Papua New Guinea
Forest Authority

CAPACITY DEVELOPMENT PROJECT FOR OPERATIONALIZATION OF PNG FOREST RESOURCE INFORMATION MANAGEMENT SYSTEM FOR ADDRESSING CLIMATE CHANGE

FINAL REPORT
(Annexes, Part I)

September 2019

JAPAN INTERNATIONAL COOPERATION AGENCY

KOKUSAI KOGYO CO., LTD.

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Part I

Technical Cooperation Outputs

Annex 1

Outputs Related to PNG-FRIMS

PNG Forest Resource Information Management System (PNG-FRIMS) Guidebook

PNG Forest Resource Information Management System (PNG-FRIMS)

Guidebook

July 2019

Papua New Guinea Forest Authority (PNGFA)

Japan International Cooperation Agency (JICA)

PNG Forest Information Management System (PNG-FRIMS) Guidebook

2019-07

PNGFA

JICA

JICA-PNGFA Project: Capacity Development Project for Operationalization of PNG-FRIMS for Addressing Climate Change

Revision Sheet

Release No.	Date	Revision Description
1.0	2019_06_30	First Version

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1 INTRODUCTION

1.1 General Information

Papua New Guinea (PNG) contains some of the largest areas of tropical rainforest in the Pacific region. The tropical rainforest plays important roles in many aspects, contributing to the national economy through timber exports, rich biodiversity and mitigation of climate change. While alarming rate of loss and degradation of forest have been reported in recent decades, there are no robust forest monitoring system in PNG. In order to address this challenge, Japan International Cooperation Agency (JICA) and PNG Forest Authority (PNGFA) implemented a capacity development project from March 2011 for three years, combined with the Japanese Grant Aid Program that provided the project with remote sensing data, GIS equipment, and training program for the officers of PNGFA and other relevant government agencies.

(1) JICA-PNGFA Project 2011-2014

The project improved Nation-wide Forest Base Map 2012 that suggested a necessity of closer monitoring on forest operation and the extent of forest degradation and deforestation over the 37 million hectares of forest in PNG. The project also established a PNG-Forest Resource Information Management System (PNG-FRIMS) based on a GIS system with remote sensing technology.

(2) JICA-PNGFA Project 2014-2019

In order to improve the cyclic management of forest in PNG in coherent manner, the new project aims to enhance capacity of PNGFA to continuously update forest information and to fully operationalize and utilize PNG-FRIMS for promoting sustainable forest management and for addressing climate change.

1.2 Background and summary

PNG-FRIMS is a system responsible for acquiring, managing, and using “geospatial information/ data” on forests in Papua New Guinea. This promotes efficiency and sophistication of forest administration, and supports PNGFA decision making.

It is a system for browsing of various geospatial information/ data within PNGFA HQ.

- Estimation of forest area using Forest Base Map (which includes vegetation and topographical information)
- Estimation of commercial timber volume using logging history
- Sharing forest information within PNGFA HQ in order to monitor and verify logging operations

PNGFA can update forest resource information and geospatial data in PNG-FRIMS using field survey data with GPS, logging plan submitted from logging companies and forest area/ condition change monitored using satellite images etc.

PNG-FRIMS can support

- Planning National Forest Plan/ Provincial Forest Plan
- Formulation of new logging project and negotiation with landowners
- Monitoring logging projects and implementation of LcoP (Logging Code of Practice)
- Finding candidate area for forest plantation and management of forest plantation

1.3 System configuration

PNG-FRIMS is composed of FIMS (Forest Inventory Mapping System), FIPS (Forest Inventory Processing System), LAN Map Browser as a WebGIS, general-purpose tools such as ArcGIS and MS-Office, and an integrated forest information database.

The previous FIMS (Forest Inventory Mapping System) was running on Mapinfo 4.5 and Microsoft Access 97 before the JICA first project starts. The JICA project introduced not only new six workstations with ArcGIS Desktop 10.2.2 on Windows 7 as its operating system, but a new server (JICA server: pngfa-hq-srv3) with ArcGIS Server 10.2.2 and Microsoft SQL Server2008R2 on Windows Server 2008R2. With the introduction, FIMS was redeveloped with reference to the requirements of existing functions.

The previous FIPS (Forest Inventory Processing System) was running on FoxPro database before the JICA project starts. In the JICA project, FIPS was redeveloped by Microsoft Access 2010 and its database integrated together with FIMS in the JICA server.

Additionally, LAN Map Browser (LAN-Map) with a portal site was introduced newly as a WebGIS in order to promote sharing forest information stored in PNG-FRIMS. The Portal Site is a gateway to LAN-Map delivering forest information to manage the access privileges.

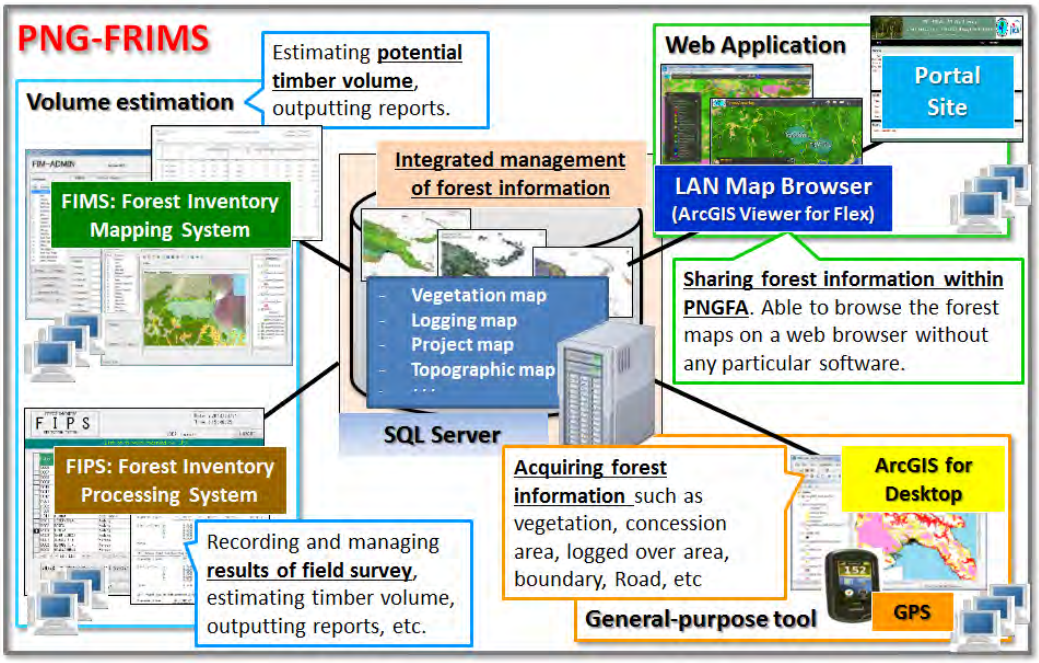


Figure 1 PNG-FRIMS applications

The list of middleware for PNG-FRIMS is as below. The operation verification has been done by the following middleware. "✓" in the table means the necessity of middleware for each application.

Table 1 Necessary middleware for PNG-FRIMS

Middleware for PNG-FRIMS		FIMS	FIPS	LAN-Map	
					Protal
Server Machine (JICA Server (pngfa-hq-srv3))					
1	Windows Server 2008 R2 (Operating System)	✓	✓	✓	✓
2	SQL Server 2008 R2	✓	✓	✓	✓
3	ArcGIS Server 10.2.2	✓		✓	
4	ArcGIS Viewer for Flex 3.7 (with Adobe AIR)			✓	
5	Internet Information Service (IIS) 7.0 or 7.5				✓
6	ASP.NET				✓
Client Machine (Workstations in Inventory & Mapping Branch)					
7	Windows 7 (Operating System)	✓	✓	✓	✓
8	ArcGIS Desktop 10.2.2 (Advanced License or Standard License)	✓			
9	Flash Player 11 or later			✓	
10	Microsoft Office Access 2010	✓	✓		

Middleware for PNG-FRIMS		FIMS	FIPS	LAN-Map	
					Protal
11	Microsoft Office Excel 2010	✓	✓		
12	SQL Server 2008 client	✓	✓		

The following figure shows the PNG-FRIMS configuration.

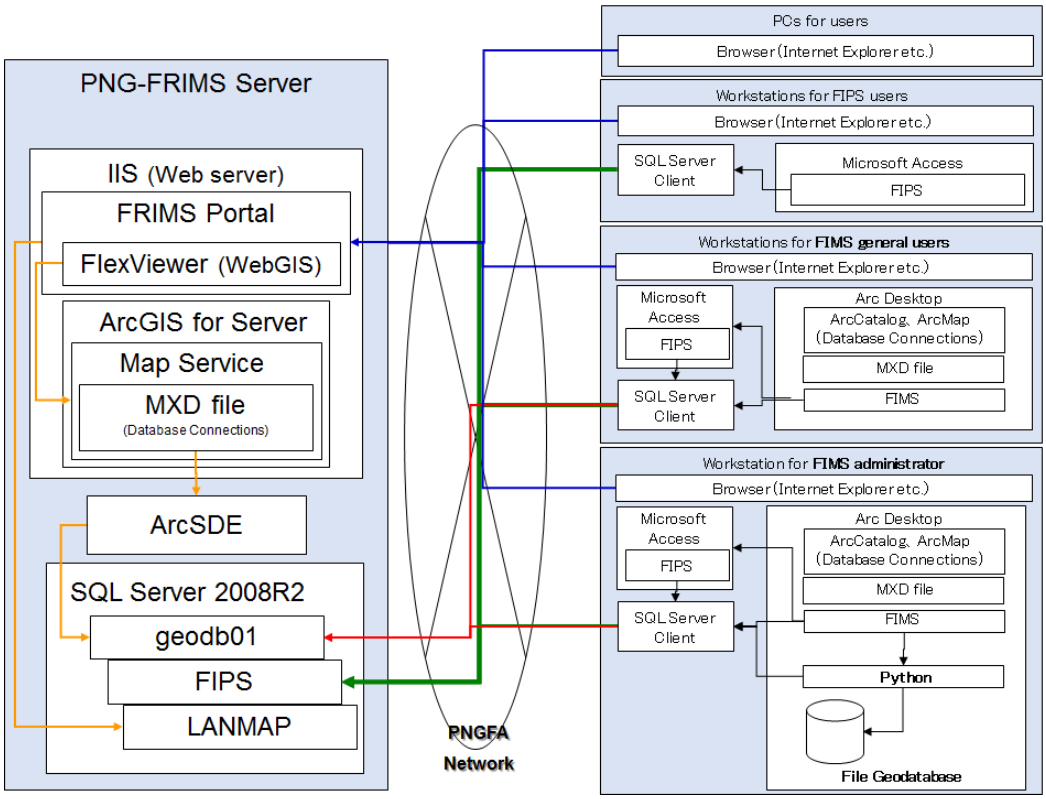


Figure 2 PNG-FRIMS configuration

The following figure shows an overview of the forest information stored in PNG-FRIMS. The forest information can be divided into four categories of geospatial data.

Logging Concession Information	Concession Area, Logged Area, Planned Area , Buffer zone Topographic info: Logging road, River/ Stream, Contour Facility info: Bridge/ Culvert, Campsite, Gravel pit, Log landing, Building, etc.
Constraints and Land Use	Social condition: FCA (Forest Clearing Authority), Plantation, Protected Area, Mining operation area Natural condition: Slope (Extreme/ Relief), Altitude (Extreme), Karst, Inundation (Extreme/ Serious), Mangrove
Forest Base/ Cover Maps	Data: Forest Base Map 1.1 (2012) Time-series forest cover maps (2000/ 2005/2011) (WNB/ WSP, as of 15th Nov 2017) Forest cover map 2015 (benchmark map) (ongoing) Old vegetation (FIMS Forest Mapping Unit) Collect Earth Landuse change Assessment (Point Sampling) PSP (Permanent Sample Plots), © FRI (Forest Research Institute) All rights reserved. Database of PINFORM (PNG International Tropical Timber Organization Natural Forest Model), © 1998 FRI All rights reserved. Attributes: Vegetation area, Tree crown size, Forest Zone, Timber volume, Carbon stock, Degradation driver, etc.
Base/ Topography	Satellite imagery: RapidEye (2011), Landsat AGP (1990/ 1995/ 2000/ 2005/ 2010/ 2011/ 2014/ 2015), PALSAR (2010/ 2011) Topomap (scale = 1:100,000, Raster) Topography: 5m mesh Digital Elevation Model (Airborne Radar in 2006 from National Mapping Bureau), Hillshade, Slope, Contour (10m), Watershed (made from GeoSAR) Global Dataset: Hansen data (Tree cover loss/ lossyer/ gain) Main road (time-series), River, Incorporated Land Group and Clan boundary/Settlement/ Local Level Government & District boundary/ Province-Region boundary (PNG Census 2000 and 2011), etc.

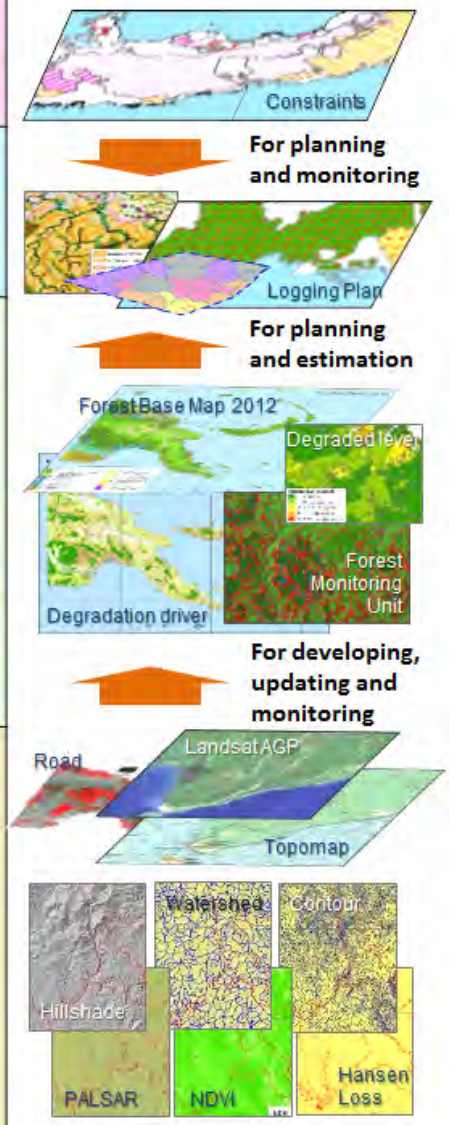


Figure 3 Overview of forest information stored in PNG-FRIMS

Database stores not only PNGFA data but also global dataset and the information from other organizations, which are updated and kept fresh periodically.

1.4 Aim of this manual

The aim of this manual is to realize a stable and sustainable operation of PNG-FRIMS. PNG-FRIMS is composed of three applications (FIMS, FIPS and LAN-Map with portal site) and their database. The chapter 2 of this manual shows an overview of each application for PNGFA staff who are users of PNG-FRIMS. The chapter 3 shows

guidance to introduce and maintain PNG-FRIMS. User manuals and installation manuals are attached as appendixes.

2 Overview of each application

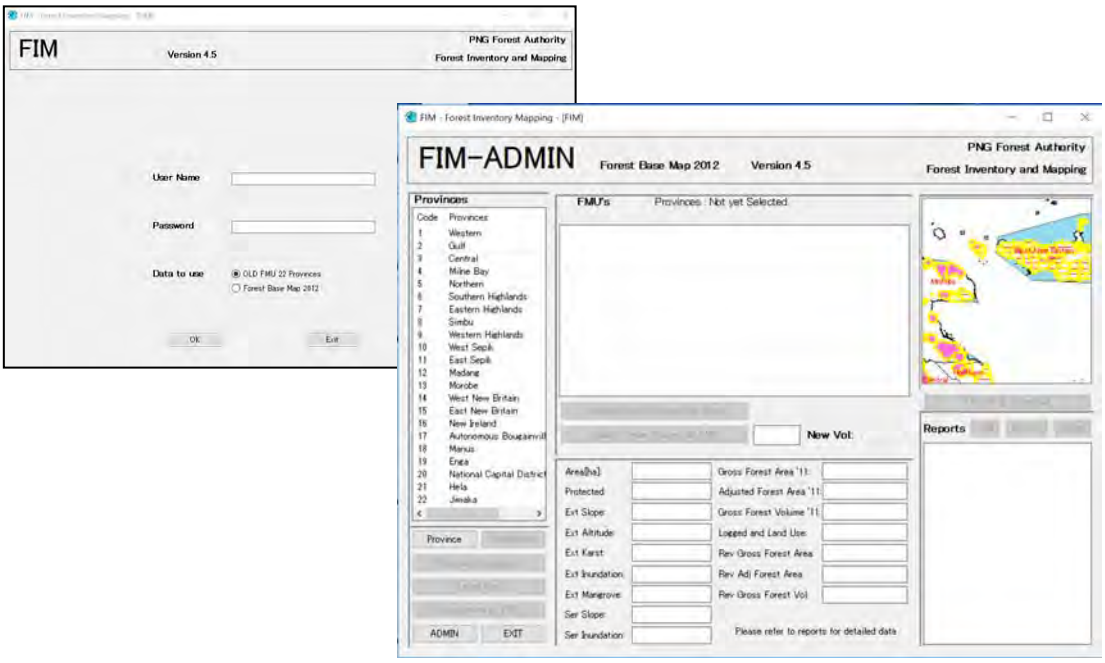
2.1 FIMS (Forest Information Mapping System)

2.1.1 Overview of FIMS

FIMS has been developed to provide a consistent and countrywide set of information on the type and extent of the forest resource and its current use by the forest industry in PNG.

FIMS shows several kinds of geospatial data such as concession areas, logged over areas, constraint areas (slope, altitude, inundation, karst, and mangrove) and forest vegetation maps (Forest Mapping Unit (FMU) as at 1975 and Forest Base Map 2012 (FBM2012)).

FIMS also makes reports of estimated merchantable volume and annual allowable cut based on timber volume in FMU and FBM2012.



