myanmar Centre for Responsible Business and the Danish Institute for Human Rights, 2016, Myanmar Mining Sector Wide Impact Assessment on Limestone, Gold and Tin. Draft report.

[133] Reynolds, N., 2014, Myanmar's Mining Industry Realities and Visions for the Future. Presentation. CSA Global.

[134] IHRB, Myanmar Centre for Responsible Business and The Danish Institute for Human Rights, 2016, Myanmar Mining Sector Wide Impact Assessment on Limestone, Gold and Tin. Draft report.

[135] Ibid, IHRB, Myanmar Centre for Responsible Business and the Danish Institute for Human Rights, 2016, Myanmar Mining Sector Wide Impact Assessment on Limestone, Gold and Tin. Draft report.

remains dominated by small scale and artisanal mining (ASM)[136] using antiquated techniques and technologies, with low productivity and extraction rates, very poor health and safety practices and effectively no environmental controls.

5.6 Environmental and social issues relating to mining

Mining in Myanmar is characterized by widespread social and environmental issues stemming from poor technology skills and regulation, underinvestment and control by vested interests. While the issues differ depending on the physical and social context of the mining operations and the type of mining operations taking place the key environmental issues that are typical of mining operations in Myanmar include:

- **Erosion** - Mining can lead directly or indirectly to increased erosion. Most mining in Myanmar is surface mining and involves extensive soil disturbance and removal of top soil and vegetation. Without any remedial action this can leave large areas of land vulnerable to erosion.[137] Hydraulic mining is particularly damaging. This is a commonly used mining techniques for the extraction of alluvial gold, tin and precious stones. A high-pressure water jet is used to dislodge the material (rock or sediments) bearing the mineral. The resulting slurry is then processed, typically through sluices to remove valuable material. This type of mining mobilizes large amounts of sediment potentially causing issues downstream, it also leaves large areas vulnerable to further erosion. Mining alluvial deposits on or near water courses also can exasperate erosion and cause issues with river bank stability.[138]
- **Deforestation and biodiversity loss** - Mining is often associated with deforestation and loss of biodiversity. This is not only a consequence of the direct disturbance of land through mining activities but also through ancillary activities associated with mining. Timber is used for fuel, construction purposes within mines and mining camps. The additional access to areas through the creation of mines may also open-up forested areas to logging. Similarly, NTFPs may be subject to unsustainable exploitation around mining camps and previously inaccessible areas opened-up to exploitation from the development of mining activities.
- **Agricultural land and productivity loss** - as with forested areas agricultural land can also be affected directly and indirectly from mining operations. Land can be lost directly to mining operations. Land can also be affected from the disposal of spoil, tailings and pollution from mines sites. Changes in erosion, sedimentation and hydrology caused by mining activities may also affect the productivity of agricultural land.
- **Water pollution** - water pollution is a key concern in mining activities as highlighted during the regional river basin consultation in Monywa for the Chindwin River Basin. The type and extent of pollution will depend upon the type of mining activities taking place. Key concerns include the widespread use of Mercury in gold mining. A recent study showed that concentrations of Mercury in mine-workers were 2.4 times that of the general population as well as high concentrations of mercury amongst sediments in gold mining locations.[139] Other heavy metals (such as lead and cadmium) may also be mobilized in the mining process and contaminate ground and surface water. Cyanide is also widely used in the processing of gold and poses a threat to animal and human health if it contaminates the water supply. Acidification of water sources either through the percolation of water through mined

[136] Small scale mining projects accounted for 1,165 of a total 1,299 licensed mining operations in late 2014. (Ibid)

[137] Connette, L. Et al, 2016, Assessment of Mining Extent and Expansion in Myanmar Based on Freely-Available Satellite Imagery; PYO, 2009, Robbing the Future. Russian backed project threatens Pa-O communities in Shan state, Burma. KDNG, 2007, Valley of Darkness Gold mining and militarization in Burma s Hugawng valley.

[138] Images Asia and Pan Katchin Development Society, 2004, At What Price? Gold Mining in Kachin State Burma; Global Witness, 2015, Jade: Myanmar's Big State Secret; PYO, 2011, Poison Clouds. Lessons from Burma's Largest Coal Project at Tigyit; Myanmar Times, 23 June 2016, Sagaing authorities start gold mine clampdown. Retrieved from http://www.mmtimes.com/index.php/business/21003-sagaing-authorities-start-gold-mine-clampdown.html ; East Asia Forum, 23 September 2015, Myanmar's mining investment and its discontents. Retrieved from http://www.eastasiaforum.org/2015/09/23/myanmars-mining-investment-and-its-discontents/

[139] Osawa, T. and Hatsukawa, Y. 2015, Artisanal and small-scale gold mining in Myanmar: Preliminary research for environmental mercury contamination. International Journal of Hummanities and Cultural Studies. No. 25, 201

materials, through contaminated water drained from mines or through the contamination of water bodies from tailings left as a result of ore processing (e.g. as in the case of copper).[140]

- **Other pollution** - dust and noise pollution from mining and quarrying activities can also cause significant localized environmental problems, impacting human and animal health.

There is an increasing awareness of the environmental problems caused by mining, but this has yet to illicit any substantive regulatory response. Although some relevant policies do exist (e.g. in the 1994 Mines Law to protect against environmental damage, prevent activities that may have detrimental impacts, and requirement for regular inspections and monitoring), the capacity and resources to enforce these requirements are largely absent.[141] In addition to these commonly cited environmental problems a number of health and social issues associated with mining activities in Myanmar have been noted in the literature. The most important of these include:

- **Drug use** - drug abuse is wide spread and well documented amongst mining areas. Miners reputedly take the drug to enable them to cope with the long hours of physically demanding work in the mines. Many miners are long term users of heroin, with some estimates suggesting that up to 60% of Jade miners in Hpakan are addicted to opiates.[142] Widespread intravenous drug use and the sharing of needles amongst miners has also lead to high rates of HIV infection.[143]
- **Accidents** - mining is a dangerous occupation. Working conditions are hazardous as people work in close proximity to large machinery and accidents involving collapses in mine workings and landslides.
- **Occupational health** - aside from accidents at work miners are also prone to work related diseases. Lung disease characterized by frequent lung infections is common and caused by the long-term inhalation of particulate matter and water droplets during drilling without suitable respiratory equipment. Other health issues relate the expose to use of poisonous substances such as mercury, cyanide and contaminated wastewater.
- **Land issues** - expropriation of land for mining remains a critical issue at many mining locations. Farmers and other land owners are frequently evicted from land without adequate consultation, compensation or resettlement. This issue is well documented at numerous locations. For example, conflict with villagers at Letpadaung copper mine where 26 villages have been affected by the development remains on-going.[144]
- **Booming sector effects** - expansion in mining in a location can cause localized price inflation as demand increases with an influx of miner workers, particularly for essential items such as food. This can cause hardship for households employed in other sectors.

5.7 Extent of mining in Myanmar and recent growth

Given the extent of illegal and quasi-legal mining and the absence of accurate figures on mining, establishing trends in the actual conduct of mining activities throughout the country is difficult. A recent study however has sought to establish the extent of mining activities through using GIS analysis to identify areas of likely ground disturbance due to mining.[145] Figure 5.5 (left) shows change in area of mining activity between 2002 and 2015, and (right) the proportion of the national total by region/state. This shows clearly the preponderance of mining activity in Kachin (gold and Jade), Sagaing (gold) and Mandalay (gold and rubies).

Figure 5.5: High certainty mining area 2002 and 2015 (left) proportion of national by region/state (right)

[140] Smith, M., 2007. Environmental governance of mining in Burma. in M. Skidmore and T. Wilson (eds), Myanmar: The State, Community and the Environment. (Canberra, ACT Asia Pacific Press, ANU): 218-45.