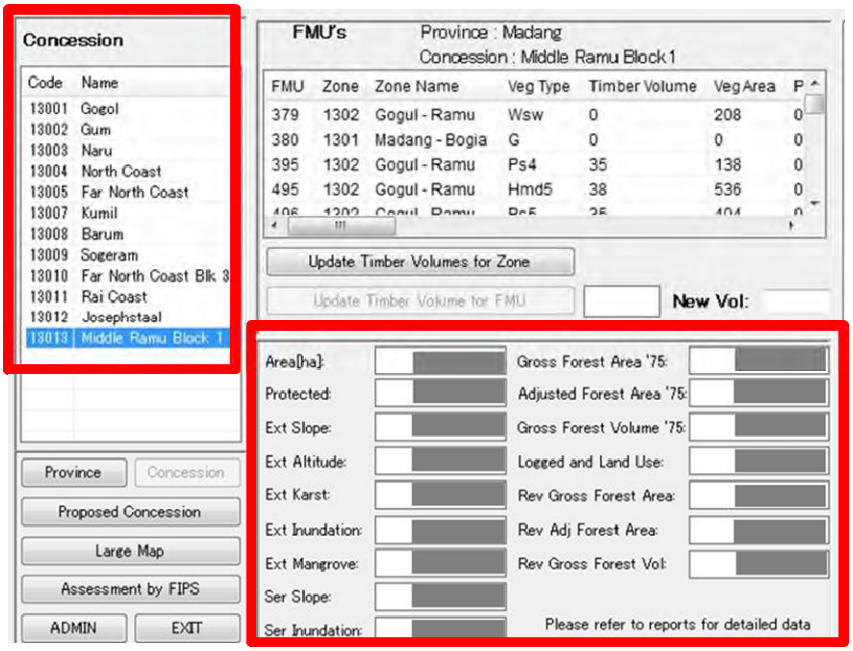
2.1.2 FIMS Basic Functions

The following table shows the FIMS functions to be used according to user privileges.

FIMS function			User privilege	
NO	Large category	Small category	Administrator	Viewer
1	Login		v	v
2	Main Screen (Province)	List of Provinces and Printing reports	v	v
3	Updating Timber Volumes	for Zone	v	-
4		for FMU	v	-
5	Reports	Print	v	V
6		Preview	v	v
7		Export	v	v
8	Main Screen (Concession data)	List of concession areas by province and Printing reports	v	v
9		File UP & Download	v	-
10	Large Map	Viewer	v	v
11		Editor	v	-
12		FMU Calculation	v	-
13		Import	v	-
14		Copy	v	v
15		Preview	v	v
16	Assessment by FIPS	List of concession areas by province	v	v
17	Administrator	Layer Management	v	-
18		User Management	v	-
19		FIPS Data Import	v	-
20		Appendix2 and 5 Calculation	v	-

(1) Main Screen

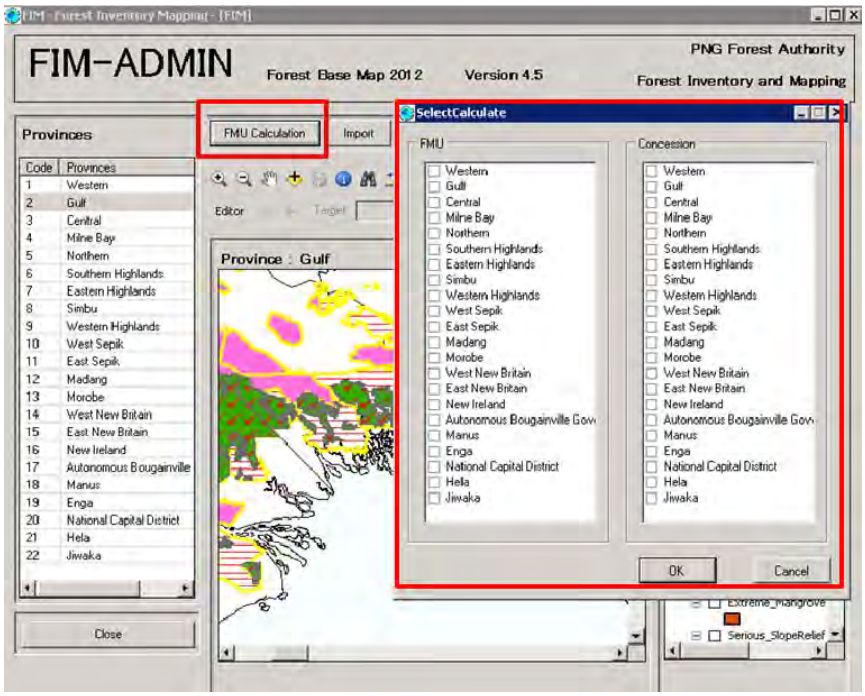
FMU is the most important data in FIMS. Each polygon of FMU has a timber volume (cu m / ha) and an area, which enable FIMS to estimate forest volume. FIMS can also estimate forest volume in each concession area by overlaying FMU map and Concession Area map.

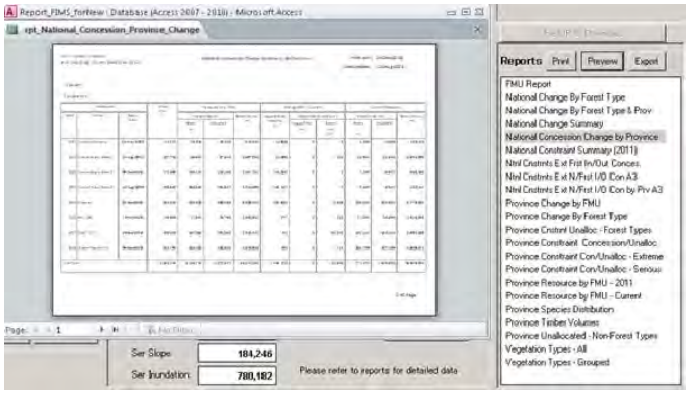


(2) FMU Calculation

FIMS can make several reports by using map data. After updating map data, FIMS need to calculate to update forest volume. The type of reports are as below.

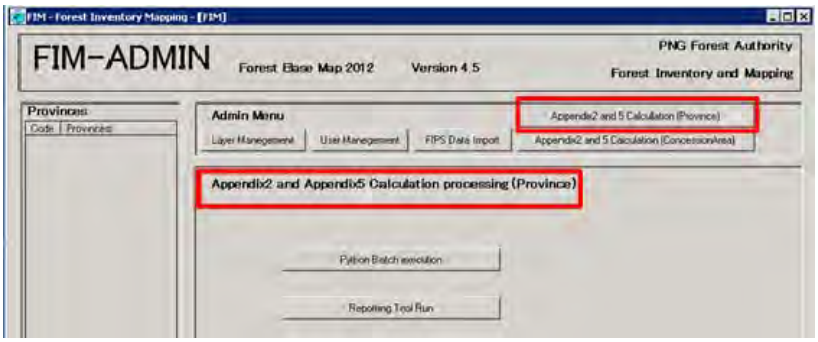
- National Reports: National change By Forest Type, etc.
- Province Reports: Province change by FMU, Province Resource, etc.
- Concession Reports: Concession change by FMU, constraint summary, etc.

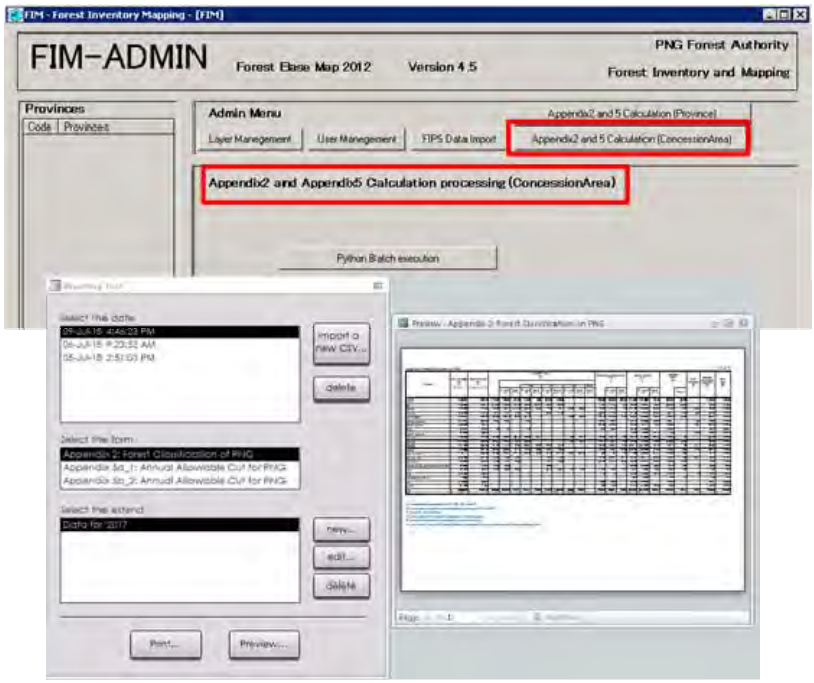




(3) AAC calculation

FIMS can estimate Annual Allowable Cut (AAC) Volume taking account of forest regrowth in the logged over areas. The reports can be created by province and by concession.





(4) Difference of the role of processing functions

There are two functions to estimate forest volume using FMU and FBM2012. There are some differences of the concept between them. FIMS can compare the reports based on FBM2012 with the reports based on old FMU created in 1990's.

Basis of estimated timber volume	Function	Calculation unit	Remarks
Forest base map 2012	FMU calculation (old concept)	Province	Forest inside constraint area (extreme slope, altitude, WMA and so on) are included.
		Concession area	
	AAC calculation (new concept)	Province	Target area is only "Net Production Area"
		Concession area	
Old FMU (22 provinces)	FMU calculation (old concept)	Province	Forest inside constraint area (extreme slope, altitude, WMA and so on) are included.
		Concession area	
	AAC calculation (new concept)	Province	Target area is only "Net Production Area"
		Concession area	

Also, the following differences between two processing functions should be understood.

	FMU calculation (old concept)	AAC calculation
Forest Area	Total area of vegetation which has a positive number other than zero (0) in timber volume.	According to the definition of forest classification in PNG. Current figures includs Sa and Sc , which are set 0 in timber volume. Forest area in AAC is lar ger than FMU calculation.
Timber Volume calculated	Includes not only Production Forest but also Potential Production Forest, Reserve Forest and Protection Forest including Constraint Areas.	AAC calculation focus on only Production Forest inside operational concession areas. Total timber volume in each province is smaller than FMU calculation
Forest Re-growth	Only subtract the area of logged over areas, which will be regarded as no potential area (volume = 0). In order to recover the timber volume in FMU calculation, FIMS need to remove logged over areas in specific areas.	Logged over area will recover over the 35 years linearly. The attribute of Harvested year is important. As of Sep 2018, AAC calculation uses the purchased year of concession because of no information about harvested year.

2.1.3 Specification of AAC calculation

(1) Forest Information used for AAC Calculation

Forest Information		Note
Vegetation	ForestBaseMap2012	New Vegetation Map
	FMU (Forest Mapping Unit)	OLD Vegetation Map stored in FIMS.
Logging Information	Concession Area	Operational Concession Areas (FMA, TPR and LFA) and Proposed Concession (PFD and Proposed PFD).
	Logged Over Area (Logged_NotLandUse)	Areas logged and left to regenerate. Currently, this layer is being updated using ALPs. In the future, Set-Ups boundaries can be identified.
	Logged Over Area (Logged_LandUse)	Areas logged and subsequently converted to other forms of non-forest forms of land use.
Constraints (Protection Forests)	Extreme Altitude	Land over 2400m altitude. (Based on SRTM30)
	Extreme Inundation	Land permanently or near permanently inundated extending over more 80% of the area of that land. (Based on PNGRIS2008)
	Extreme Karst	Land with polygonal karst landform.
	Extreme Slope	Land with over 30 degree dominant slope. (Based on SRTM30)
	Mangrove	Land covered by mangroves. (Extracted form ForestBaseMap2012)
	Protected Area	Wildlife Management Area, etc. (From CEPA)
	Serious Inundation	*50-80% permanent or near permanent inundation. (Based on PNGRIS2008). AAC calculation ignores the Serious Innundation.*
	Serious SlopeRelief	*Land with dominant slope of 20-30 degrees and sub-dominant slope over 30 degrees and with high to very high relief. AAC calculation ignores the Serious SlopeRelief.*
Plantation	Forest Plantation	(Extracted form ForestBaseMap2012)
Grassland	FCA (Forest Clearance Boundary)	FCA boundary has not been prepared.

(2) Vegetation Type and Forest Classification

1) Forest Base Map 2012

Vegetation Code (New Map)		Description	Classification
1	P	Low altitude forest on plains and fans - below 1000 m	Forest
2	H	Low altitude forest on uplands - below 1000 m	Forest
3	L	Lower montane forest - above 1000 m	Forest
4	Mo	Montane forest - above 3000 m	Forest
5	B	Littoral forest	Forest
6	D	Dry seasonal forest	Forest
7	Fri	Seral forest	Forest
8	Fsw	Swamp forest	Forest
9	M	Mangrove	Protection
10	W	Woodland	Forest
11	Sa	Savanna	Forest
12	Sc	Scrub	Forest
13	G	Grassland and herbland	Grassland
14	Ga	Alpine grassland - above 3200 m	Grassland
15	Gi	Subalpine grassland - above 2500 m	Grassland
16	O	Cropland/Agriculture land	Other Area
17	Qa	Plantation other than forest plantation	Other Area
18	Qf	Forest plantation	Forest Plantation
19	Z	Bare area	Other Area
20	U	Larger urban centre	Other Area
21	E	Waterbody	Other Area
22	Es	Sea	Other Area

2) FMU (OLD Vegetation Map stored in FIMS)

Vegetation Code (Old Map)		Description	Classification
1	Pl	Large to medium crowned forest	Forest
2	Po	Open forest	Forest
3	Ps	Small crowned forest	Forest
4	Hl	Large crowned forest	Forest
5	Hm	Medium crowned forest	Forest
6	HmAr	Medium crowned forest with Araucaria common	Forest
7	Hmd	Medium crowned depauperate/damaged forest	Forest
8	Hme	Medium crowned forest with an even canopy	Forest
9	Hs	Small crowned forest	Forest
10	Hse	Small crowned forest with an even canopy	Forest
11	HsAv	Small crowned forest with Araucaria common	Forest
12	HsCa	Small crowned forest with Castanopsis	Forest
13	HsCp	Small crowned forest with Casuarina papuana	Forest
14	HsN	Small crowned forest with Nothofagus	Forest
15	HsRt	Small crowned forest with Rhus taitensi	Forest
16	L	Small crowned forest	Forest
17	LAr	Small crowned forest with Araucaria common	Forest
18	LN	Small crowned forest with Nothofagus	Forest
19	Lc	Small crowned forest with conifers	Forest
20	Ls	Very small crowned fores	Forest
21	LsCp	Very small crowned forest with Casuarina papuana	Forest
22	LsN	Very small crowned forest with Nothofagus	Forest
23	Mo	Very sma!! crowned forest	Forest

Vegetation Code (Old Map)		Description	Classification
24	D	Dry evergreen forest	Forest
25	B	Mixed forest	Forest
26	Bce	Foresl wilh Casuarina equiselifolia	Forest
27	BMl	Foresl wilh Melaleuca leucadendron	Forest
28	Fri	Riverine mixed successions	Forest
29	FriCg	Reverine successions with Casuarina grandis	Forest
30	FriK	Riverine successions with Eucalyptus deglupta	Forest
31	Fritb	Riverine successions with Terminalia brassii	Forest
32	Fv	Volcanic successions	Forest
33	Fsw	Mixed swamp forest	Forest
34	FswC	Swamp forest with Campnosperma	Forest
35	FswMl	Swamp forest with Melaleuca leucadendron	Forest
36	FswTb	Swamp foresl with Terminalia brassii	Forest
37	W	Woodland	Forest
38	Wri	Riverine successions dominated by woodland	Forest
39	WriCg	Riverine successions with Casuarina grandis woodland	Forest
40	Wv	Volcanic successions dominated by woodland	Forest
41	Wsw	Swamp woodland	Forest
42	WswMl	Swamp woodland with Melaleuca leucadendron	Forest
43	Sa	Savanna	Forest
44	Saf	Savanna with galley forest	Forest
45	SaMl	Savanna with Melaleuca leucadendron	Forest
46	Sc	Scrub	Forest
47	ScBc	Scrub with Bambusa and Cyathea	Forest

(3) Reporting formats of AAC calculation

1) Appendix2

Appendix 2: Forest Classification of PNG

Provinces	Total Land Area (ha) (a) ((b)+(h)+(i))	Gross Forest area (ha) (b) ((c)+(d)+(e)+(f)+(g))	Production Forest*1 (ha) (c)										Potential Production Forest*2 (ha) (d)			Reserve Forest*3 (ha) (e)			Protection Forest*4 (ha) (f)		Forest Plantations (ha) (g)	Grassland (afforestation potential) (ha) (h)	Other Areas (ha) (i)
						FMA		TRP		LFA		TA - 01											
				Un-logged area	Logged-over area	Un-logged area	Logged-over area	Un-logged area	Logged-over area	Un-logged area	Logged-over area	Logged-over area		Un-logged area	Logged-over area		Un-logged area	Logged-over area		Mangrove			
Western	*5 9,819,987	5,927,342	1,221,000										1,735,488			265,104			2,705,750			1,014,055	3,892,645
Gulf	3,471,860	3,095,690	2,238,137										230,386			0			627,167			72,990	303,180
Central	2,975,504	2,212,554	360,432										434,763			757,657			659,702			272,554	490,396
Milne Bay	1,416,665	1,011,139	113,720										125,351			557,179			214,889			122,689	282,837
Oro	2,263,371	1,670,623	221,000										503,191			208,337			738,095			154,898	437,850
SHP	2,560,344	1,997,252	98,750										334,444			70,735			1,493,323			112,339	450,753
Enga	1,173,438	781,656	0										82,856			0			698,800			69,833	321,949
WHP	913,520	481,176	0										54,708			119,602			306,866			35,715	396,629
Simbu	613,341	424,638	0										59,474			107,599			257,565			37,112	151,591
EHP	1,114,676	674,042	0										40,000			19,256			614,786			194,994	245,640
Morobe	3,368,621	2,444,932	195,941										347,891			771,185			1,129,915			324,928	598,761
Madang	2,890,325	2,020,680	384,980										129,342			479,194			1,027,164			172,842	696,803
East Sepik	4,368,599	2,475,341	521,500										116,529			0			1,837,312			615,703	1,277,555
Sandaun	3,592,766	3,240,601	1,055,627										993,650			437,970			753,354			110,684	241,481
Manus	193,076	178,420	32,667										42,035			82,131			21,587			5,789	8,867
New Ireland	939,696	795,080	209,115										155,767			246,591			183,607			24,986	119,630
ENB	1,529,425	1,278,398	215,689										210,314			341,444			510,951			17,545	233,482
WNB	2,034,000	1,679,527	657,799										0			366,448			655,280			32,075	322,398
AGB	946,255	782,559	46,720										0			634,923			100,916			41,282	122414
Total	*5 **46,185,469**	*6 **33,171,650**	**7,573,077**										**5,596,189**			**5,465,355**			**14,537,029**			**3,433,013**	**10,594,861**

Source: Original table and figures are prepared for NFB on 19th Nov. 2015 based on FIMS Database

***1: Area already acquired for FMA, TRP, LFA and TA**

***2: Area under acquisition and allocation process for FMA or TRP**

***3: Area not yet classified**

***4: Area under WMA, extreme constraints and Mangrove**

***5: Cause of calculation inconsistency to be found out**

***6: Gross Forest Area in this table includes Woodland, Scrub and Savanna in Forest BaseMap 2012**

Figures in italic indicates original values copied from the draft prepared for NFB on 19th Nov. 2015

Item			Description	Calculation Order
a	Total Land Area		The total area of Forest Base Map other than “Sea (code = Es)” by province. (b)+(h)+(i)	1
b	Gross Forest area		(c)+(d)+(e)+(g)	9
c	Production Forest		The forest area in the operational Concession Areas with FMA, TRP, LFA and TA-01 other than the area overlapping with Protection Forest and Grassland.	6
	Total	Un-logged area	The total forest area in the operational concession areas that have not been harvested.	
		Logged-over area	The total forest area in the Logged Over Areas in operational concession areas. Logged-over area includes two GIS layers. (1) ‘Logged_NotLandUse’, which are areas logged and left to regenerate. (2) ‘Logged_LandUse’, which are areas logged and subsequently converted to other forms of non-forest forms of land use. Re-growth does not happen in ‘Logged_LandUse’.	
	FMA	Un-logged area	The total forest area in the operational FMAs not covered by Logged Over Area.	
		Logged-over area	The total forest area in operational FMAs overlapping with Logged Over Area.	
	TRP	Un-logged area	The total forest area in the operational TRPs not covered by Logged Over Area.	
		Logged-over area	The total forest area in the operational TRPs overlapping with Logged Over Area.	
	LFA	Un-logged area	The total forest area in the operational LFAs not covered by Logged Over Area.	
		Logged-over area	The total forest area in the operational LFAs overlapping with Logged Over Area.	
	TA01	Logged-over area	No data for now. Field Services has coordinates information of the center of each TA-01 on the map. It can be available to estimate forest area.	
d	Potential Production Forest		The forest area in Proposed Concession Areas other than the area overlapping with Protection Forest and Grassland. Proposed Concession for AAC calculation means PFD (Potential Forest Development) and Proposed PFD listed in Provincial Forest Plans. This calculation excludes the concession data having the attributes which are ‘Status=proposed’ ,and ‘Remarks= tentative’ or " Remarks = cancellation".	7

Item			Description	Calculation Order
		Un-logged area	The total forest area in the proposed concession areas not covered by Logged Over Area	
		Logged-over area	The total forest area in the proposed concession areas overlapping with Logged Over Area	
e	Reserve Forest		The forest area in the expired concession areas, and the forest area that has never been designated and planned as concession area.	8
		Un-logged area	The total forest area in the reserved forest not covered by Logged Over Area	
		Logged-over area	The total forest area in the reserved forest overlapping with Logged Over Area. This calculation regards whole area of expired concession as Logged-Over Area. Because it is too difficult to search for old maps recording logging history of expired concession, especially TRP.	
f	Protection Forest		Includes "Extreme Slope (> 30 degree)", "Extreme Altitude (> 2,400m)", "Extreme Karst", "Extreme Inundation (over more 80% permanent)", "Mangrove" of Forest Base Map, and "Protected Area". *Protection Forest excludes "Serious Inundation (50-80% permanent)" and "Serious Slope (20-30 degree)".*	4
		Mangrove	Pick out the area of Mangrove (Code = M) included in Forest Base Map	
g	Forest Plantation		Pick out the area of Forest Plantation (Code = Qf) included in Forest Base Map	5
h	Grassland (afforestation potential)		The area of Grassland other than the area overlapping with Protection Area. The area of FCA (Forest Clearance Boundary) other than the area overlapping with Protection and Grassland.	2
i	Other Areas		Pick out the area of Other area <u>other than the area overlapping with Protection Area</u> (Code = O, Qa, Z, U and E)	3

(Calculation order)

Grassland > Other Areas > Protection Forest > Forest Plantation > Production Forest > Potential Forest > Reserve Forest

2) Appendix5a_1 : Net Production Area = Production Forest (c)

Calculation Example 1 Net Production Area = Production Forest

Appendix 5a_1: Annual Allowable Cut for PNG in NFP 2015 – 2020

Province	Net Production Area (ha) (c)	Logged Over Area in Net Production Area (ha) (k)	Un-logged Area in Net Production Area (ha) (l) ((c)-(k))	Rerowth Volume in Logged Over Area (m^3) (m)	Volume in Un-logged Area (m^3) (n)*1	Gross Merchantable Volume (m^3) (o) ((m)+(n))	AAC (m^3) (p) ((o)/ 35)	Permitted Cut Under Projects (2013) (q)	Balance AAC (2013) (r) ((p)-(q))	Projected AAC 2015-2019 (000 m^3)				
										2015	2016	2017	2018	2019
Western	1,221,000					0		*826,000*	*817,793*	*736*	*736*	*736*	*736*	*736*
Gulf	2,238,137					0		*1,186,000*	*-348,997*	*1,046*	*1,046*	*1,046*	*1,046*	*1,046*
Central	360,432					0		*270,000*	*583,194*	*343*	*343*	*343*	*343*	*331*
Milne Bay	113,720					0		*58,000*	*228,773*	*109*	*109*	*109*	*109*	*109*
Oro	221,000					0		*288,000*	*422,728*	*153*	*153*	*153*	*153*	*153*
Morobe	195,941					0		*185,000*	*925,885*	*241*	*241*	*241*	*241*	*141*
Madang	384,980					0		*568,000*	*178,338*	*418*	*288*	*288*	*138*	*138*
East Sepik	521,500					0		*397,000*	*428,252*	*150*	*150*	*150*	*150*	*150*
Sandaun	1,055,627					0		*907,200*	*226,154*	*554*	*554*	*554*	*554*	*554*
Manus	32,667					0		*212,000*	*-177,880*	*146*	*146*	*132*	*132*	*132*
New Ireland	209,115					0		*180,000*	*-46,985*	*180*	*180*	*180*	*60*	*60*
E.NB	215,689					0		*562,500*	*-243,788*	*380*	*380*	*380*	*380*	*380*
WNB	657,799					0		*2,538,700*	*-2,307,765*	*2,434*	*1,704*	*1,549*	*1,549*	*1,549*
AGB	46,720					0		*0*	*254,716*	*0*	*0*	*0*	*0*	*0*
SHP	98,750					0		*80,000*	*924,292*	*80*	*80*	*80*	*80*	*80*
EHP	0					0		*0*	*385,002*	*0*	*0*	*0*	*0*	*0*
Simbu	0					0		*0*	*213,179*	*0*	*0*	*0*	*0*	*0*
WHP	0					0		*0*	*266,584*	*0*	*0*	*0*	*0*	*0*
Enga	0					0		*0*	*508,097*	*0*	*0*	*0*	*0*	*0*
Total	**7,573,077**	**0**	**0**	**0**	**0**	**0**		***8,258,400***		***6,970***	***6,110***	***5,941***	***5,671***	***5,559***

Source: Original table and figures are prepared for NFB on 19th Nov. 2015 based on FIMS Database

***1: Volume is calculated by Forest Monitoring Unit of Forest Basemap 1.2 and its tentative volume**

Figures in italic indicates original values copied from the draft prepared for NFB on 19th Nov. 2015

・ Net Production Area = Production Forest (c)

Item		Description
c	Net Production Area	Net Production Area = Production Forest
k	Logged Over Area in Net Production Area	Logged over area in Production Forest
l	Un-logged Area in Net Production Area	(c)-(k) (As same as Un-logged area of (c))
m	Regrowth Volume in Logged Over Area	[Production Forest (c)] The volume of Logged Over Areas (of 'Logged_NotLandUse' layer) in the operational Concession Areas is calculated. The target Concession types are FMA and TRP except for LFA. Regrowth does not happen in LFA. (Option 1)The volume of the Logged Over Area with harvested year will recover over the 35 years linearly based on the harvested year per each polygon data of the logged over area. (Option 2) If Logged Over Areas in the operational concession area have no harvested year, the sum total area of the Logged Over Areas will be divided equally by elapsed years from the purchased year. The area divided will recover over the next 35 years linearly. The elapsed years increase up to 35. Option1 and Option2 are implemented in the AAC calculation function.
n	Volume in Un-Logged Area	The formula is as below. Volume per unit area of each vegetation type * area of each vegetation type inside Un-Logged Area.
o	Gross Merchantable Volume	(m) + (n)
p	AAC (m^3)	(o) / 35
q	Permitted Cut Under Projects (Year)	Permit Cut Volume that is managed by Project Branch will be entered. The year shown in the table will be designated by the editor of the Appendix 5a.
r	Balance AAC (Year)	(p) – (q) The year shown in the table will be designated by the editor of the Appendix 5a.
	Projected AAC	Projected AAC Volume will be entered by the editor of the Appendix 5a. The years shown in the table will be according to the planning year of the title.

3) Appendix5a_2

Calculation Example 2 Net Production Area = Production Forest + Potential Production Forest + Reserve Forest

Appendix 5a_2: Annual Allowable Cut for PNG in NFP 2015 – 2020

Province	Net Production Area (ha) (j)	Logged Over Area in Net Production Area (ha) (k)	Un-logged Area in Net Production Area (ha) (l) ((j)-(k))	Rerowth Volume in Logged Over Area (m^3) (m)	Volume in Un-logged Area (m^3) (n)*1	Gross Merchantable Volume (m^3) (o) ((m)+(n))	AAC (m^3) (p) ((o)/ 35)	Permitted Cut Under Projects (2013) (q)	Balance AAC (2013) (r) ((p)-(q))	Projected AAC 2015-2019 (000 m^3)				
										2015	2016	2017	2018	2019
Western	3,221,592					0		*826,000*	*817,793*	*736*	*736*	*736*	*736*	*736*
Gulf	2,468,523					0		*1,186,000*	*-348,997*	*1,046*	*1,046*	*1,046*	*1,046*	*1,046*
Central	1,552,852					0		*270,000*	*583,194*	*343*	*343*	*343*	*343*	*331*
Milne Bay	796,250					0		*58,000*	*228,773*	*109*	*109*	*109*	*109*	*109*
Oro	932,528					0		*288,000*	*422,728*	*153*	*153*	*153*	*153*	*153*
Morobe	1,315,017					0		*185,000*	*925,885*	*241*	*241*	*241*	*241*	*141*
Madang	993,516					0		*568,000*	*178,338*	*418*	*288*	*288*	*138*	*138*
East Sepik	638,029					0		*397,000*	*428,252*	*150*	*150*	*150*	*150*	*150*
Sandaun	2,487,247					0		*907,200*	*226,154*	*554*	*554*	*554*	*554*	*554*
Manus	156,833					0		*212,000*	*-177,880*	*146*	*146*	*132*	*132*	*132*
New Ireland	611,473					0		*180,000*	*-46,985*	*180*	*180*	*180*	*60*	*60*
E.NB	767,447					0		*562,500*	*-243,788*	*380*	*380*	*380*	*380*	*380*
WNB	1,024,247					0		*2,538,700*	*-2,307,765*	*2,434*	*1,704*	*1,549*	*1,549*	*1,549*
AGB	681,643					0		*0*	*254,716*	*0*	*0*	*0*	*0*	*0*
SHP	503,929					0		*80,000*	*924,292*	*80*	*80*	*80*	*80*	*80*
EHP	59,256					0		*0*	*385,002*	*0*	*0*	*0*	*0*	*0*
Simbu	167,073					0		*0*	*213,179*	*0*	*0*	*0*	*0*	*0*
WHP	174,310					0		*0*	*266,584*	*0*	*0*	*0*	*0*	*0*
Enga	82,856					0		*0*	*508,097*	*0*	*0*	*0*	*0*	*0*
Total	**18,634,621**	**0**	**0**	**0**	**0**	**0**	**0**	***8,258,400***		***6,970***	***6,110***	***5,941***	***5,671***	***5,559***

Source: Original table and figures are prepared for NFB on 19th Nov. 2015 based on FIMS Database

***1: Volume is calculated by Forest Monitoring Unit of Forest Basemap 1.2 and its tentative volume**

Figures in italic indicates original values copied from the draft prepared for NFB on 19th Nov. 2015

- Net Production Area = Production Forest (c) + Potential Production Forest (d) + Reserve Forest (e)

Item		Description
j	Net Production Area	Net Production Area = Production Forest (c)+Potential Production Forest (d)+Reserved Forest (e)
k	Logged Over Area in Net Production Area	Logged over Area of (c) + Logged over area of (d) + Logged over area of (e)
l	Un-logged Area in Net Production Area	(j)-(k) (as same as Un-logged are of (c) + Un-logged area of (d) + Un-logged area of (e))
m	Regrowth Volume in Logged Over Area	[Production Forest (c)] As same formula as Appendix5a_1 [Potential Production Forest (d)] Regrowth is not taken into consideration if there are no harvested year information for Logged Over Area in Proposed Concession. If Logged Over Area have it, Regrowth volume can be calculated. [Reserve Forest (e)] This calculation regards whole area of expired concession as Logged-Over Area. Constant logging rate is adopted during the contract of TRP. **(see the following figures and formulas)**
n	Volume in Un-Logged Area	The formula is as below. Volume per unit area of each vegetation type * area of each vegetation type inside Un-Logged Area. The Un-Logged Areas are in Production Forest (c), Potential Production Forest (d) and Reserve Forest (e).
o	Gross Merchantable Volume	(m) + (n)
p	AAC (m^3)	(o) / 35
q	Permitted Cut Under Projects (Year)	Permit Cut Volume that is managed by Project Branch will be entered. The year shown in the table will be designated by the editor of the Appendix 5a.
r	Balance AAC (Year)	(p) – (q) The year shown in the table will be designated by the editor of the Appendix 5a.
	Projected AAC	Projected AAC Volume will be entered by the editor of the Appendix 5a. The years shown in the table will be according to the planning year of the title.

(4) Example of Re-growth calculation

When a logged-over area is digitized in a concession area, FRIMS (FIMS) regards the volume of the logged-over area as zero. The volume of the logged-over area will recover over the next 35 years linearly.

Example: Logging started in 2000 over the next 35 years

2000	2001	2002	2003	2004	2005	2006
2007	2008	2009	2010	2011	2012	2013
2014	2015	2016	2017	2018	2019	2020
2021	2022	2023	2024	2025	2026	2027
2028	2029	2030	2031	2032	2033	2034

Recovery ratio as of 2001 (2nd Year).

3%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%

Recovery ratio as of 2002 (3rd Year).

6%	3%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%

Recovery ratio as of 2034 (35th Year).

97%	94%	91%	89%	86%	83%	80%
77%	74%	71%	69%	66%	63%	60%
57%	54%	51%	49%	46%	43%	40%
37%	34%	31%	29%	26%	23%	20%
17%	14%	11%	9%	6%	3%	0%

Recovery ratio as of 2036 (37th Year).

100%	100%	97%	94%	91%	89%	86%
83%	80%	77%	74%	71%	69%	66%
63%	60%	57%	54%	51%	49%	46%
43%	40%	37%	34%	31%	29%	26%
23%	20%	17%	14%	11%	9%	6%

Recovery ratio as of 2035 (36th Year).

100%	97%	94%	91%	89%	86%	83%
80%	77%	74%	71%	69%	66%	63%
60%	57%	54%	51%	49%	46%	43%
40%	37%	34%	31%	29%	26%	23%
20%	17%	14%	11%	9%	6%	3%

Recovery ratio as of 2068 (69th Year).

100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	97%

Recovery ratio as of 2069 (70th Year).