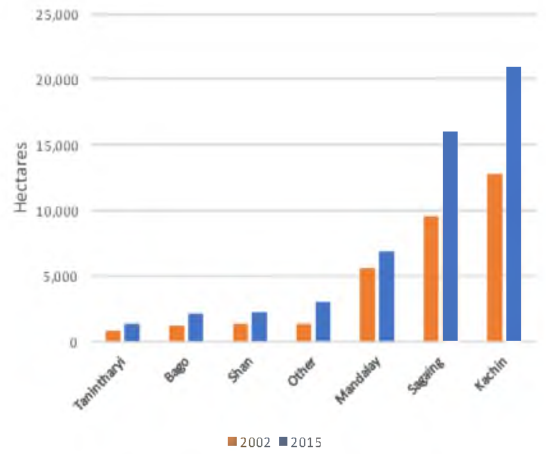
[141] ADB, 2012, Interim Country Partnership Strategy: Myanmar 2012-2014.

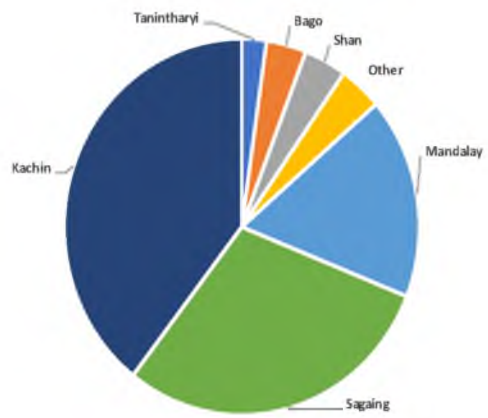
[142] VOA, 27 May 2016, Dangerous Myanmar Jade Mines Bring Income, Death. Retrieved from http://www.voanews.com/a/dangerous-myanmar-jade-mines-bring-income-death/3348378.html

[143] Médecins Sans Frontières treats nearly 2,000 HIV/AIDs patients in Hpakant, and an additional 8,000 at four other clinics in Kachin state. Myanmar Now, 20 June 2016, Jade miners' hopes of fortune often become tragedy of addiction. Retrieved from http://www.myanmar-now.org/news/i/?id=07855944-5f27-4095-b358-d1bca7733090

[144]Zerrouk, E. and Neef, A., 2013, The Discourse of Land Grabbing and Resistance in Newly Reforming Myanmar: The Monywa Copper Mine.

[145] Connette, L. Et al, 2016, Assessment of Mining Extent and Expansion in Myanmar Based on Freely-Available Satellite Imagery





Source: Connette, L. Et al, 2016, Assessment of Mining Extent and Expansion in Myanmar Based on Freely-Available Satellite Imagery.

Those estimates are conservative. Table 5.3 gives a breakdown of estimates of surface disturbance due to mining in terms of the certainty of the attribution of the activity to mining by river basin. This serves to emphasise the preponderance of mining in the Ayeyarwady (and Chindwin) basin.

Table 5.3: Mining area by major river basin and certainty in Myanmar 2014

Region	Certainty (area, Km²)			Total	
	High	Medium	Low	Area (Km²)	Share (%)
Ayeyarwady	44,096	22,320	8,597	75,013	87.0
Sittaung	2,756	936	292	3,984	4.6
Tanintharyi	1,692	582	532	2,806	3.3
Thanlwin	1,654	1,025	262	2,941	3.4
Others	19	291	1,213	1,523	1.8
Total	50,217	25,154	10,896	86,267	100

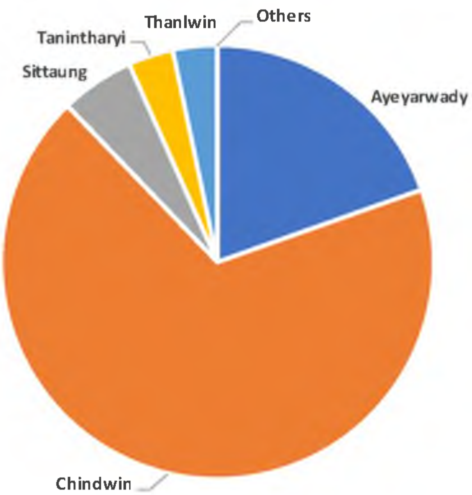
Source: Consultants analysis based upon Connette, L. Et al, 2016, Assessment of Mining Extent and Expansion in Myanmar Based on Freely-Available Satellite Imagery.

This analysis does not capture much of the placer gold mining that takes place on in-stream deposits which are subject to flooding during the wet season, nor does it include mining of river sediments using floating dredgers or shaft/tunnel mining. Nevertheless, these conservative estimates do indicate the large extent and rapid expansion of mining activity in Myanmar over the last decade or so, and suggest a minimum bound for mining activity.

5.8 Mining activities by major river basin

A significant amount of mining activity is indicated in the Chindwin, Ayeyarwady, Sittaung, Thanlwin river basins and the Tanintharyi coastal basin. Moreover, there are indications that the extent of these activities has increased significantly over the last decade in all these basins. Nevertheless, the Chindwin and Ayeyarwady basins, covering a combined 61 % of Myanmar's land area, together account for almost 90% of the mining activity in the country (Figure 5.6).

Figure 5.6: High certainty land disturbance due to mining in 2015 by major river basin



Source: Connette, L. Et al, 2016, Assessment of Mining Extent and Expansion in Myanmar Based on Freely-Available Satellite Imagery.

5.8.1 Ayeyarwady

The Ayeyarwady river basin hosts several important mining areas, particularly to the north of the basin (

Figure 5.8). These include precious stone mining areas at Mogok in Mandalay region and Mong Shu in Shan state, precious stone belts and a ruby mine at Mong Shu in Shan state. Mandalay is also the location of extensive gold mining activity (Figure 5.9). Other important mining activities in the basin include the nickel mine at Tagaung Taung, also in Mandalay, the Silver-Zinc-Lead mine at Bawdin in Shan state, and the Modi Taung gold mine.