100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%

Calculating Formula of Regrowth Volume for 2034 ('V' = Forest Volume in the concession area before logging operation starts)

$(V \times 1/35 \times 97/100) + (V \times 1/35 \times 94/100) + (V \times 1/35 \times 91/100) + \cdots + (V \times 1/35 \times 3/100) + (V \times 1/35 \times 0/100)$

Calculating Formula of Regrowth Volume for 2035

$(V \times 1/35 \times 100/100) + (V \times 1/35 \times 97/100) + (V \times 1/35 \times 94/100) + \cdots + (V \times 1/35 \times 6/100) + (V \times 1/35 \times 3/100)$

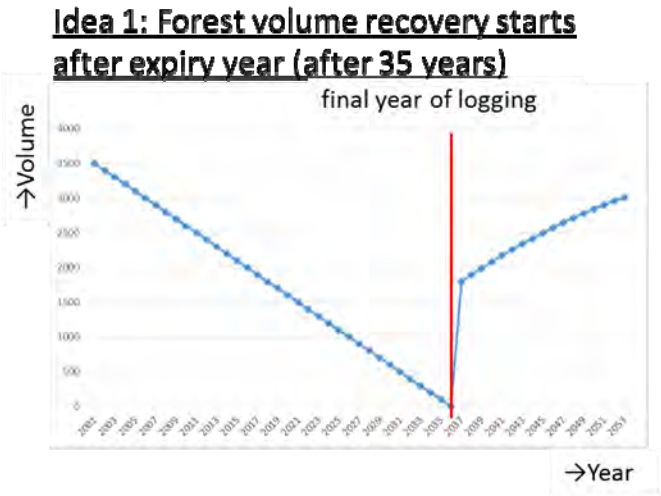
Calculating Formula of Regrowth Volume for 2036

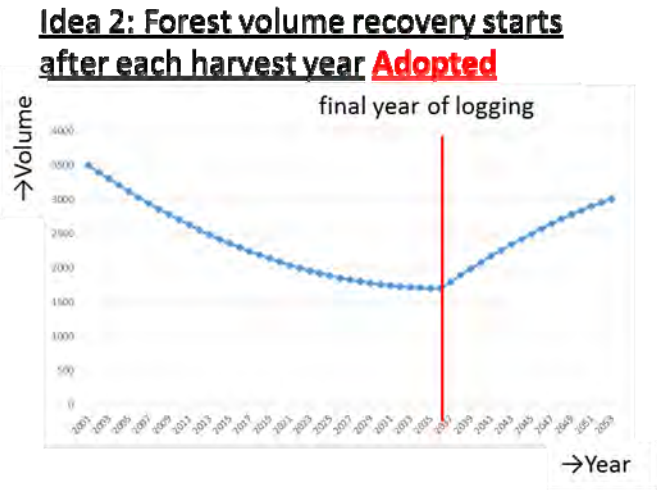
$(V \times 1/35 \times 100/100) + (V \times 1/35 \times 100/100) + (V \times 1/35 \times 97/100) + \cdots + (V \times 1/35 \times 9/100) + (V \times 1/35 \times 6/100)$

Calculating Formula of Regrowth Volume for 2068

$(V \times 1/35 \times 100/100) + (V \times 1/35 \times 100/100) + (V \times 1/35 \times 100/100) + \cdots + (V \times 1/35 \times 100/100) + (V \times 1/35 \times 97/100)$

There can be two possible scenarios in case that same amount of area is harvested and forest volume reduces same amount of volume every year up to expiry year. At this version, the following idea2 was adopted.





The default setting of recovery period is “35years” and the default setting of timing of starting re-growth is after each harvest year. It is possible to change both setting as necessary. (see 3.1.2)

2.1.4 Provincial Coding system

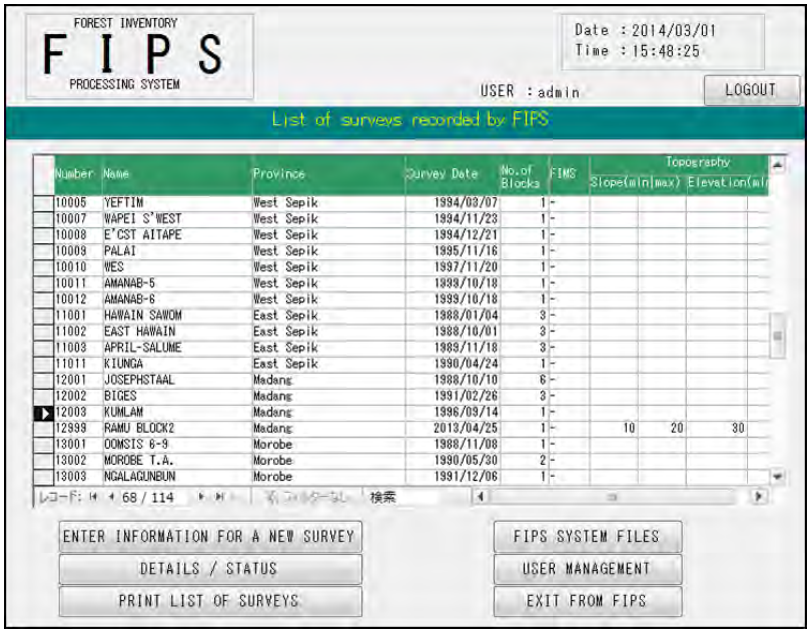
The Provincial Coding system which FIMS adopts was revised as below.

Code	Province	Region	Latest FIMS	PNGFA File Index	TP Number in PAD	National Statistical Office	Previous FIMS
WES	Western	Southern	1	1	1	1	1
GUL	Gulf	Southern	2	2	2	2	2
CEN	Central	Southern	3	3	3	3	3
NCD	National Capital District	Southern	20			4	4
MIL	Milne Bay	Southern	4	4	4	5	5
ORO	Oro	Southern	5	5	5	6	6
SHP	Southern Hilands	Highlands	6	6	6	7	7
HEL	Hela	Highlands	21			21	
ENG	Enga	Highlands	19	19		8	8
WHP	Western Highlands	Highlands	9	9	9	9	9
JIW	Jiwaka	Highlands	22			22	
SIM	Chimbu	Highlands	8	8	8	10	10
EHP	Eastern Hilands	Highlands	7	7	7	11	11
MOR	Morobe	Momase	13	13	13	12	12
MAD	Madang	Momase	12	12	12	13	13
ESP	East Sepik	Momase	11	11	11	14	14
WSP	West Sepik	Momase	10	10	10	15	15
MAN	Manus	Islands	18	18	18	16	16
NIP	New Ireland	Islands	16	16	16	17	17
ENB	East New Britain	Islands	15	15	15	18	18
WNB	West New Britain	Islands	14	14	14	19	19
ARB	Autonomous Region of Bougainville	Islands	17	17	17	20	20

2.2 FIPS (Forest Inventory Processing System)

2.2.1 Overview of FIPS

FIPS is a simple computer system to process PNG inventory assessments of natural forest. FIPS was developed and first used in 1986 to processed inventory assessment data.

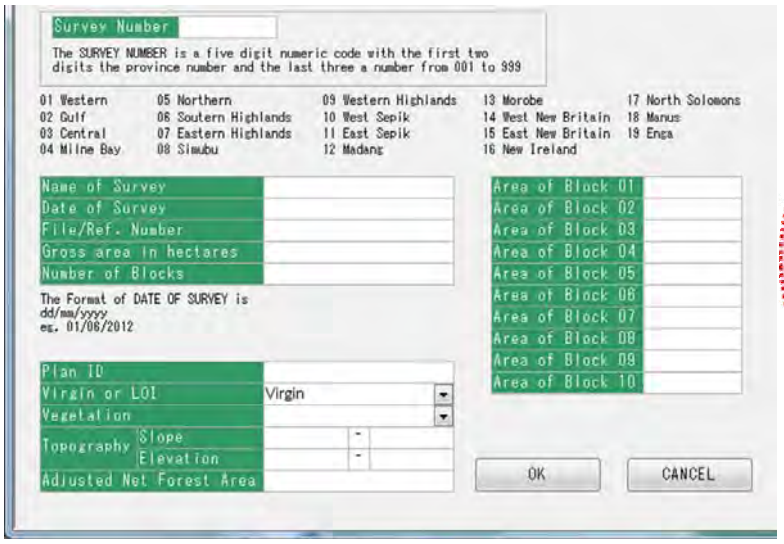


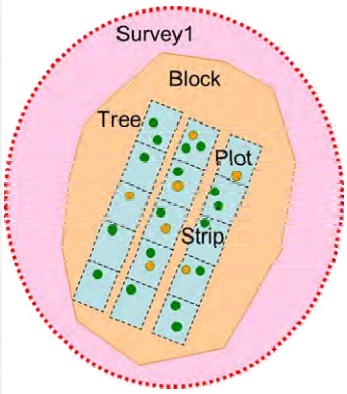
2.2.2 FIPS Basic Functions

(1) Edit the details of field survey

FIPS has the following basic data on field survey.

- Name of survey
- Date of the survey
- Gross area of resource area in hectares
- Number of block, Area of each block in hectares
- Topography

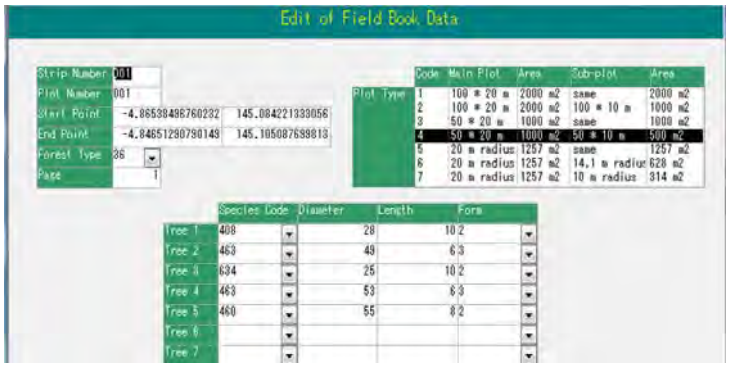




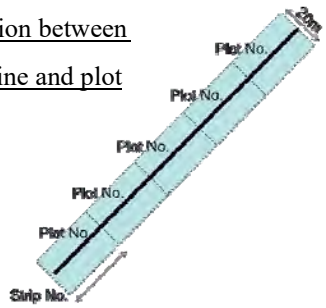
(2) Edit the field book data

FIPS has the following data on each tree surveyed.

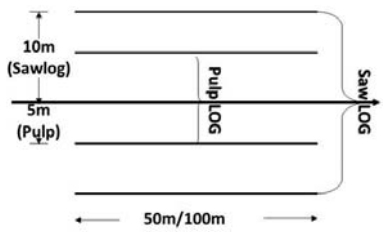
- Strip number, Plot number
- Forest Type : Combination of topography and dominant species
- Plot Type : plot sizes used for collection of field information
- Species Code, Diameter, Length : for each tree
- Form : The tree stem form classes are denoted by ranking between Form A – F based on the straightness of the bole



Relation between stripline and plot

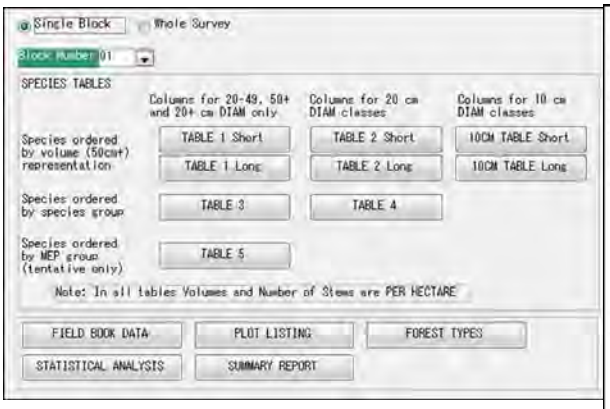


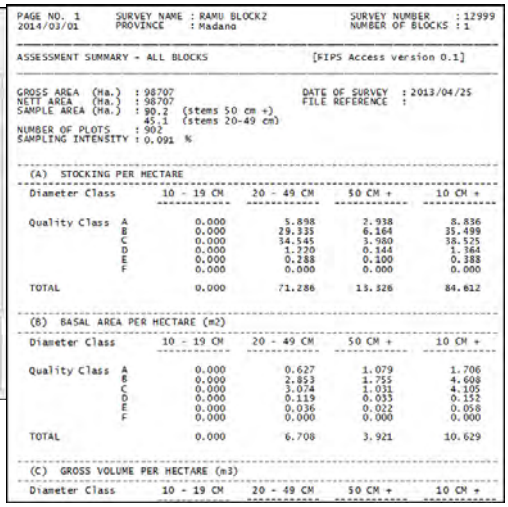
Plot size



(3) Process field book data and make reports

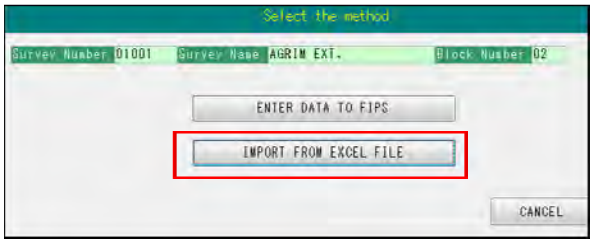
FIPS can make several reports by using the field book data. There are two types of reports. First is an assessment summary which shows “Stocking per ha”, “Basal area per ha ” and “Gross Volume per ha”. Second is a species listing in order of volume representation in the assessment.

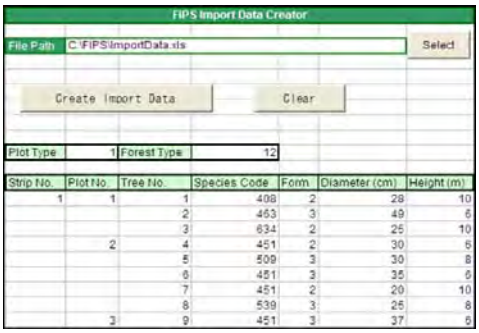




(4) Import spreadsheet of field survey result

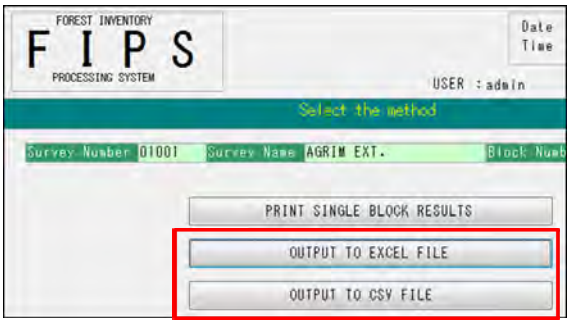
FIPS makes it possible to import field book data from excel spread sheet, which makes it easier to update the FIPS database.

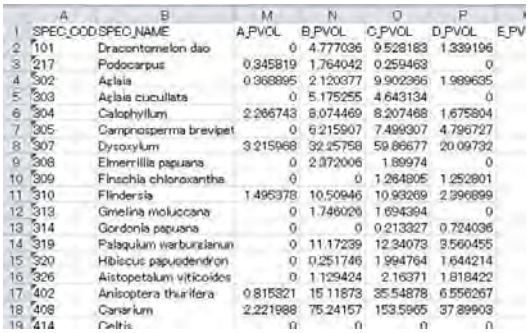




(5) Output reports to excel and csv format

FIPS makes it possible to export processed FIPS data to excel and csv format, which makes it easier for staff who is interested in FIPS data to do further analysis and summarize forest marketable volume in each species, diameter of tree and log form.

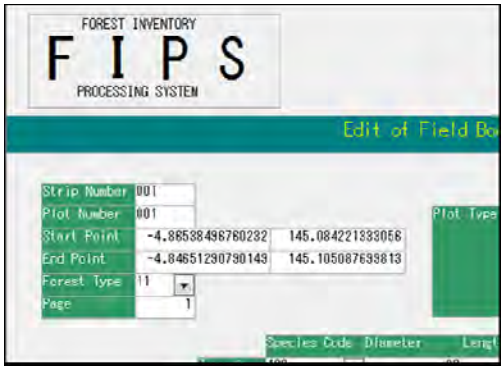


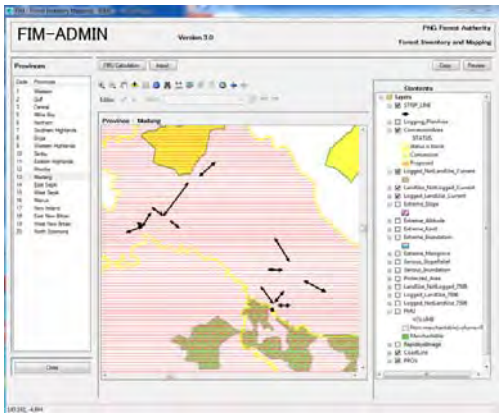


	A	B	M	N	O	P
1	SPEC_COD	SPEC_NAME	A_PVOL	B_PVOL	C_PVOL	D_PVOL
2	101	Dracontomelon dao	0	4.777036	9.528183	1.339196
3	217	Podocarpus	0.345819	1.764042	0.259463	0
4	302	Aglaia	0.368895	2.120377	9.902366	1.989635
5	303	Aglaia cucullata	0	5.175255	4.643134	0
6	304	Calophyllum	2.266743	8.074469	8.207468	1.675804
7	305	Campnosperma brevipet	0	6.215907	7.499307	4.796727
8	307	Dysoxylum	3.215968	32.25758	59.86677	20.09732
9	308	Elmerrillia papuana	0	2.372006	1.89974	0
10	309	Flnschia chloroxantha	0	0	1.264805	1.252801
11	310	Flindersia	1.495378	10.50946	10.93269	2.396899
12	313	Gmelina moluccana	0	1.746026	1.694394	0
13	314	Gordonia papuana	0	0	0.213327	0.724036
14	319	Palaquium warburgianun	0	11.17239	12.34073	3.560455
15	320	Hibiscus papuodendron	0	0.251746	1.994764	1.644214
16	326	Aistopetalum viticoides	0	1.129424	2.16371	1.818422
17	402	Anisoptera thurifera	0.815821	15.11873	35.54878	6.556267
18	408	Canarium	2.221988	75.24157	153.5965	37.89903
19	414	Celtis	0	0	0	0

(6) Enter GPS coordinates of strip line

FIPS makes it possible to enter GPS coordinates of strip line, which makes it possible to see the strip line stored in FIPS database on FIMS Map.





2.2.3 FIPS Volume Equation

There were two kinds of volume equation for processing when FIPS was improved by JICA. The current FIPS adopted the equation which old FIPS was adopting.

(1) based on diameter only

- Existing Excel spreadsheet to calculate volume

V = 0.00000515025(3.1459*diameter)^2.4762

- **Old FIPS**

<u>V = 0.00000515025(3.14159*diameter)^2.4762 (adopted)</u>

(2) Trees 50cm+

- Existing Excel spreadsheet to calculate volume

V=0.189523+0.0000547982D^2-0.0089213H+0.0000528219D^2H

- OLD FIPS

V=0.189523+0.0000547982(D-2.4)^2-0.0089213H+0.0000528219(D-2.4)^2H (adopted)

(3) Trees 20-50cm

- Existing Excel spreadsheet to calculate volume

V=0.001508+0.000044658D^2+0.00005310227D^2H-0.00000061883*D^2H^2

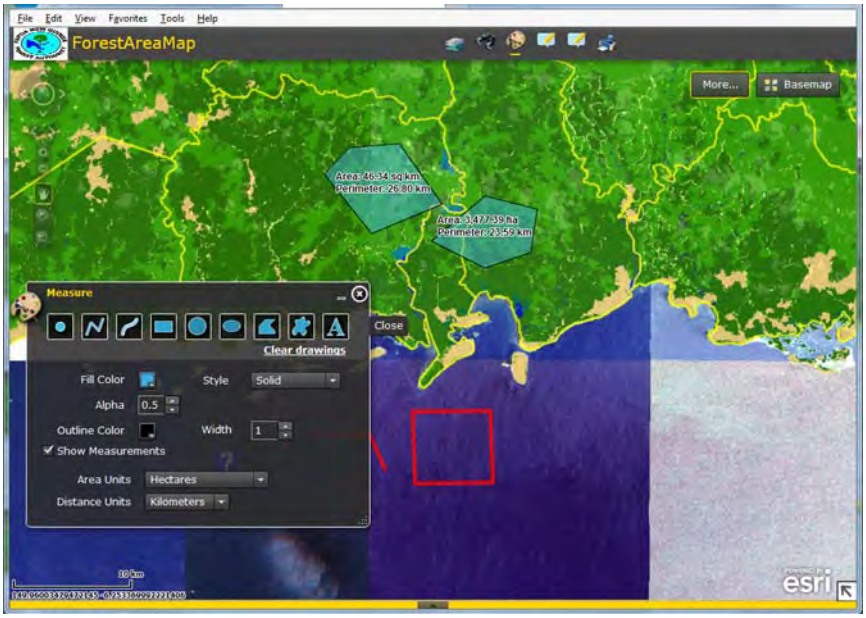
- OLD FIPS

V=-0.001508+0.000044658D^2+0.00005310227D^2H-0.00000061883*D^2H^2 (adopted)

2.3 LAN-Map (LAN Map Browser)

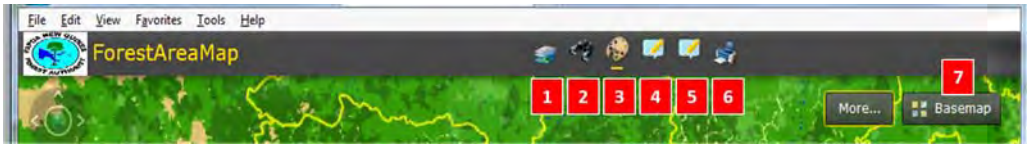
2.3.1 Overview of LAN-Map

LAN-Map is a Web-GIS established on the intranet of PNGFA for sharing forest information and its usage. It is possible to customize functions according to each purpose, and it makes it easy to see and print a map of area of interest for staffs who are not familiar with GIS. LAN-Map is able to see the map stored in the PNG-FRIMS through a Web Browser without ArcGIS software. In order to prevent from information leakage, there are no access to the map through Internet from outside. (Access from only inside PNGFA HQ)



2.3.2 LAN Map Basic Functions

LAN Map provides several Web-GIS functions. The representative functions are as below.



Functions		Remarks
1	Layer List	To turn layers on and off.
2	Search	To search for the attribute "Name" in the concession area layer.
3	Measure	To measure length and area for simple graphics (line or polygon) drawn by users.
4	Sketch	To create simple graphics (point, line and polygon) for planning or monitoring.
5	Feedback	To create feedbacks (e.g. the data error which user noticed, the request for adding information or adding new functions) as new point features on the map.
6	Print	To print all visible map displayed.
7	Switch Basemap	To choose background topography.

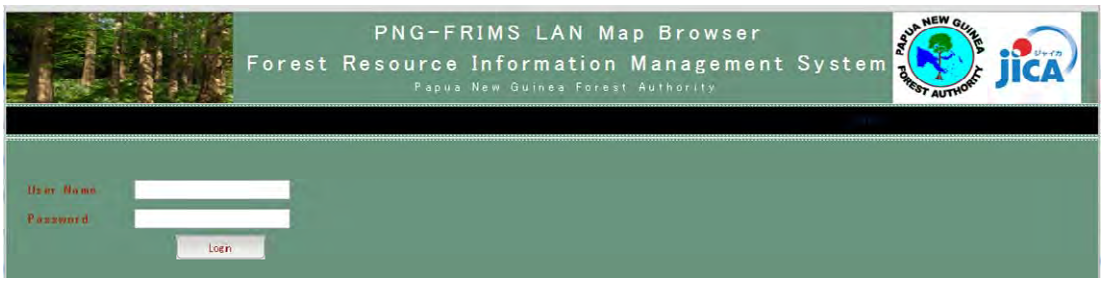
2.3.3 Portal Site

According to the introduction of LAN Map, the PNGFA officers can access several maps, including forest resource information, any time via their computers connected to the intranet inside PNGFA. However, forest information stored in PNG-FRIMS sometimes has confidential information that limited specific officers are allowed to access. Therefore, a gateway to LAN-Map delivering forest information was developed by installation of a portal site managing the access the access privileges to forest information stored in PNG-FRIMS.

The URL of the portal site to LAN Map is "http://pngfa-hq-srv3/FRIMS-LAN-Map".

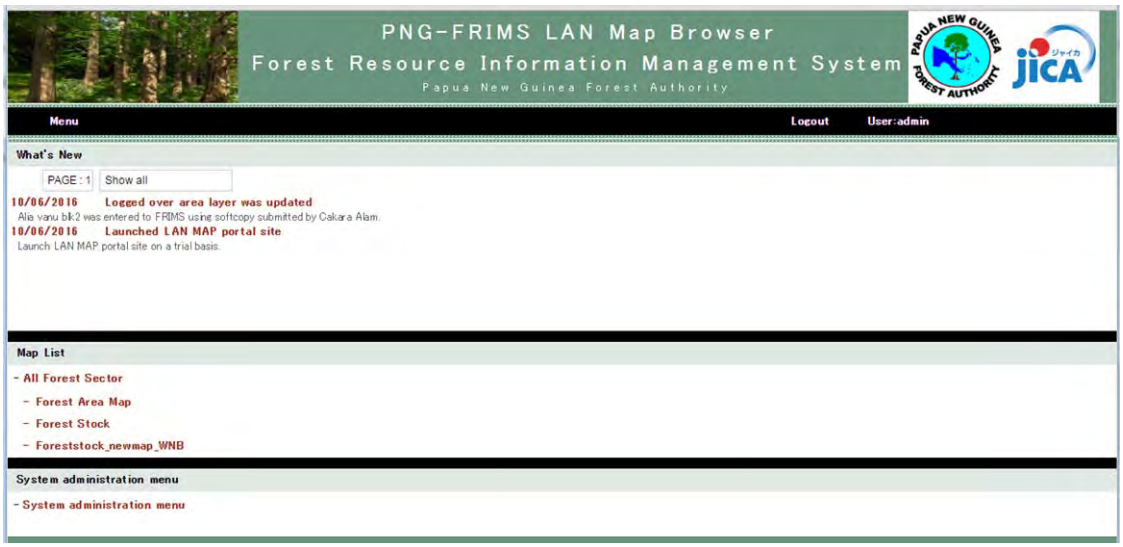
(1) Login

The access to the portal site needs a user name and password.



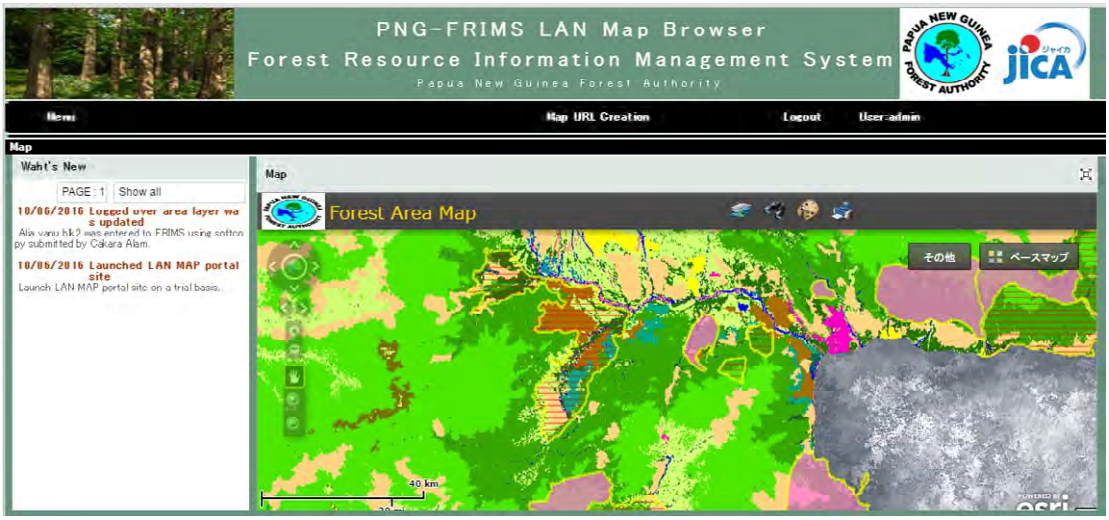
(2) Menu

The Menu screen after login displays recent news and a list of maps that the user can see. Also, the user who has administrator privilege can move to the system administration screen.



(3) Map

The user can move to the map screen after clicking a map displayed on the menu screen. The news about LAN Map are displayed on the left side of the map screen. If there is 'Map URL Creation' button on the upper side of the screen, which enables creation of a permalink to the logging project map.



3 For Administrator

3.1 FIMS

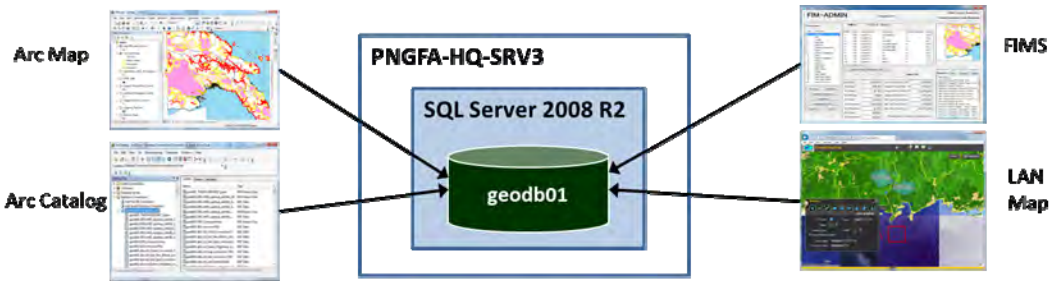
3.1.1 Procedure of updating Logged Over Area

It is important to update “Logged Over Area” timely in order to estimate more accurate forest volume using FIMS.

(1) How to access the database in JICA server “pngfa-hq-srv3”

The data which are used by new FIMS and LAN Map are stored in SQL Server of pngfa-hq-srv3 as an enterprise geodatabase. The database name is “geodb01”.

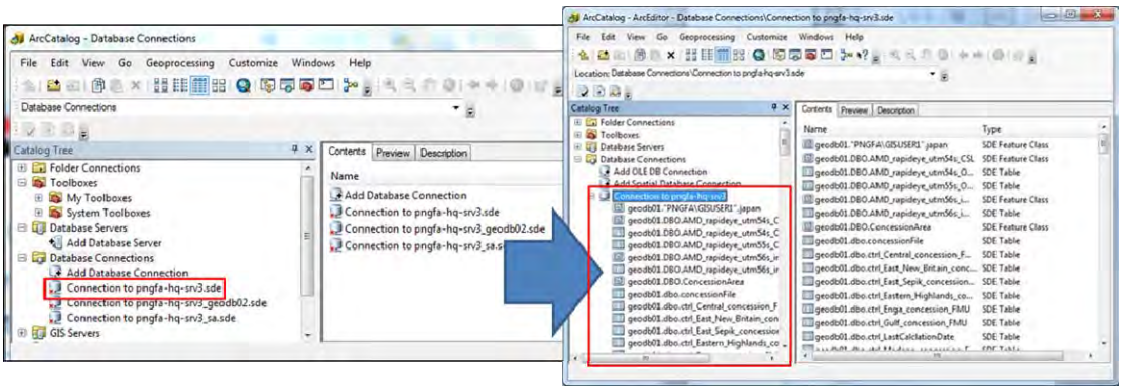
The database can be accessed using Arc Catalog and Arc Map. If you edit a map layer in this geodatabase, the result will be reflected to LAN Map immediately. Also, the database allows multiuser editing because of enterprise geodatabase established on the SQL server.



The following specific users can only access the geodatabase.

pngfa¥jicasupport / pngfa¥pmalan / pngfa¥plaa / pngfa¥jantiko

You can see all layers through “Connection to pngfa-hq-srv3”.



(2) Step of updating

Step1: Data in SHP format digitized will be accumulated in the folder 'NFRDMS2¥ALREADY DIGITIZED' under pngfa-hq-srv3.

Step2: Confirm the spreadsheet (ALP List.xlsx) whether there are new data which should be integrated with the database in the SQL server (Connection to pngfa-hq-srv3.sde).

Step3: Integrate SHP files of logged over area and planned area with relevant layers for LAN-Map.

You need to update the following three layers.

- geodb01.DBO.CoupePlannedArea
- geodb01.DBO.SetupLoggedOver
- geodb01.DBO.SetupPlannedArea

You need to edit and update the existing layers taking account of the structure of attributes.

Step4: Integrate the SHP file of logged over area (SetupLoggedOver) with a relevant layer for FIMS.

You need to update the following layer.

- geodb01.DBO.Logged_NotLandUse_Current

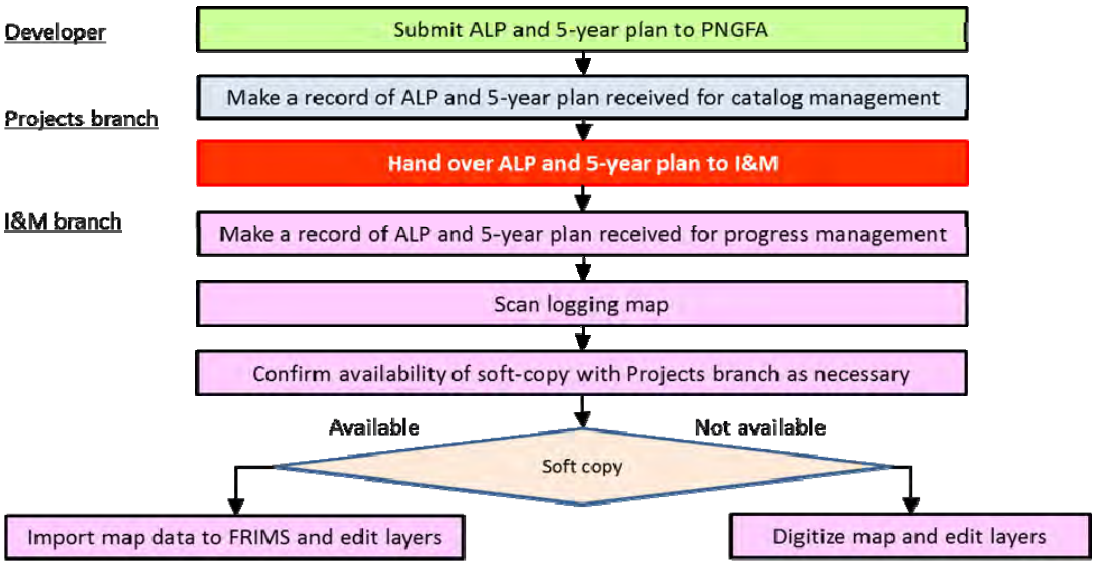
You need to edit and update the existing layers with ArcMap taking account of the structure of attributes.

After editing, you need to execute FMU calculation (FMU/ Concession) of relevant provinces with FIMS.

Step5: Other layers such as logging road, river, and bridge in ALP except for logged over and planned area should be updated as well.

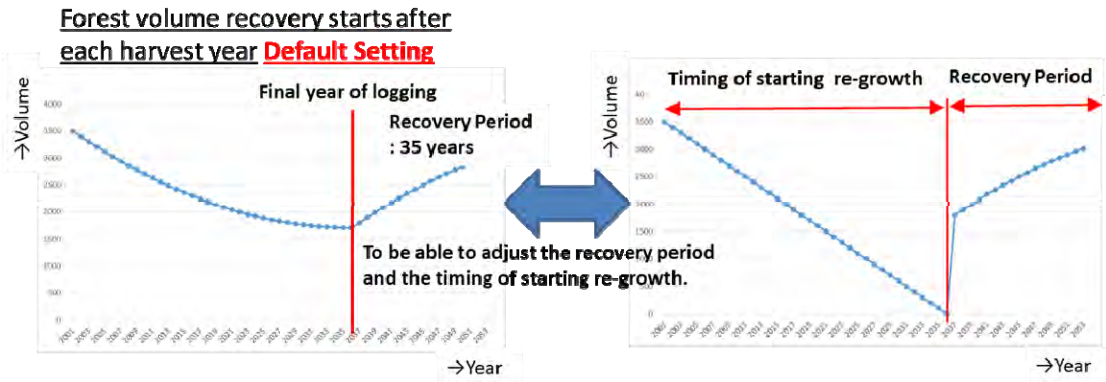
Currently, there are no layers for integration in the SQL server. It is OK to maintain them as one File Geodatabase under the rule of PNG-FRIMS management. Because those data are background data, FIMS does not need them for volume processing.

(3) Work flow between I&M and PAD



3.1.2 Setting on the recovery duration and the timing of re-growth for AAC calculation

About the AAC calculation function on FIMS, the recovery duration and the timing of starting re-growth are changeable by administrator.



The following is the way to change the setting. You need to change four python script files under the folder "C:¥fims¥appendix25" on the administrator workstation (POM-MAP-GIS06, as of June 2019).