Figure 5.7 Mining activity in Ayeyarwady River Basin

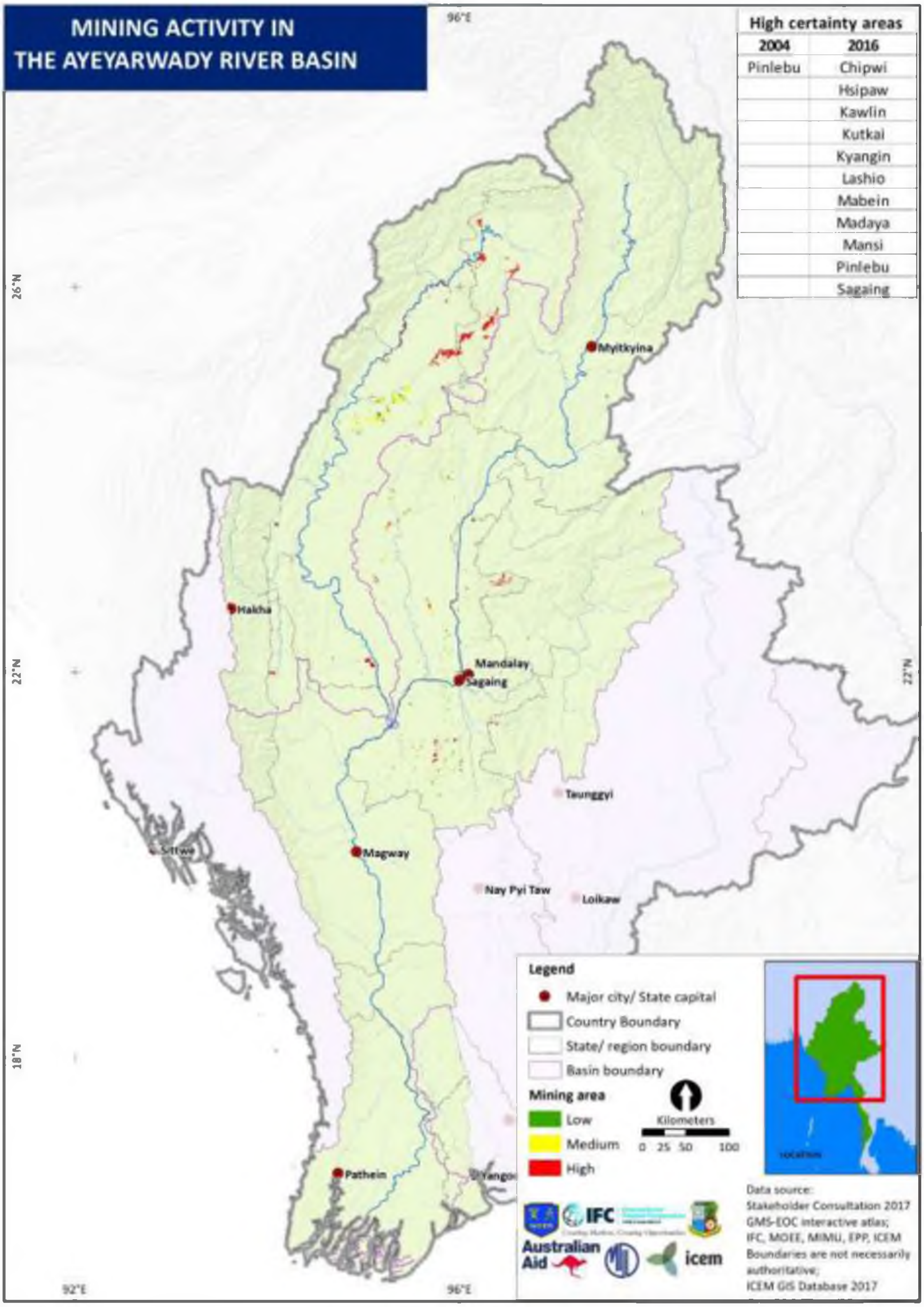
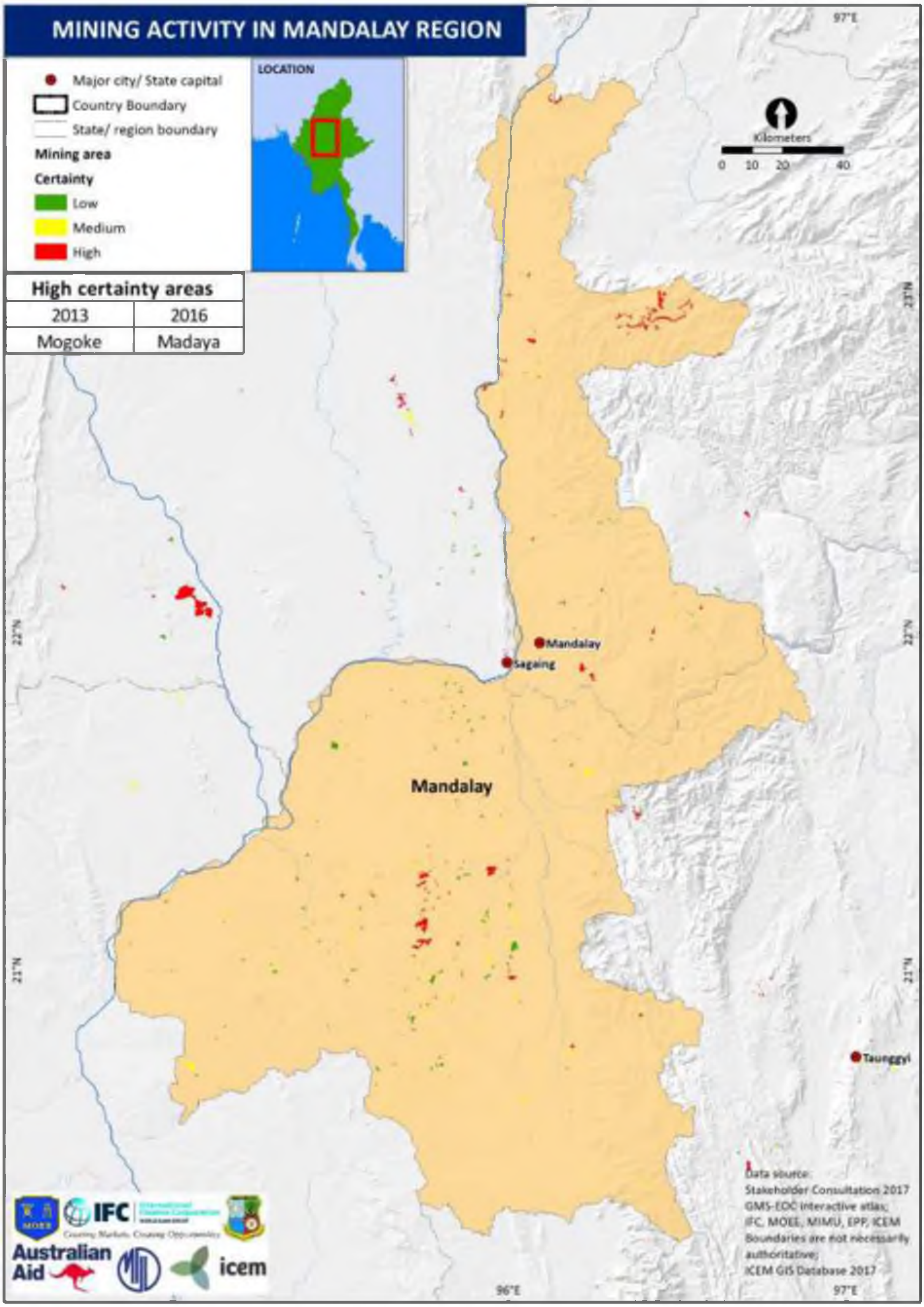


Figure 5.8. Mining activity in the Mandalay Region



5.8.2 Chindwin

The Uyu river basin is home to the Hpakant Jade deposit in its headwaters. There is also a considerable amount of gold mining along the length of the Uyu river (Figure 5.10), as well as elsewhere in the Chindwin Basin (Figure 5.9). The Monywa copper mine and associated power plant at Kalewa are also on the Chindwin River. The Chindwin and Uyu River Basin are probably the areas with the greatest concentration of mining activity in the country, as such there are numerous reports of environmental and social problems relating to mining in these areas.