- OLD_Appendix2_and_Appendix5_E.py
- NEW_Appendix2_and_Appendix5_E.py
- OLD_Appendix2_and_Appendix5_ConcessionArea_E.py
- NEW_Appendix2_and_Appendix5_ConcessionArea_E.py

The all python scripts have following description in each file. You can change figures described in red below.

```
# Period recovered years
list_Recovery_year=[0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]
list_Recovery_year[0] = 35      # WES
list_Recovery_year[1] = 35      # GUL
list_Recovery_year[2] = 35      # CEN
list_Recovery_year[3] = 35      # MIL
list_Recovery_year[4] = 35      # ORO
list_Recovery_year[5] = 35      # SHP
list_Recovery_year[6] = 35      # EHP
list_Recovery_year[7] = 35      # SIM
list_Recovery_year[8] = 35      # WHP
list_Recovery_year[9] = 35      # WSP
list_Recovery_year[10] = 35     # ESP
list_Recovery_year[11] = 35     # MAD
list_Recovery_year[12] = 35     # MOR
list_Recovery_year[13] = 35     # WNB
list_Recovery_year[14] = 35     # ENB
list_Recovery_year[15] = 35     # NIP
list_Recovery_year[16] = 35     # ABG
list_Recovery_year[17] = 35     # MAN
list_Recovery_year[18] = 35     # ENG
list_Recovery_year[19] = 35     # NCD
list_Recovery_year[20] = 35     # HLA
list_Recovery_year[21] = 35     # JIW

# Year of regrowth inception
DEF_Year_reflecting_regrowth = 1
```

The recovery year can be set by province.
The timing of starting re-growth is common among provinces.

3.1.3 To keep forest information related to FIMS up to date

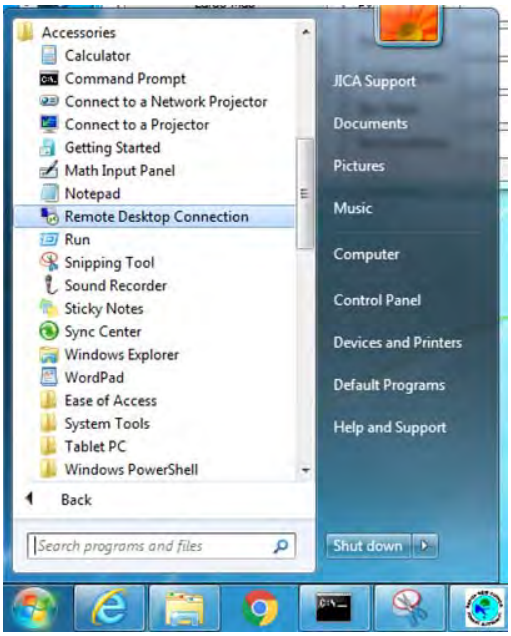
Administrator has to continue maintenance of forest information related to FIMS in daily business. The following table shows major tasks of the administrator.

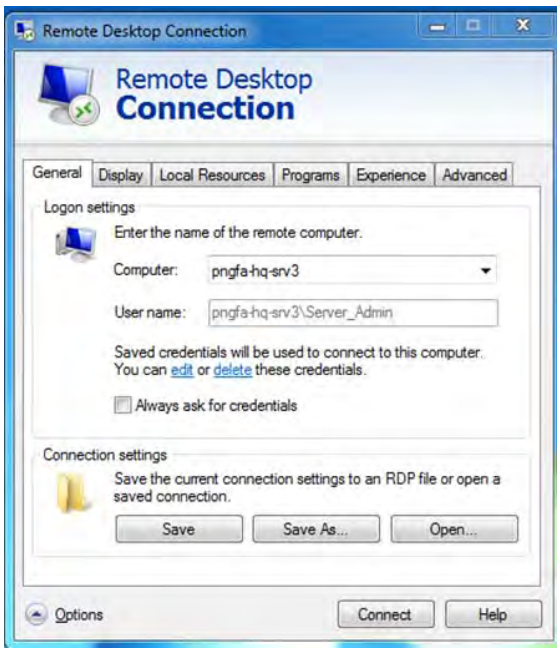
	Daily business of administrator	Remarks
1	Continue to digitize ALPs and to update "Logged_NotLandUse_current"	" Logged_NotLandUse_current" is taken Re-growth into account by AAC calculation.
2	Consider whether polygons overlapping with expired concession area should be removed (archived) or left.	Existing data is too old and maybe some of those areas have already recovered
3	Verify and update "LandUse_NotLogged_Current" using Urban Area (vegetation code = U)	This layer has not been updated since JICA project started. "U" should be reflected after comparison between the existing data and FBM2012.
4	Verify and update "Logged_LandUse_Current" using clear-cut area in FCA	This layer has not been updated since JICA project started. Need FCA boundary and harvesting history.
5	Verify and update the concession area layer including boundaries and attributes.	The status (current, proposed and expired) of each concession area will be changed with time. Last verification was carried out around 2016.
6	Get FCA boundaries and integrate them with concession area layer.	Timber volume in FCAs affects the gross merchantable volume in AAC table. Currently, AAC calculation does not take it into account. So will need to improve the function.
7	Examine the necessity of TA-01 boundaries and get boundaries as necessary	TA-01 may affect the gross merchantable volume. Currently, AAC calculation does not take it into account. So will need to improve the function. (It is not sure to be able to get boundary info.)

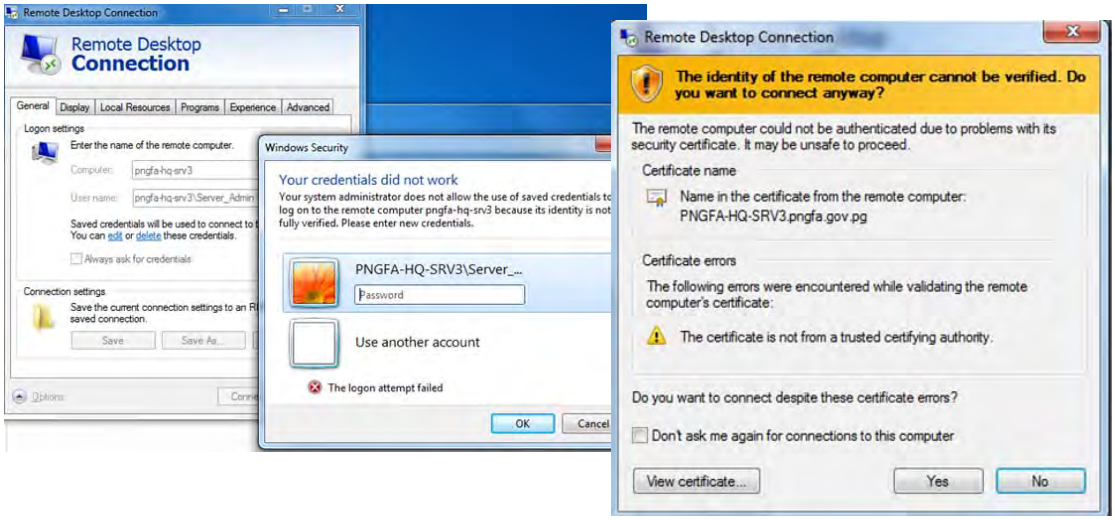
3.1.4 Create a backup file of the database of FIMS “geodb01”

It is recommended to create a backup file of the database of FIMS “geodb01” stored in SQL Server 2008 R2 of JICA Server (pngfa-hq-srv3) on a regular schedule.

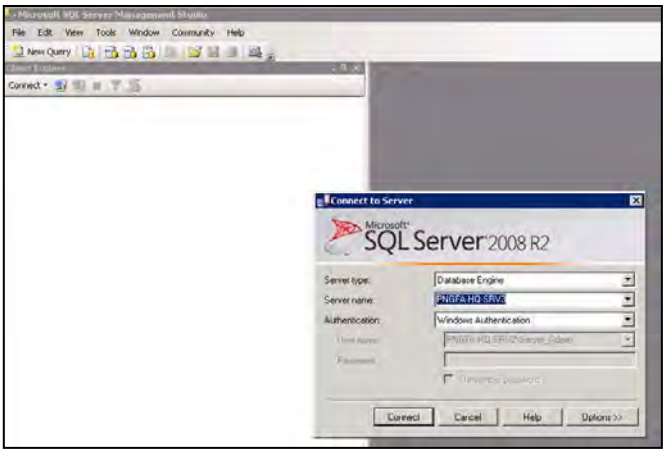
[Step1] Remote Desktop Connection to JICA Server (pngfa-hq-srv3) from JICA workstations

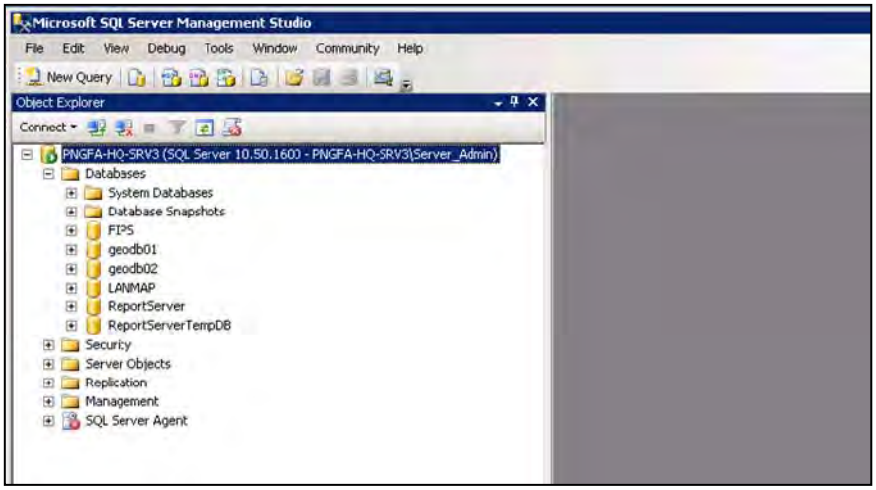




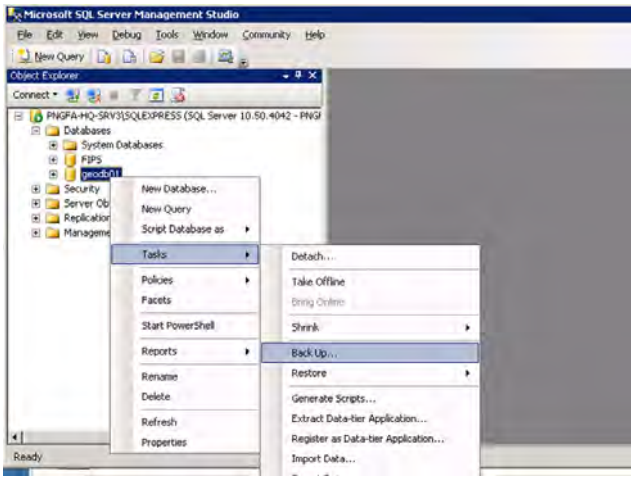


[Step2] Start “SQL Server Management Studio” on JICA Server (pngfa-hq-srv3)

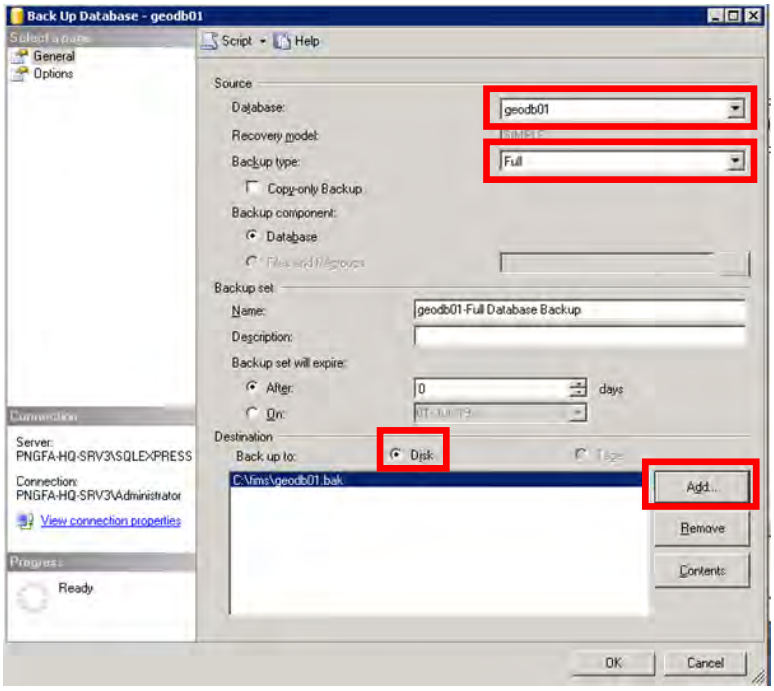




[Step3] Select “geodb01”, then go to “Tasks” > Back up.



[Step4] Save the backup file of “geodb01”.



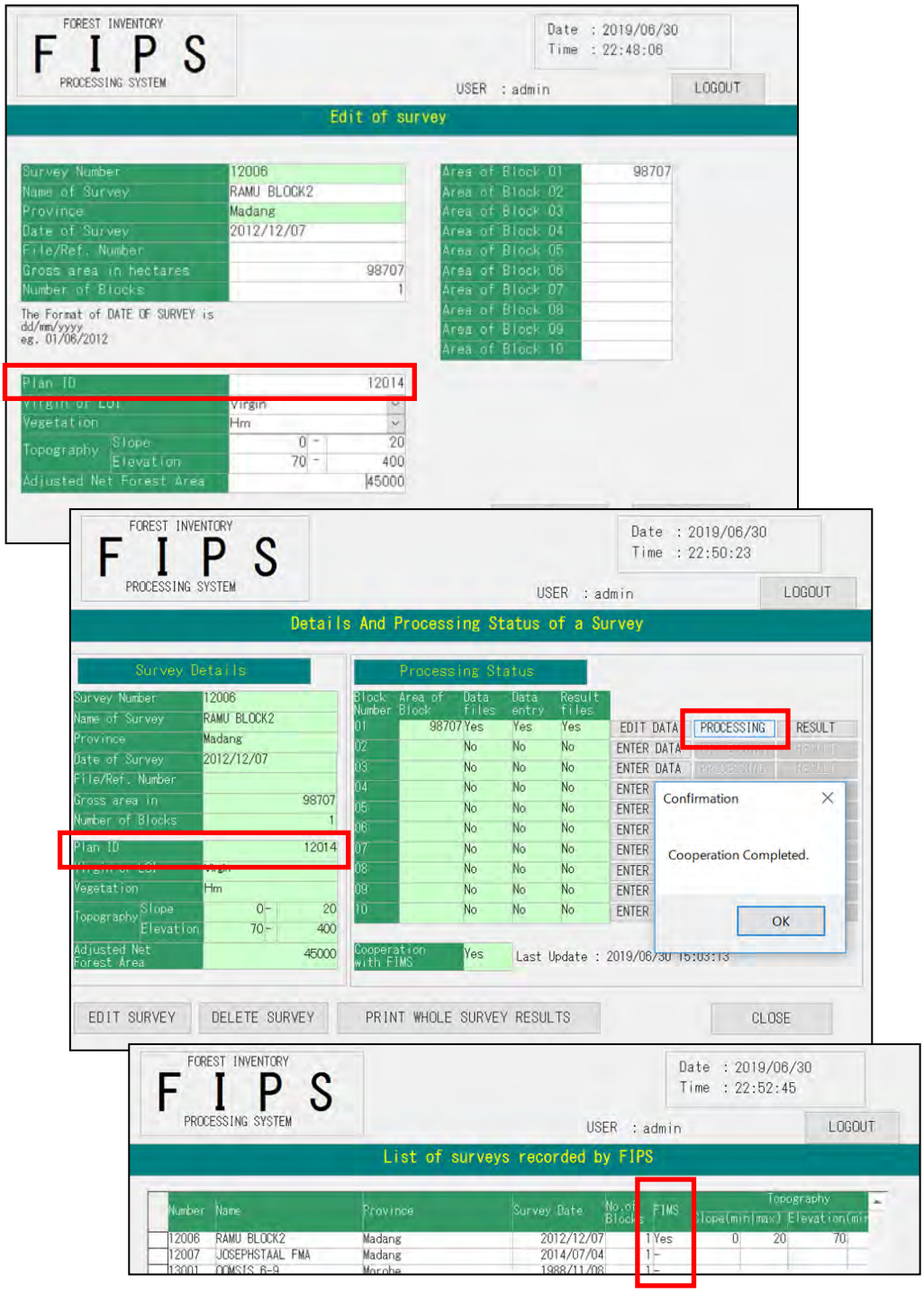
3.1.5 Operating precaution

The workstation for Admin-FIM (POM-MAP-GIS06) will have a heavy workload while executing “FMU calculation” or “AAC calculation” using Forest Base Map 2012. Therefore you are not supposed to use POM-MAP-GIS06 while the processing goes on. Especially, if you open not only FIMS with processing but also ArcMap or Arc Catalog, the processing will be stopped. Unexpected error will occur.

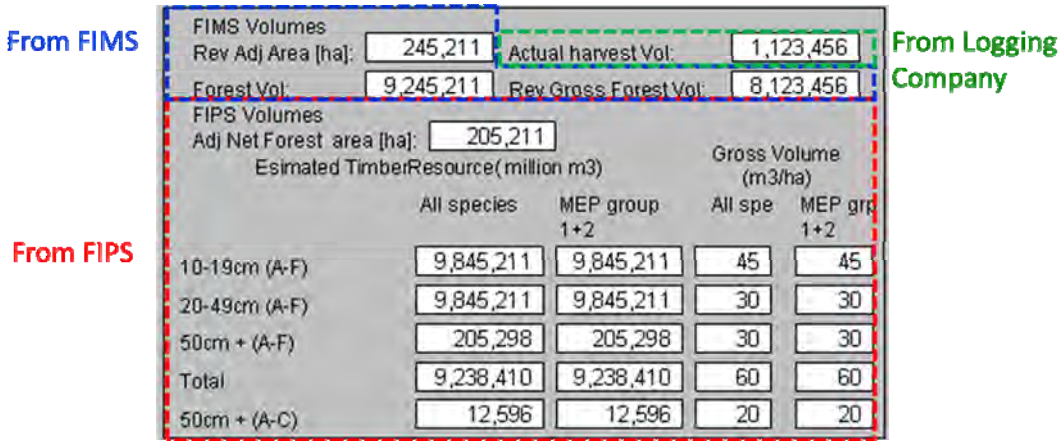
3.2 FIPS

3.2.1 Import FIPS DB to FIMS

FIPS records coordinates of strip line, FIMS can import FIPS data, which makes it possible to integrate FIMS and FIPS database. Not only entering coordinates of strip line but also “Plan ID” of concession area is necessary.