Figure 5.9. Mining Activity in the Chindwin Basin

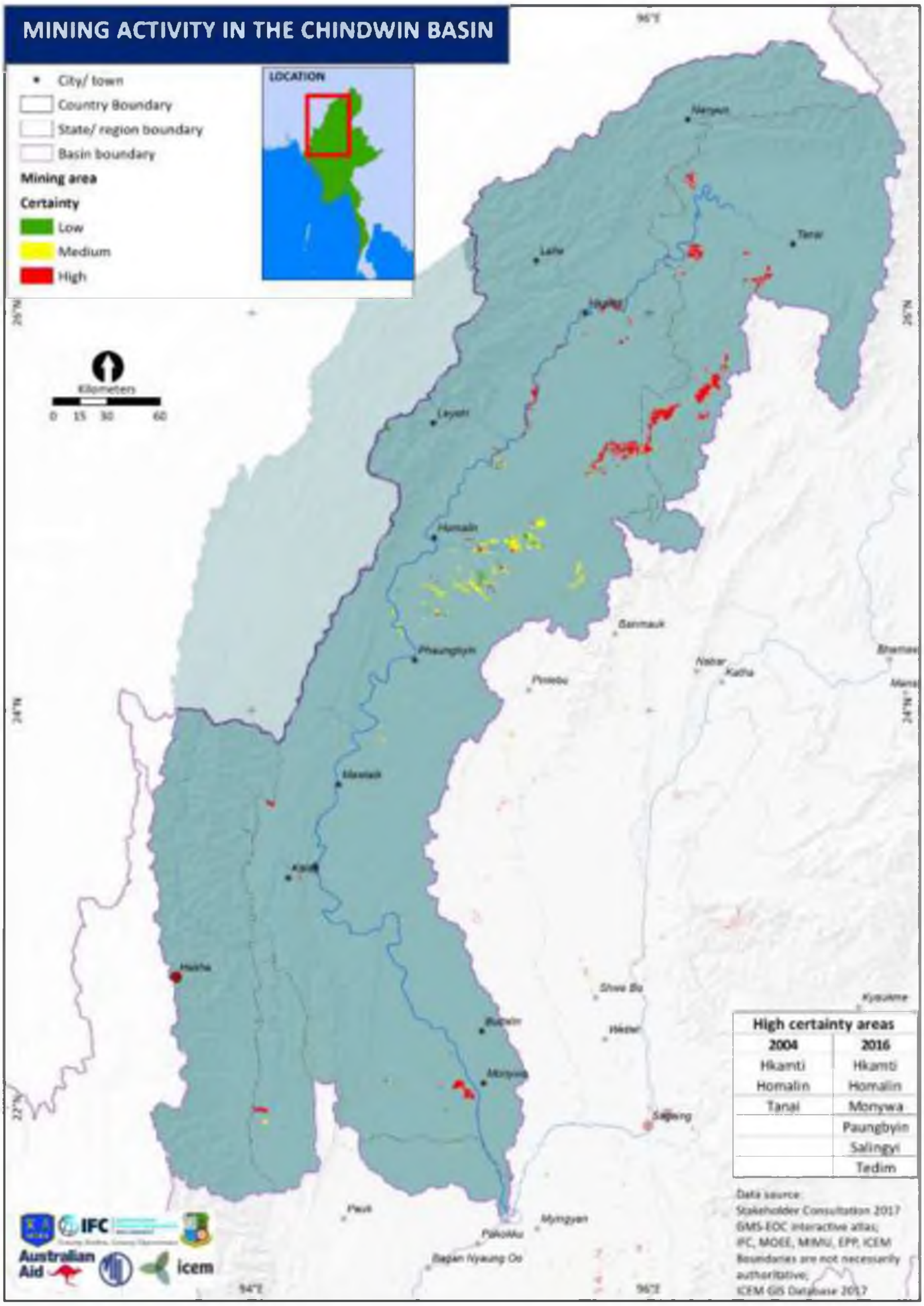
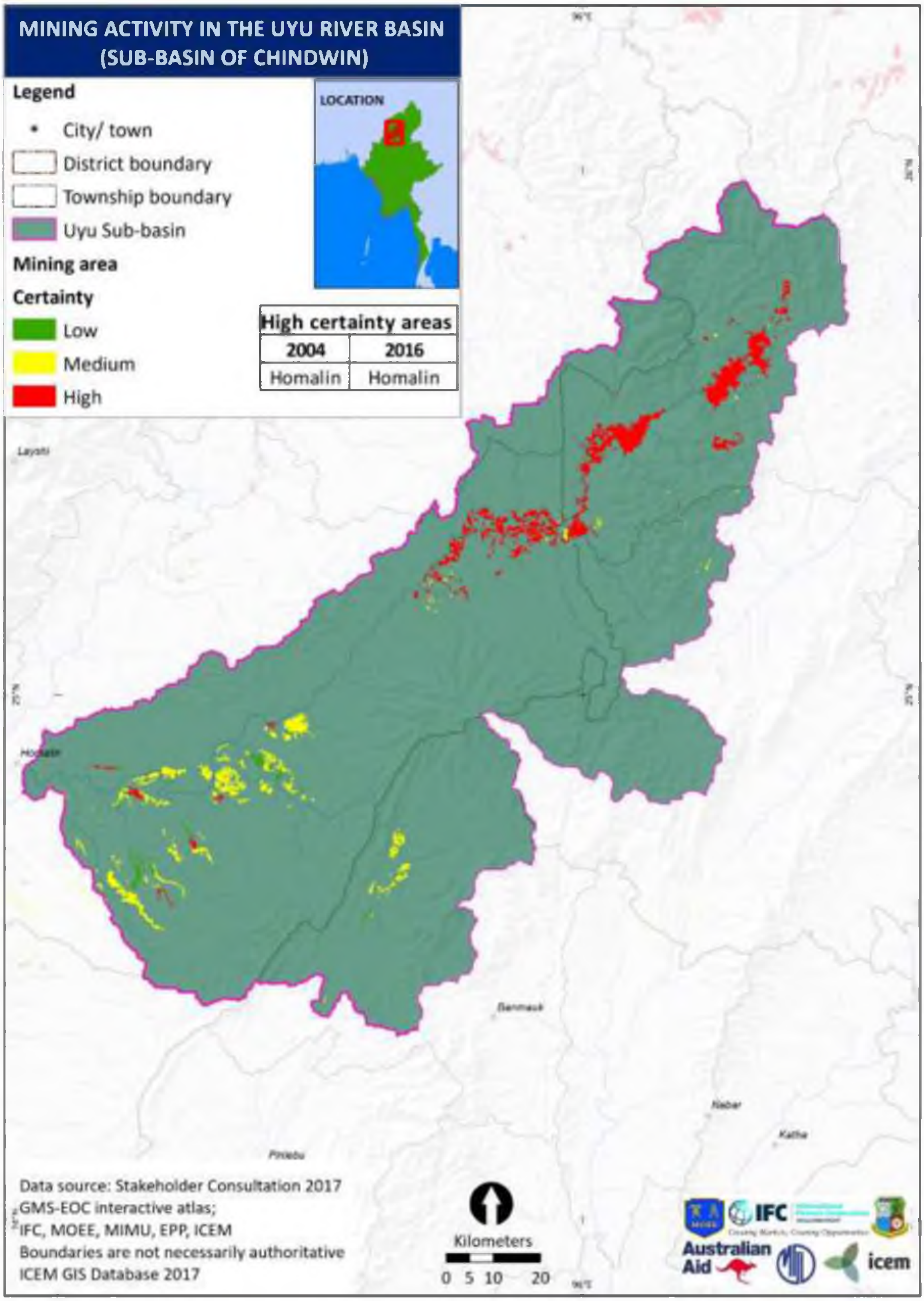


Figure 5.10. Mining areas in Uyu River Basin



5.8.3 Thanlwin

The Thanlwin is also the site of mining for limestone, some ASM gold mining, and Mawchi tin-tungsten mine. There is also a mine mouth coal fired power plant at Mawchi + coal

5.8.4 Sittaung

There are indications of significant mining activity in the Sittaung river basin. Some of this is accounted for by granite mining and ASM gold mining. Other mining activity may also be present in the basin. There are no known reports of issues related to mining occurring in this river basin.

5.8.5 Taninthayri

The Tanintharyi hosts a considerable amount of tin and tungsten mining, although there are no reports of environmental or social issues related to mining in this area.

5.9 Sand mining

Sand mining has been widespread on major rivers and beaches throughout Myanmar. Up and down the major rivers of Myanmar sand dredgers are a common sight. Moreover, judging by the experience of other countries in the region (notably Vietnam, Cambodia and Indonesia) demand from every sector can be expected to increase. Regulatory environment and enforcement are weak. Although the central government has banned sand mining from beaches enforcement seems be weak and it is unclear whether this is enforced at the local level.[146]

While firm figures are difficult to come by, in 2008, Singapore imported 600,000 tonnes of sand for construction purposes. There are no figures on domestic demand, but based upon domestic cement demand of 8 million tonnes in 2016, domestic sand demand in the region of 64 million tonnes is feasible.[147] With burgeoning demand for construction materials domestically and high levels of regional demand - particularly from China and Singapore - the market will continue to drive an expansion in sand mining. Some evidence suggests that a recent tightening of regulations on sand mining in Cambodia acted to increase demand for sand in Myanmar.

As transportation constitutes a large share of the cost of sand, extraction tends to be concentrated as close as possible to the sources of demand. This typically means urban areas where most construction takes place. Moving large quantities of sand and gravel from the same location can quickly alter channel morphology, which can have impacts at the site and downstream (these may include impacts on bank stability, increased erosion around instream infrastructure and loss of habitat). At present little is known about the sediment budget for the major rivers in Myanmar, or about the actual extent of sand extraction from rivers (see Sediment chapter in this SEA baseline assessment report). Further investigation of sediment budget and extent of sand mining will be carried out under SOBA Package 4: Sediment and Geomorphology for the Ayeyarwady Basin.

5.10 Potential Interactions between hydropower and mining

Table 5.4 summaries the potential interaction between the hydropower sector and the mining sector, setting out the potential impact of hydropower development on the mining sector, the impact of mining sector activities on hydropower development and potential cumulative impacts.

Table 5.4: Potential interactions between hydropower and mining

Impact	Narrative
Of **hydropower** on mining	

[146] Myanmar Times, 8 April 2015, Ministry orders ban on sand mining. Retrieved from http://www.mmtimes.com/index.php/national-news/13983-ministry-orders-ban-on-sand-mining.html

[147] This is based upon the assumption that most sand demand comes from construction demand for concrete, a typical mix which would be one part cement to eight parts sand. This is a conservative estimate as it does not take account of sand demand for other uses such as asphalt, other construction uses and industrial purposes.

Impact	Narrative
Changes in river flow	Hydropower plants, depending on design and management will alter water flows downstream of the project. This may affect downstream mining activities in a number of ways including: 1) If HP plants are used to supply peak demand this may imply the significant fluctuation of river water levels, particularly in the dry season. This would negatively affect mining taking place along the river course, in particular ASM involved in alluvial gold mining; 2) The storage and release of water from HP plants over the dry season may substantially increase dry season flows improving water availability for mining activities (e.g. hydraulic mining).
Availability of electricity	To the extent that HP plants improve the availability, price and quality of electricity supplies, this may improve the productivity of the mining sector which can rely heavily upon electricity for operating mine equipment and ore processing.
Access to mineral deposits	Any mineral deposits in the inundation areas of reservoirs will become inaccessible for the period of the project.
Of **mining** on hydropower	
Watershed erosion and sedimentation	Surface mining activity leads to increased erosion and increased sediment loads in the water. Mining activities may also lead to wider land use change in an area and forest loss. Increased sediment load will affect the productivity of hydropower projects. Increased sedimentation in the reservoir may over time decrease storage volumes in the reservoir. Increased sediment loads may also increase wear and tear on plant machinery potentially increasing O&M costs for operators.
Disposal of mining waste	Disposal of mining waste in-stream, up-stream of HP plants may cause issues similar to those of increased erosion, such as increased reservoir sedimentation.
Water pollution and reservoir water quality	Water pollution caused by mining up-stream of HP plants may accumulate in reservoir sediments affecting water quality and posing a long term threat to human health and the environment.
Cumulative impacts	
Deforestation and biodiversity loss	Deforestation and unsustainable use of NTFPs caused by mining will add to pressures exerted by other sectors including forestry, hydropower, agriculture and other infrastructure development.
Erosion, sedimentation, land degradation	Deforestation, agriculture, infrastructure development and mining are all likely to compound these issues.
Water pollution	Water pollution from mining may compound impacts from other sectors, such as increasing pollution from agricultural run-off, urban and industrial development as well as HP induced water quality issues.
In channel erosion, channel stability	Sand mining along with the likely reduction in sediment loads due to hydropower development may result in increased down-steam erosion and increased channel instability.

5.11 Business As Usual (BAU) projection

Mining has been identified as a sector with substantial potential for growth. However, the current institutional, policy and political conext is unlikely to encourage significant investment for the reasons

cited above. Given current conditons, it is therefore deemed unlikely that significant increases in the level of investment in the sector are likely to take place. This of course may change, in particular if the governance and instirutional context becomes more favourable. International commodity market prices may also have a significant influence on activity in the sector.

ASM presents a different picture. Anecdaoal evidence suggests that the number of people enganged in ASM has increased significantly over the last few years. However, this information insufficient to generate a trend. The data on land disturbance cited above also suggests a significant expansion of ASM activity throughout the country over the last decade. However, known vialble mineral deposits are limited, and it is deemed unlikely that the extent of mining will increase at a similar rate in coming decades. Therefore, for the purposes of future projections we assume that the level of ASM activity remains at approximately the same level as is currently the case.

6 TRANSPORTATION

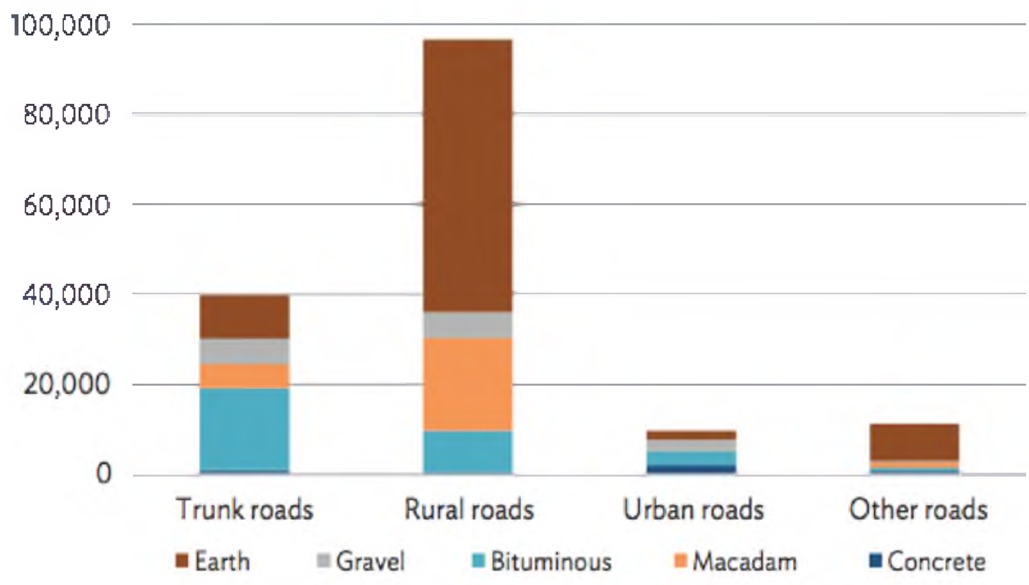
Transportation infrastructure has been included as a key sector for consideration in the SEA due to potential interactions between the development of the sector and hydropower and the potential for cumulative environmental impacts stemming from transportation sector development and hydropower. However, unlike other sectors it is possible to delimit the scope of analysis in this sector to i) the provision of transportation infrastructure outside urban areas; and, ii) navigation in inland waterways, as other aspects of sectoral development (e.g. urban transport, air, public transport, transport services, and railways) are unlikely to have important environmentally determined interactions with hydropower development.