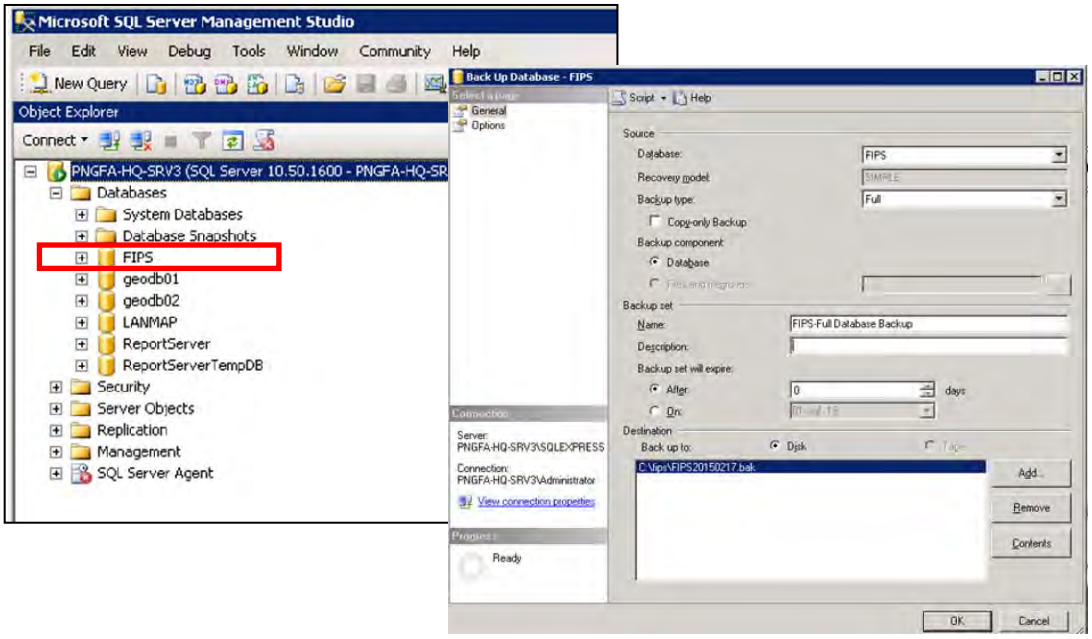
If you enter the PlanID and carry out “processing” on FIPS, you can link the survey result to the related FIMS concession area, and see in FIMS the estimated forest volume which is calculated by FIPS.



3.2.2 Create a backup file of the database of FIPS “FIPS”

It is recommended to create a backup file of the database of FIPS “FIPS” stored in SQL Server 2008 R2 of JICA Server (pngfa-hq-srv3) on a regular schedule.

The procedure is as same as creating a backup file of the database of FIMS. (see 3.1.4)

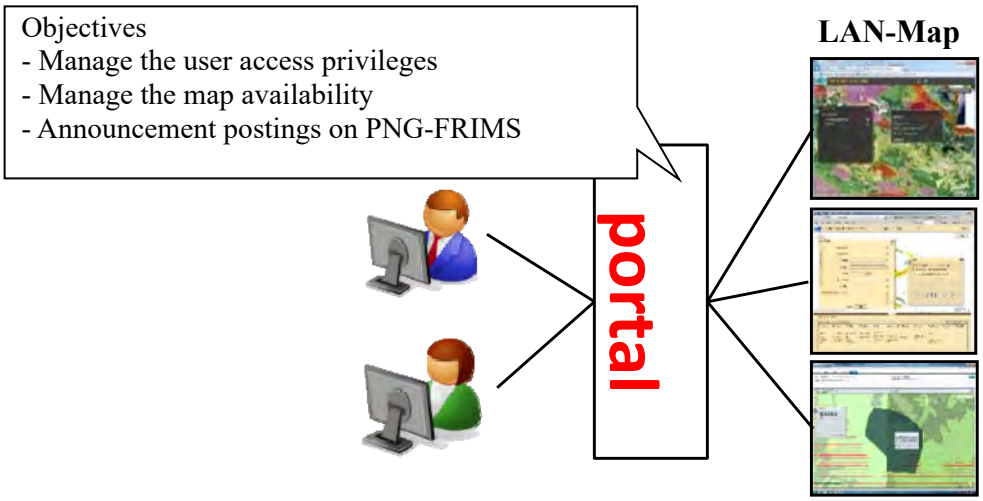


3.3 LAN-Map

3.3.1 Maintenance of the portal site

(1) Background and summary

According to the introduction of LAN Map, the PNGFA officers can reach several maps including forest resource information any time via their computer connecting to the intranet inside PNGFA. However, forest information stored in PNG-FRIMS sometimes has confidential information that limited specific officers are allowed to access. Therefore, the portal site was developed as the gateway to LAN Map delivering forest information stored in PNG-FRIMS to manage the access privileges.



http://pngfa-hq-srv3/FRIMS-LAN-Map

The list of the portal site functions is as below.

Category		Function		Summary
1	Common	1-1	Logout	Executes logout processing and returns to the login window.
		1-2	Log output	Outputs log file including user's access histories.
2	Login	2-1	Login	Logs-in the portal site with inputting a user ID and password. Controls map availability in accordance with the privilege of each group that user belong to.
		2-2	Group select	Selects a group if the user belongs to two or more groups.
3	Menu	3-1	News list	Shows the list of news.

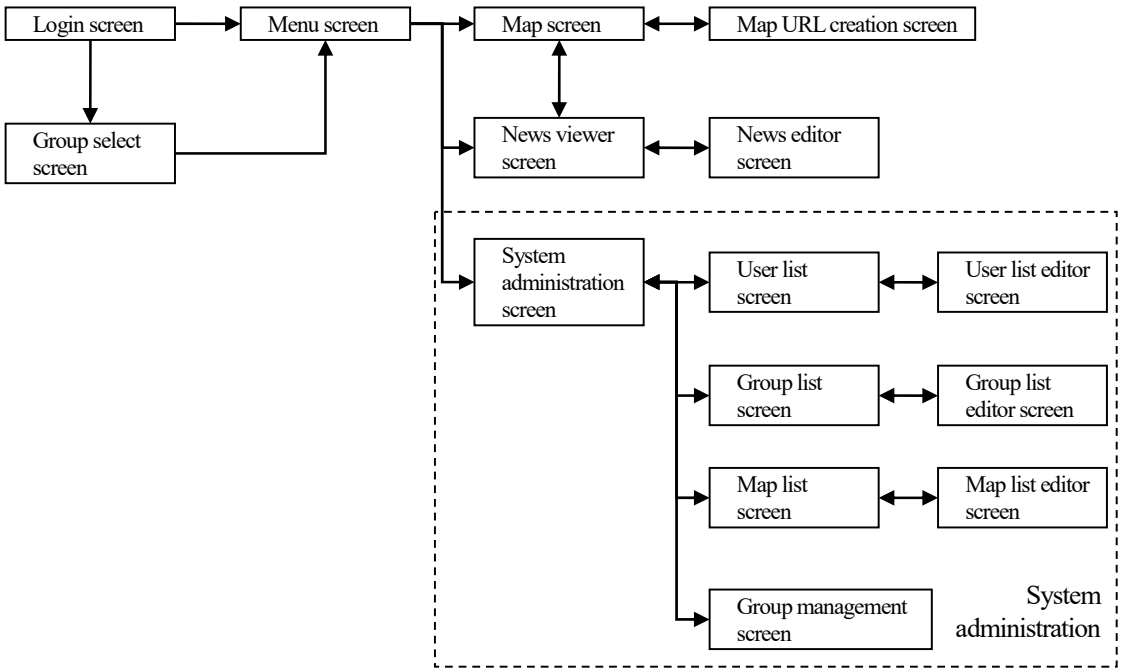
Category		Function		Summary
		3-2	Map list	Shows the list and link of maps that user can see.
4	Map	4-1	Map viewer	Shows a map published on LAN Map.
		4-2	Article editor	Creates, updates and deletes an article.
		4-3	News viewer	Shows the list of news and its contents.
		4-4	Function linkage	Starts other functions from the map window.
5	System administration	5-1	User management	Shows the list of users, and creates, updates and deletes user information.
		5-2	Group list	Shows the list of groups, and creates, updates and deletes them.
		5-3	Map management	Edits the name of map and connects the name with URL.
		5-4	Group management	Defines the privilege of each group to access each map.
6	Map sharing	6-1	Map url creation	Creates a URL for shared map with customized scale for a specific point of interest.

The portal site has three type of users, namely 'Administrator', 'Editor' and 'viewer'. The relation between user type and functions is as below.

Functions			Administrator	Editor	Viewer
1	Common	Logout	✔	✔	✔
		Log output	✔	-	-
2	Login	Login	✔	✔	✔
		Group select	✔	✔	✔
3	Menu	News list	✔	✔	✔
		Map list	✔	✔	✔
4	Map	Map viewer	✔	✔	✔
		Article editor	✔	✔	-
		News viewer	✔	✔	✔
		Function linkage	✔	✔	✔
5	System administration	User management	✔	-	-

Functions			Administrator	Editor	Viewer
		Group list	✔	-	-
		Map management	✔	-	-
		Group management	✔	-	-
6	Map sharing	Map URL creation	✔	✔	✔

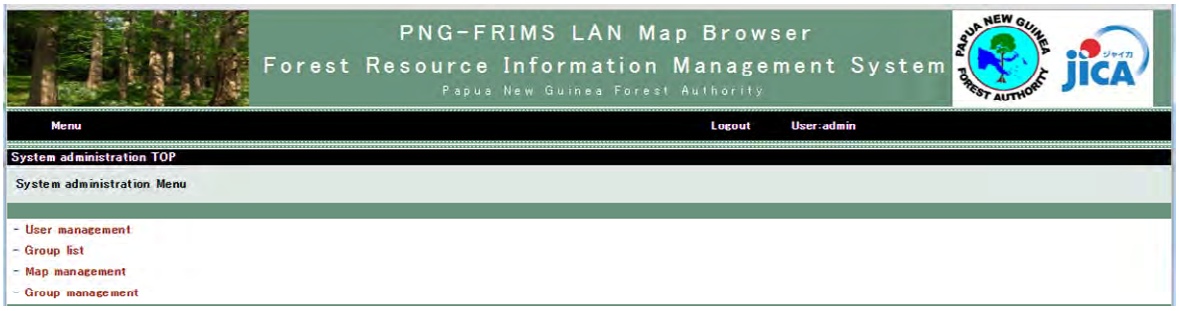
The following shows the screen transition of portal site.



(2) System administration function

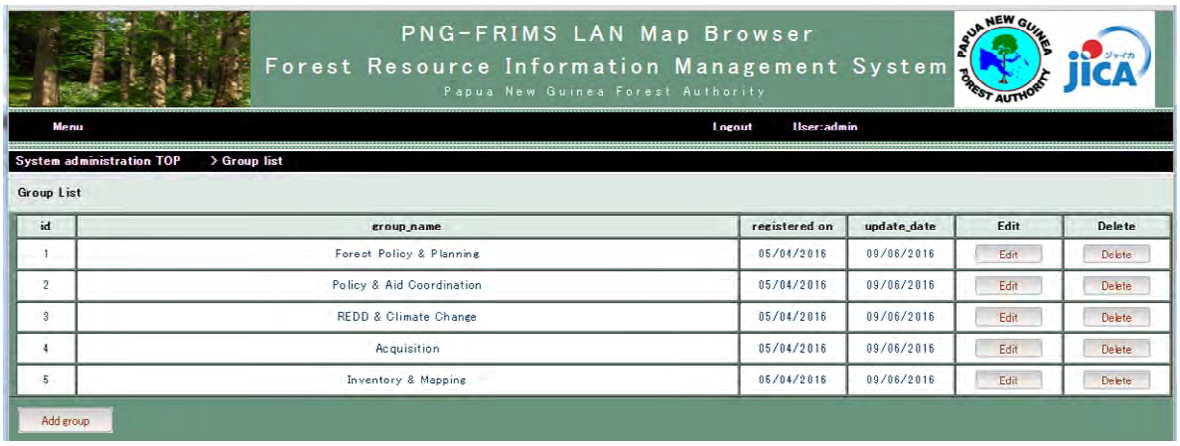
The system administration has four functions:

- 'Group management'
- 'User management'
- 'Map management'
- 'Group role management'

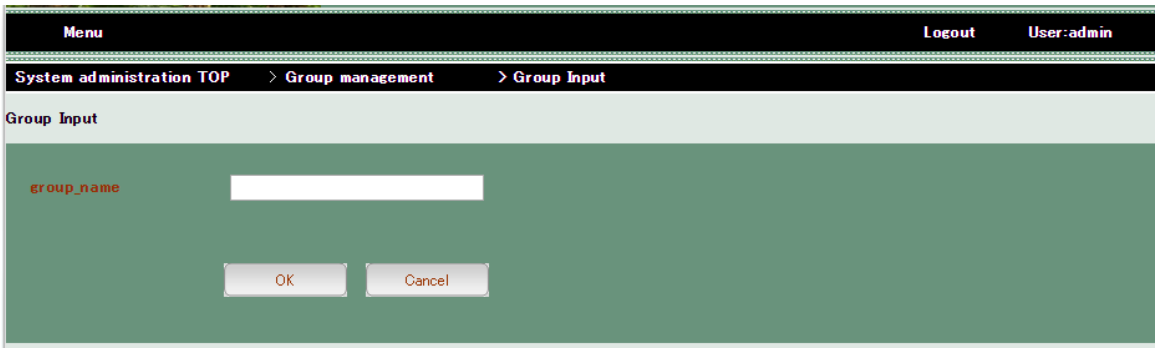


1) Group list

The group list function defines the group. The rights of users to view maps will be assigned by the group they belong to.

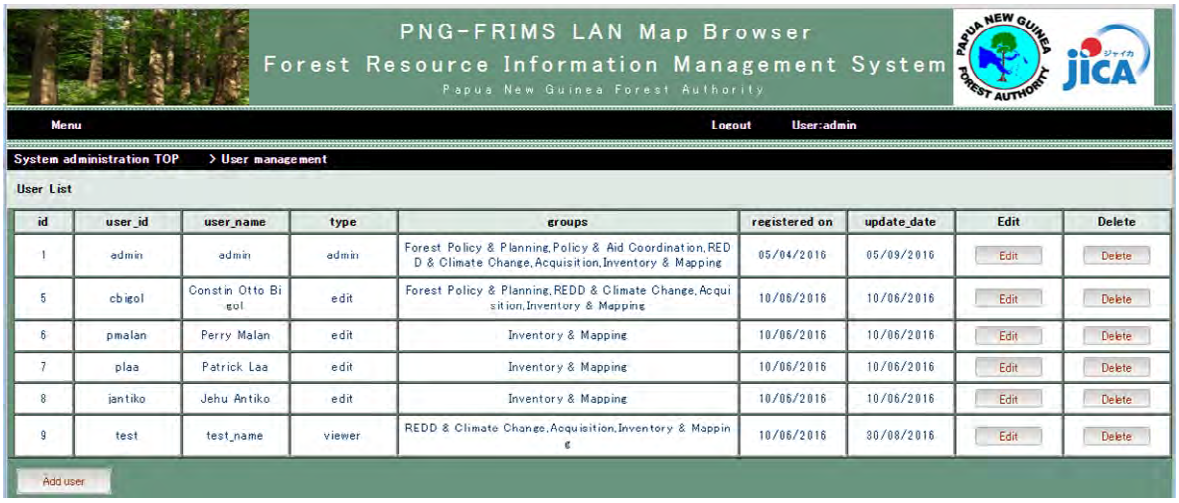


After clicking ‘Add group’ button, ‘Group input’ screen opens. You can define a new group.

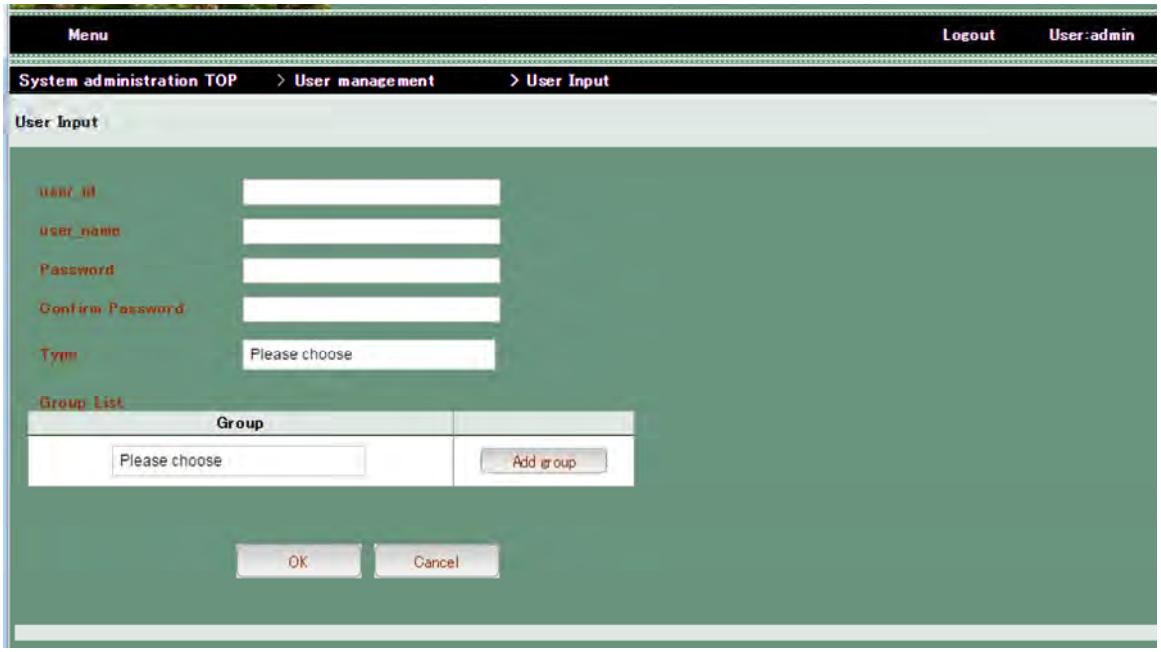


2) User management

The user management function defines the user name and password, and sets the group of each user.