6.1 Myanmar's road network

Myanmar has around 157,000 Km of roads, of these roads around 97,000 Km (62%) are village-to-town roads, 40,000 Km (26%) are trunk roads, 9,500 Km (6%) are urban roads, and 11,000 Km of other roads managed by the Army Corps of Engineers (Figure 6.1).[148] Myanmar has road density of 0.23 km/km^2, around the same level as Lao PDR and Cambodia, but much lower than Thailand at 0.77 km/km^2.[149] However, according to recent analysis given population density, economic size and vehicle fleet the figure is quite large.[150]

Myanmar's road network is also of generally poor quality. Only 53% of the trunk-road network is currently paved, and of those 80% are paved using rough-penetration macadam, and around two-thirds of paved trunk roads are only around 3.7 m wide (12ft). In 2015, over half of trunk roads were regarded as in "poor condition" with basic road safety features generally absent and road alignments frequently dangerous.[151]

Figure 6.1: Road Construction Type by Length (Km) 2013



Source: ADB, 2016, Myanmar transport sector policy note: Trunk roads

The rural road network is similarly underdeveloped (Figure 6.2). With only around 5% of the 49,000 Km paved, 70% with earthen construction, and around 73% of village roads are only classified as "tracks".[152] In remote and mountainous areas such as Chin and Kachin states the proportion of all-weather roads is even lower. During the rainy season many of these roads become impassable to most

[148] ADB, 2016, Myanmar Transport Sector Policy Note. Summary for Decision Makers.
[149] ADB, 2016, Myanmar transport sector policy note: Rural roads and access. Mandaluyong City, Philippines: Asian Development Bank.
[150] ADB, 2016, Myanmar transport sector policy note: Trunk roads
[151] Ibid.
[152] ADB, 2016, Myanmar transport sector policy note: Rural roads and access.

motorized vehicles. Moreover, there are many of the timber bridges on rural roads that need to be replaced frequently and are easily damaged in storms and floods.

Figure 6.2: Myanmar's road network

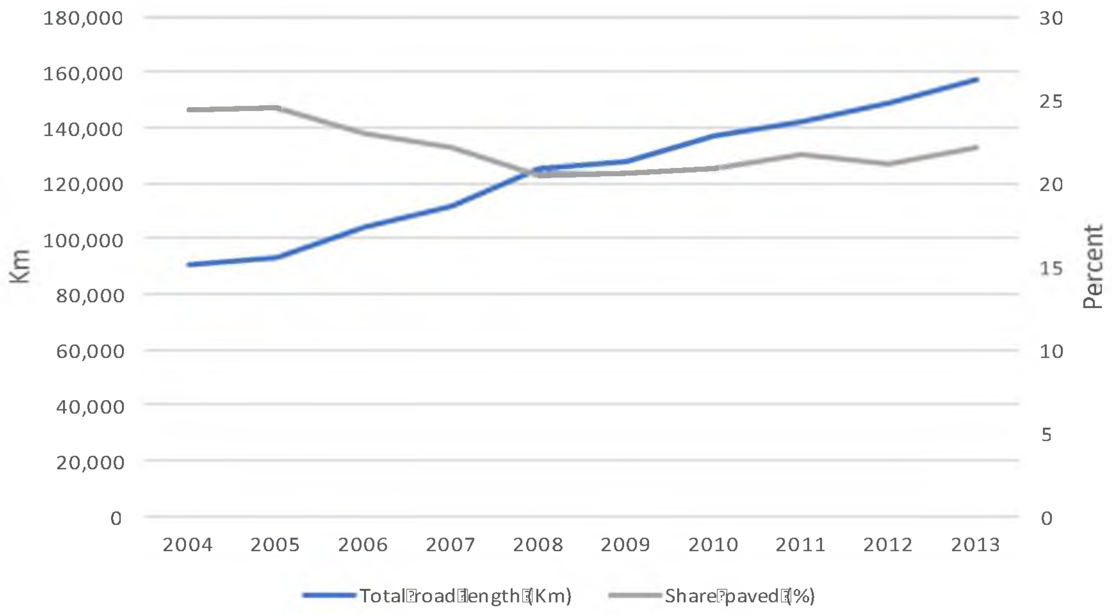
Source: ADB, 2016, Myanmar Transport Sector Policy Note. Summary for Decision Makers.

Road bridges also form an essential part of the terrestrial transport infrastructure, particularly in providing all season access. Most bridges are constructed from timber which needs to be replaced relatively frequently. Concrete bridges are becoming more common. Most bridges are less than 30 m in length, although there are a substantial number of larger bridges. In 2013 there were 7,056 bridges, of which 2,421 were concrete, 4,584 were timber, 16 were bailey bridges and 35 suspension bridges. There were also 1,220 culverts.

6.2 Road network development

Myanmar has been rapidly developing its road network. Up to 2014, the country had been developing approximately 8,000 Km of new road per year, of which around 2,500 Km has been paved. Trunk roads have been extended by around 1,000 Km per year between 2004 and 2014 (Figure 6.3).

Figure 6.3: Road expansion and share of paved road 2004-2013



Source: ADB, 2016, Myanmar transport sector policy note: Trunk roads

The number of bridges has similarly increased with around 20,800m of bridges, causeways and culverts constructed between 2011 and 2014 by the Department of Rural Development, of which 858m have been of concrete bridges, 13,143m have been of timber bridges, 5,771m of culverts and 1,033m have been of causeways. In addition, a total of 1,664 small bridges, 212 large bridges (of greater than 30m span) and 86 suspension bridges have been built by MOBA since 1994.[153]

6.3 Key development issues related to road sector development

While the development of the road network in Myanmar has been progressing rapidly, there are a number of important issues facing the provision of transportation infrastructure:

- **Limited provision of all season rural road infrastructure** - much of the road infrastructure in rural areas becomes impassible during the wet season. About 20 million people live in villages without access to all season roads. In rural areas with poor road access the costs of transportation services remain very high. The problem of rural road access is particularly acute in Chin, Kachin and Kayin states.[154]
- **Poor quality of roads** - most trunk roads are in poor or bad condition (60%), requiring urgent maintenance or full rehabilitation.
- **Underinvestment and lack of efficient investment** - Myanmar has been under investing in transport infrastructure. Countries at a similar level of development typically invest 3-5% of

[153] *Ibid.*
[154] *Ibid.*

GDP, but in the decade between 2005 and 2015 Myanmar only invested around 1.0-1.5% of GDP. Spending on road infrastructure is around a third of what is needed, and current spending is not efficient.[155]

6.4 Environmental issues related to road development

There are a number of key issues related to road development.

- **Deforestation and forest degradation** - The provision of roads in forested areas enables the extraction of timber and NTFPs and is a factor in forest degradation and deforestation. While an issue well documented globally,[156] it is not clear to what extent this is an issue in Myanmar. The relationship is complex. Roads enable the distribution of population over a wider area, meaning a greater area of forest can be affected. Land beside roads is more likely to undergo permanent conversion to agriculture, relative to land situated at a greater distance from roads which may regenerate naturally.
- **Ecosystem fragmentation and biodiversity loss** - Transport infrastructure presents a number of threats to biodiversity (i) Physical disturbances - impact on soils, hydrology and aquatic ecosystems (e.g. increased run-off, erosion and turbidity of water bodies) (ii) Chemical and nutrient pollution - pollution from transportation and freight including heavy metals, oil, and air pollution- especially important where there are water bodies near roads which receive a pulse of pollutants with run-off from heavy rain fall; (iii) Edge effects - physical and biotic changes associated with abrupt changes in land cover (i.e. such as road verges); (iv) Road related mortality - some species may be vulnerable to traffic on roads, increased predation or increased hunting activity; (v) Barrier effects - roads may act as a barrier to movement for certain fauna ; (vi) Exotic species invasion - roads can act as a conduit for the ingress of invasive species ; (vii) human invasion - roads facilitate access for hunters, miners, loggers, farmers and other colonists.[157]
- **Roads and logging** - the creation of roads or tracks for logging. The FAO comments that "Forest roads are complex engineering structures … [t]hey are unquestionably the most problematic features of timber harvesting operations since a major part of the total soil erosion resulting from timber harvesting operations can be attributed directly to roads, often because of design or construction flaws or poor maintenance practices".[158] This is a likely to be an importance category of road infrastructure not properly accounted for in the literature on transportation in Myanmar. The extent of and damage done by roads associated with timber extraction is likely to be significant (see point below on erosion and landslides).
- **Erosion** - the physical disturbance of the surface by transport and road construction can result in erosion. Typical erosion mechanisms related to road type are given in Table 6.1. At present it is not possible to attribute land degradation issues with road development in Myanmar, but it is likely to be a significant contributor, particularly in hilly areas.

Table 6.1: Typical erosion mechanisms and environmental impacts related to road type

Type of	Type of road

[155] ADB, 2016, Myanmar Transport Sector Policy Note. Summary for Decision Makers.

[156] See for example, Dasgupta, S., and Wheeler, D., 2016, Minimizing Ecological Damage from Road Improvement in Tropical Forests. World Bank Policy Research Working Paper 7826; and, Laurance, W.F., Goosem, M., and Laurance, S.G.W., 2009, Impacts of roads and linear clearings on tropical forests. Trends Ecol Evol. 2009 Dec; 24(12):659-69.

[157] Laurance, W.F., Goosem, M., and Laurance, S.G.W., 2009, Impacts of roads and linear clearings on tropical forests. Trends Ecol Evol. 2009 Dec; 24(12):659-69.

[158] FAO, 1996, FAO Model Code for Forestry Harvesting Practice. Retrieved from http://www.fao.org/docrep/V6530E/V6530E06.htm

impact	Formal (Bituminous, concrete, macadam)	Formal low-cost (earth, gravel)	Informal (earth)
On-site	Minimal	Compaction Sheet wash Rills Gullies Mechanical Dislodgement Flow confinement	Compaction and disaggregation Rills Gullying Flow confinement Mechanical dislodgement
Off-site	Piping Bank collapse	Gullies Sod breakaway and transport Bank Collapse	Gullies
Environmental Impacts	High turbidity Reservoir siltation	High turbidity Mass transport Loss of accessibility Loss of land Decline in land productivity	High turbidity Lateral shift of impact Lateral degradation with multiple tracts Loss of land Decline in productivity

Source: Based on Beckedahl, H.R., Hill, T.R., and Moodley, M., 1999, Soil Conservation Perspectives of Road Infrastructure within a Development Context in South Africa.

- **Landslides** - The development of roads through cutting into slopes along a contour line can be a contributory factor to landslides. Landslides are also a major problem for road development, particularly in hilly areas in areas which receive heavy seasonal rainfalls. Other activities such as deforestation and mining can affect slope stability and the likelihood of landslides. Recent heavy rainfall events in Myanmar have shown how vulnerable road infrastructure can be.[159]

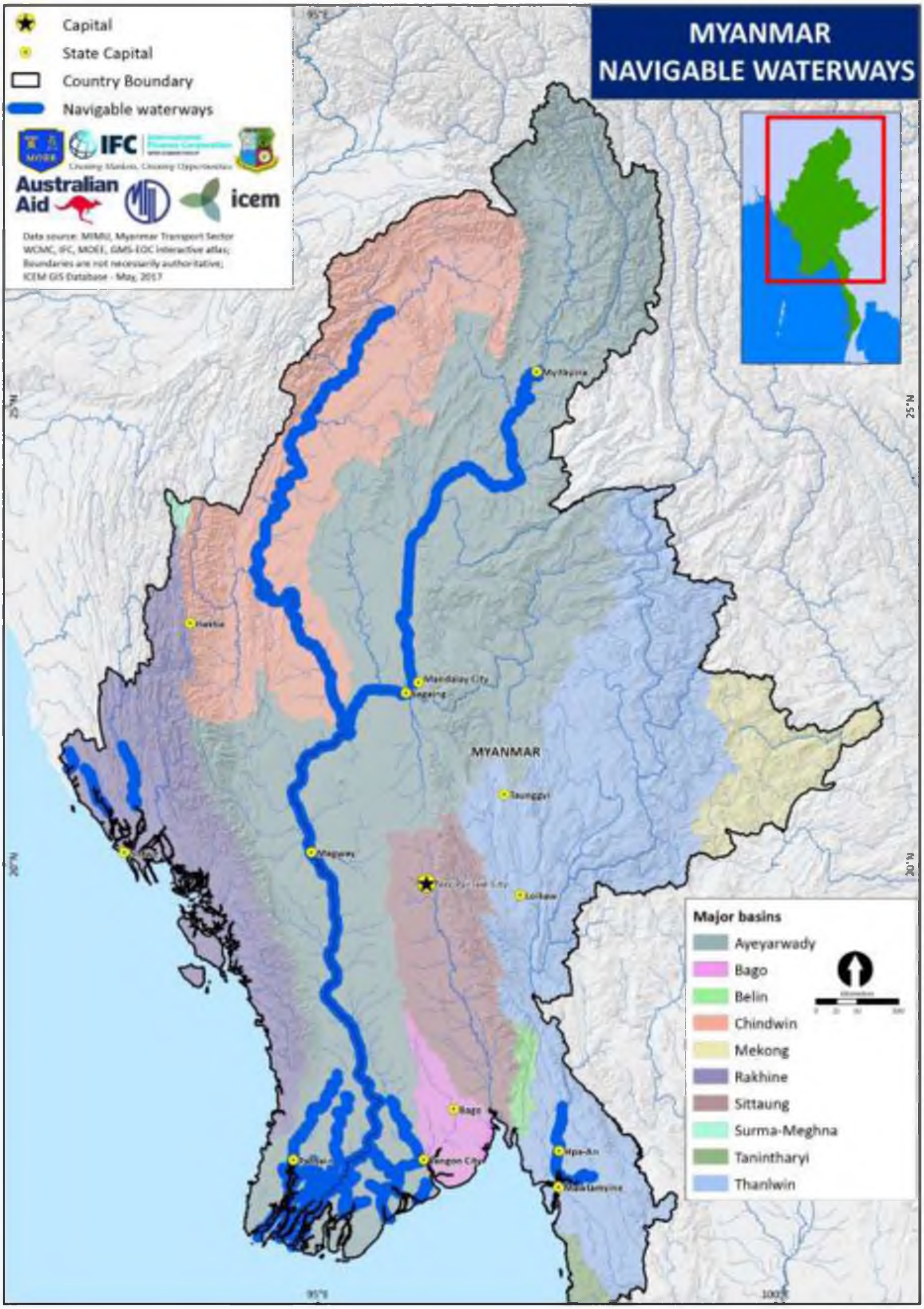
6.5 River transport network

Myanmar has over 9,600 Km of navigable rivers. Around 6,650 Km of navigable waterways are situated in the five largest rivers (Ayeyarwady, Thanlwin, Chindwin, Sittaung and Kaladan) with easy access to population centres. The most important navigable waterways are those of the Ayeyarwady, Chindwin and the network of waterways in the Ayeyarwady delta. The Ayeyarwady is navigable to Bhamo year-round (1,332 km upstream of Yangon) and to Myitkyina during the dry season (1,526 km upstream of Yangon). During the wet season the stretch between Bhamo and Myitkyina is not navigable due to rapids. The Chindwin is navigable from the confluence with the Ayeyarwady to near Minsin district in Sagaing region. The Ayeyarwady delta contains a large network of navigable waterways consisting of river channels and canals. Heavy siltation in the Sittaung restricts its use for commercial navigation. The Thanlwin has a large number of rapids again restricting its use for commercial navigation. Coastal rivers in Rakhine and Tanintharyi states are served by small steamers (

Figure 6.4).[160]

[159] Government of the Union of Myanmar, 2015, Myanmar Post Disaster Needs Assessment of Floods and Landslides.
[160] ADB, 2016, Myanmar transport sector policy note: River transport.

Figure 6.4: Navigable waterways in Myanmar



Source: ADB, 2016, Myanmar transport sector policy note: River transport.

Despite the potential of the physical network, navigation is often difficult along the main rivers because of shallow water during the dry season, shifting river channels and the lack of adequate terminal facilities:

- **Navigation channels** - the rivers are still basically used in their natural state, with channel improvement taking place on an ad hoc and sporadic basis. Nautical charts are not available. Large variations in seasonal discharges mean that river levels fluctuate significantly, navigation is difficult in many stretches during the dry season when water levels are low. The river systems are also subject to heavy sedimentation which results in changes in river course and channel instability.
- **Navigation** - navigation is restricted to daylight hours and relies on local pilots who know the conditions in a stretch of river, heavy sedimentation and shifting channels mean channel markers are temporary, adequate charts and route maps are not available.
- **Ports** - there are 50 ports along the Ayeyarwady, the Chindwin, and the Ayeyarwady Delta. However, these are often only landing beaches, approach channels and mooring areas are not defined and cargo and passenger handling facilities are inadequate. Seasonal changes in water levels also make construction of port facilities difficult and costly.[161]

Table 6.2: Navigable waterways by length

Navigable waterways	Length (Km)
Ayeyarwady	1,534
Chindwin	730
Thanlwin and rivers in Mon State	380
Rivers in the Ayeyarwady Delta	2,404
Rivers in Rakhine State	1,602
Total	**6,650**

Source: ADB, 2016, Myanmar transport sector policy note: River transport.

6.6 River transport development

Despite the potential for river transport in Myanmar figures suggest that the sector has declined in recent decades, mainly as a consequence of the development of better road transport. In the 1990s the sector accounted for more than 20% of national freight. This figure has shrunk to 6% in 2013.[162] While the sector has the potential to be competitive, it has not received adequate investment. According to a recent ADB report, the sector has been "abandoned by the Government". Starved of even basic investment its competitiveness has been eroded by more modern road-based transport.[163]

The fleet has been increasing gradually since the 1990s. In 2014, there were approximately 4,590 vessels registered for inland waterway operations with the Department of Marine Administration, with a cumulative capacity of around 93,400 passengers and 68,600 tonnes of freight. Smaller vessels and dumb barges are registered at the local level, numbering an estimated 38,000 in 2013. Estimates suggest that around 60% of river freight reaching Mandalay was carried by barges, 24% by private passenger-cum-cargo vessels and 16% by state owned passenger-cum-cargo vessels. Most vessels are small and made of wood. Utilization rates are very low at around 20,000 Km/year.[164]

[161] *Ibid.*
[162] *Ibid.*
[163] *Ibid.*
[164] *Ibid.*

6.7 Environmental issues

Key environmental issues related to navigation include:

- **Pollution** - spills of oil, chemicals or other freight into waterways is a key concern. Information on the frequency of this kind of incident has not been available. However, given the currently large share of oil and oil products in cargoes (around 31%)[165] this risk is likely to be significant.
- **Channel and navigational infrastructure construction** - the construction of channels or instream infrastructure can disrupt the dynamic balance, disrupting morphological processes. However, there is little evidence of this happening in Myanmar to date - with future navigational improvements it may become an issue.
- **Backwash** - Wakes generated by navigation vessels may cause additional erosion to river banks.

6.8 Navigation by major river basin

Currently the only significant potential for commercial navigation operations is in the Ayeyarwaddy and Chindwin river basins.

6.9 Potential interaction with hydropower

Table 6.3: Potential interactions between hydropower and transport

Impact	Narrative
Roads	
Impacts of **hydropower** on roads	
Inundation of road in impoundment area	Roads with-in inundation area will need replacement.
Increased erosion around bridges and other instream transportation infrastructure downstream	Sediment trapping and flow variability may increase erosion down-stream of hydropower projects. This may necessitate the provision of more protection form erosion for in-stream infrastructure.
Unpredictable water levels	If plants are used for peaking, or in the event of unplanned releases river levels downstream may change significantly over a short period of time. This may make fording the river or crossing causeways difficult/dangerous.
Flood protection	If hydropower plants are managed to prevent flooding this could result reduce damage risks for downstream infrastructure such as roads.
Impact of **roads** on hydropower	
Improved transportation infrastructure from development of access roads	Access roads built as part of hydropower project development may improve access for remote communities.
Loss of power production from management for multiple use	If HP are managed for flood prevention this may reduce overall power output.
Cumulative impacts	

[165] *Ibid.*

Impact	Narrative
Deforestation and land degradation and associated impacts	Additional road construction due to hydropower may allow access to previously inaccessible areas and through over exploitation of natural resources may indirectly lead to deforestation and land degradation
Navigation	
Impacts of **hydropower** on navigation	
Increased dry season flows	If HP plants release significant amounts of water during dry season, this may improve navigability of the river in some areas.
Blockage of navigation route	While major navigation route are well downstream of hydropower projects, navigation by smaller locally used craft will be blocked by hydropower projects. Navigation will also no longer be possible in the dewatered section of the river downstream of the dam.
Changes in river morphology	Changes in sedimentation and river flow due to HP construction may change river morphology in unpredictable ways. Reduction in sediment load may improve navigability but also increase erosion around in-stream infrastructure.
Unpredictable changes in water level	Unplanned or peaking operations may pose a hazard for navigation particularly for small boats. Unpredictable changes in water levels may leave some boats stranded if there is a sudden reduction in flow.
Impact of **navigation** on hydropower	
Pollution	Pollution issues related to navigation up-stream of hydropower projects may have impacts on reservoir water quality.
Cumulative impacts	
Water quality	Together with HP development navigation may be a significant contributor to a decline in water quality.
River morphology	Navigation improvements together with HP development and the change in sediment loads and flows this implies may have significant, unpredictable impacts on morphological processes.

6.10 Business As Usual (BAU) projection

For the puroses of this analysis we concentrate on the development of rural roads as these represent the transportation sub-sector which are likely to have key interactions with hydropower development.

The current 20-year plan (2011-2030) has the objective of providing road access to all villages by 2030. This includes 10,000 Km of village road construction and 19,000 Km of village road imporvements - mostly upgrading roads to macadam or bituminous surfaces. The plan also envisages the construction of 17,000 m of bridge construction and 77,500 m of casueways and culverts.[166] This is likely to have significant knock-on impacts on upland aeas in particular. For example, a recent study modelling possible impacts of rural road upgrading on forests in Myanmar found substantial increases in deforestation. This will likely intensify pressures on forests and terrestrial ecosysms discussed in section 4 and the baseline report on terrestrial ecosystems.[167]

[166] ADB, 2016, Myanmar Transport Sector Policy Note. Summary for Decision Makers.

[167] Dasgupta, S., and Wheeler, D., 2016, Minimizing Ecological Damage from Road Improvement in Tropical Forests. Policy Research Working Paper 7826. World Bank, Washington D.C.

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