After clicking 'Add user' button, 'User input' screen opens. You can define a new user.



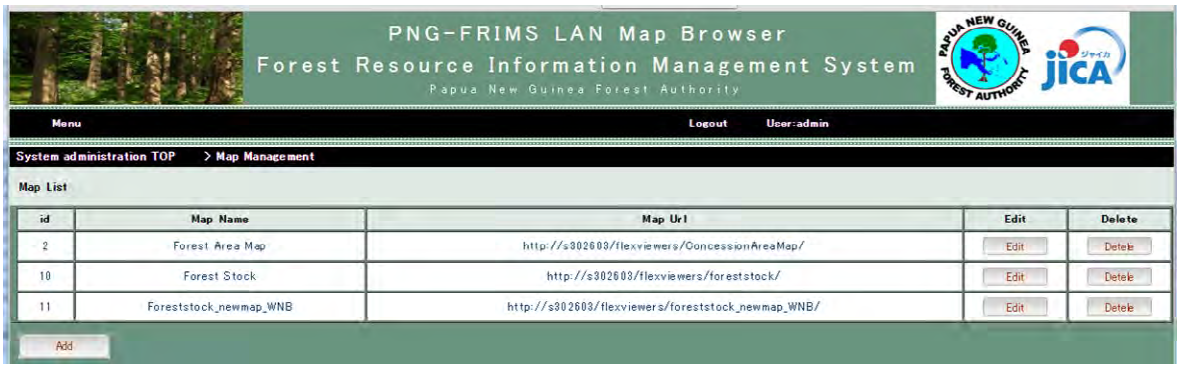
After clicking 'Add group' button, 'Group input' screen is open. You can define a new group on this screen.

- user_id: This should be identical to 'domain user name' which is part of PNGFA e-mail address. This 'user_id' is used at the time of login
- user_name: This 'user_name' will be shown on the screen after login.
- Password: Only administrator can define and change a password for each user. The user cannot change the password by themselves. (Need to inform the users of their password.)
- Confirm Password: Type a password above again.

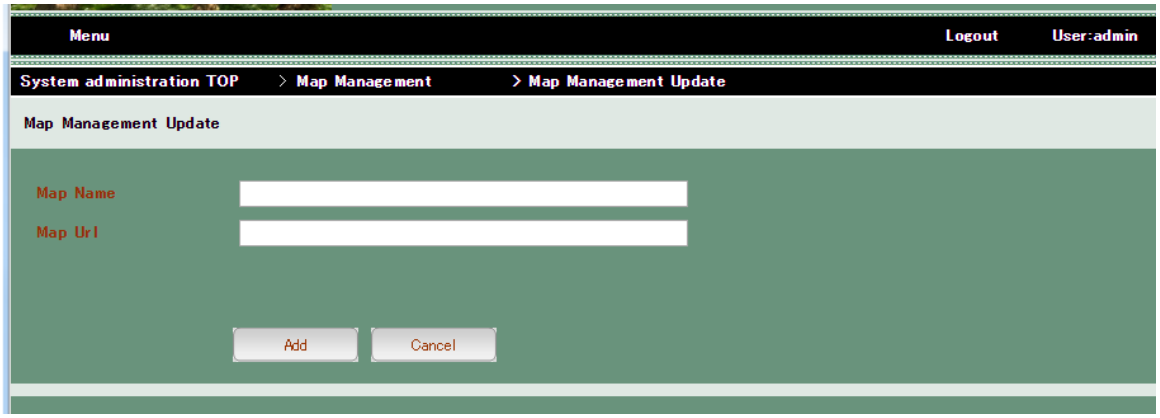
- Type: Choose a user type.
- Group List: Choose one or more groups. A user can view maps according to the privileges of each group.

3) Map management

The map management function controls the map name and its URL delivered on the LAN Map. This portal site hides the URLs to prevent unauthorized access.



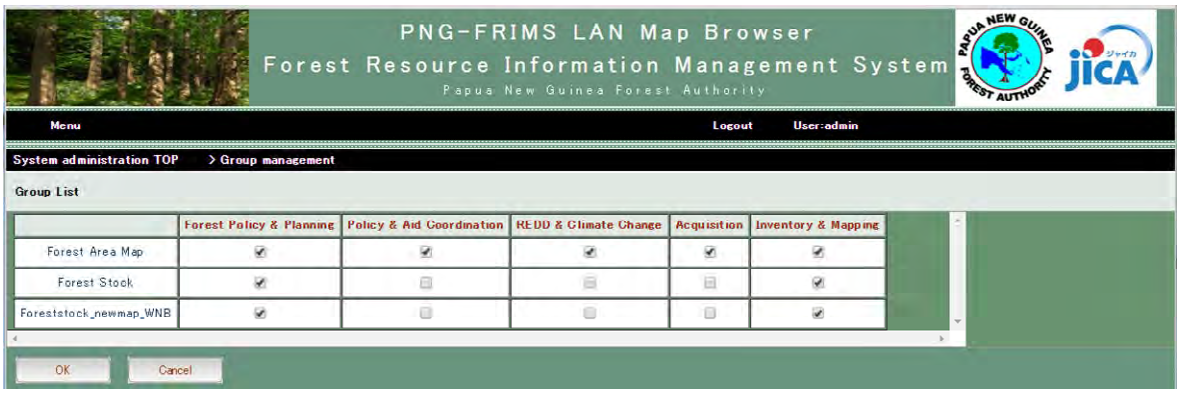
After clicking 'Add' button, 'Map Management Update' screen opens. You can enter 'Map Name' and 'Map URL' which has been already published by ArcGIS viewer for Flex.



[Advice] When you create a map by ArcGIS viewer for Flex, you should make a URL complicated not to guess it easily for anyone.
One of the measures is to add 'Date' and 'Time' at the end of the URL
e.g. http://172.20.7.10/ConcessionArea_31_08_2016_08_24_30

4) Group management

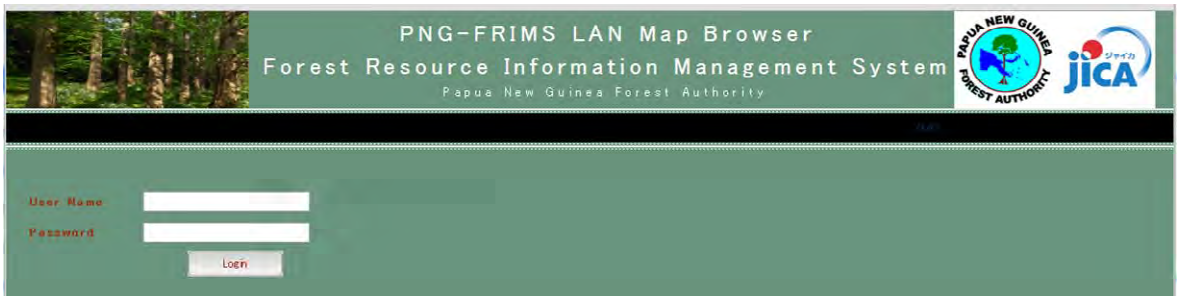
The group management function chooses one or more maps that each group can see.



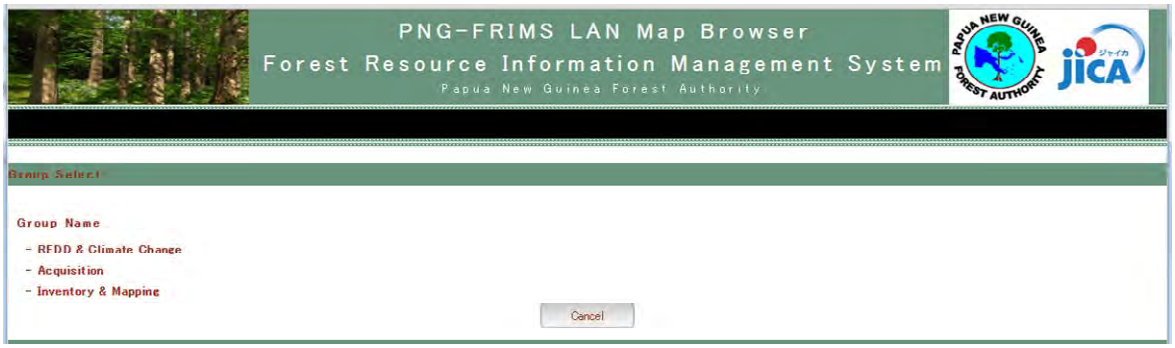
(3) General user function (for viewer, editor and administrator)

1) Login

The access to the portal site needs a user name and password.

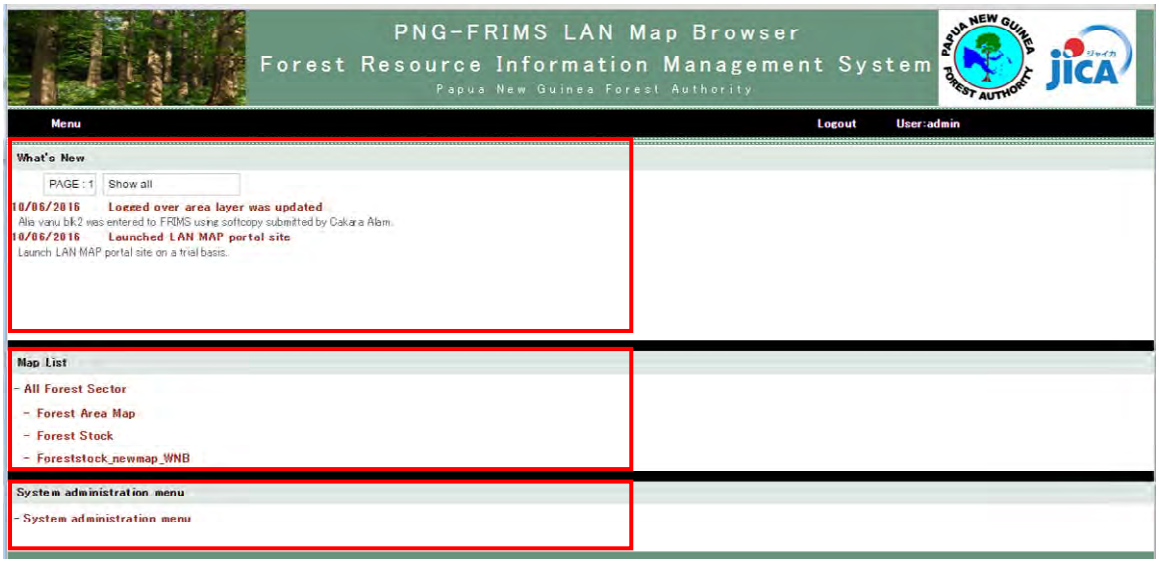


The user can belong to two or more groups and view maps in accordance with the privileges of each group. If the user belongs to two or more groups he/she must choose one of the groups after login.



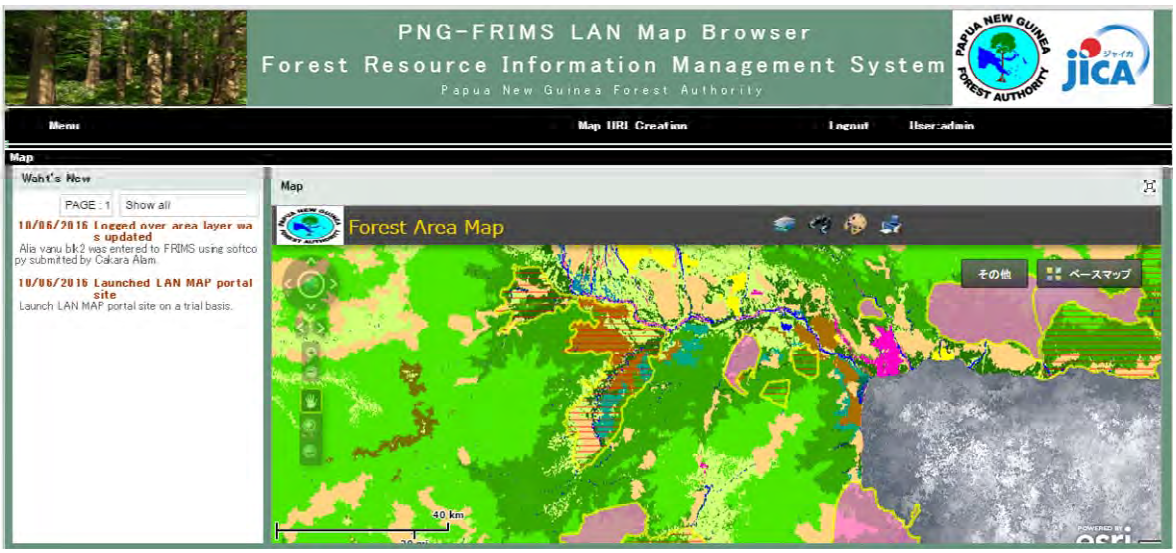
2) Menu function

The Menu screen after login displays recent news and a list of maps that the user can see. Also, the user who has administrator privilege can move to the system administration screen.



3) Map function

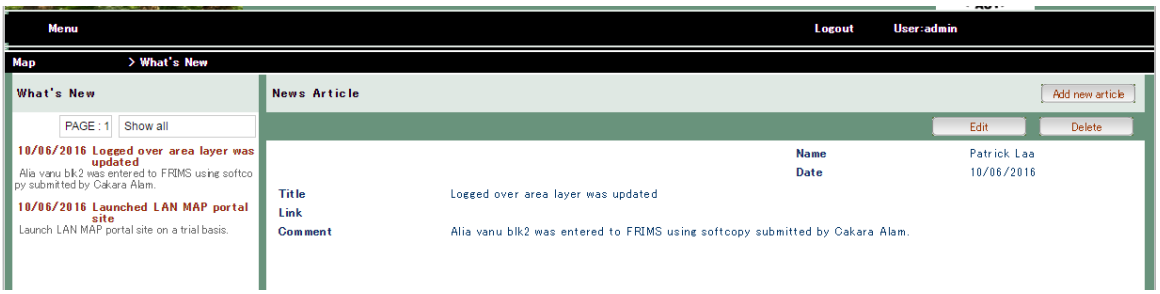
The user can move to the map screen after clicking a map displayed on the menu screen. The news about LAN Map are displayed on the left side of the map screen. Only for the shared map, there is 'Map URL Creation' button on the upper side of the screen which enables creation of a permalink to the currently displayed map.



By clicking on the upper right button on the displayed map, the map window will expand.

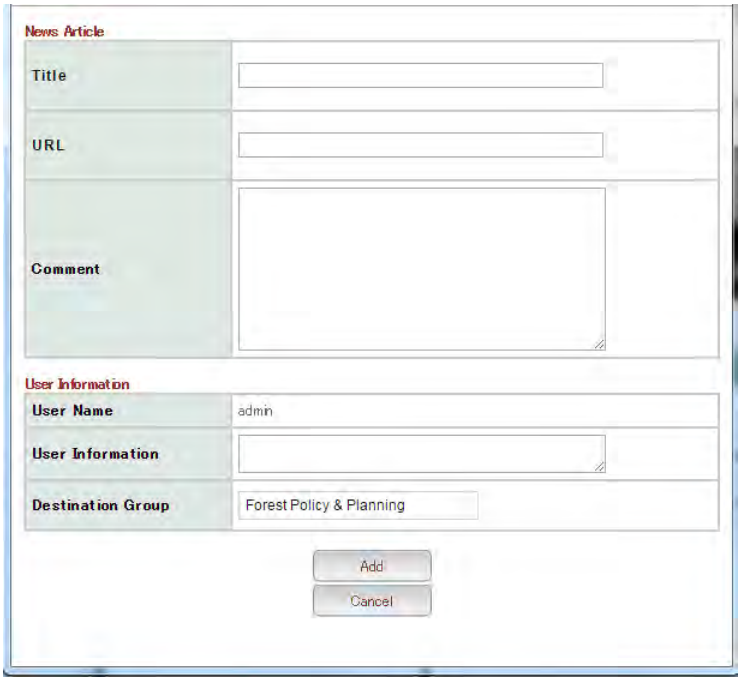
4) News viewer and editor function

By clicking on the 'What's New', you can move to the detailed news viewer screen. If a user has a privilege of administrator or editor, 'Add new article' button will appear.



The news article editor will open after clicking on 'Add new article' button.

- Title: Article title will be displayed on the menu screen and the map screen.
- URL: You can type the URL that you want to share within group members.
- Comment: You can type comment up to 500 letters.
- User information: You can note a memorandum.
- Destination Group: Choose a group that can access the news.



5) Map sharing function

The URL creation screen issues the permalink that shows the map with focus on the point of interest by magnifying or scaling down the map.

For the shared map, the 'Map URL Creation' screen appears after clicking 'Map URL Creation' link at the upper on the Map screen.

The map for creation of URL is not changeable. Therefore, you need to prepare the dedicated map for getting the coordinates of the point of interest.
And also, the shared map also is not changeable. Because everyone need to know the URL of the shared map. Basic policy is to hide the URLs to prevent users from guessing URLs.

C:¥inetpub¥wwwroot¥FRIMS-LAN-Map¥Web.config (under JICA server "pngfa—hq-srv3")

- Set the map for getting the coordinates (88 line from the top)
  You need to define the restURL of the map. You can confirm the restURL at the ArcGIS 10.2.2 for server 'Services Directory'.

e.g.

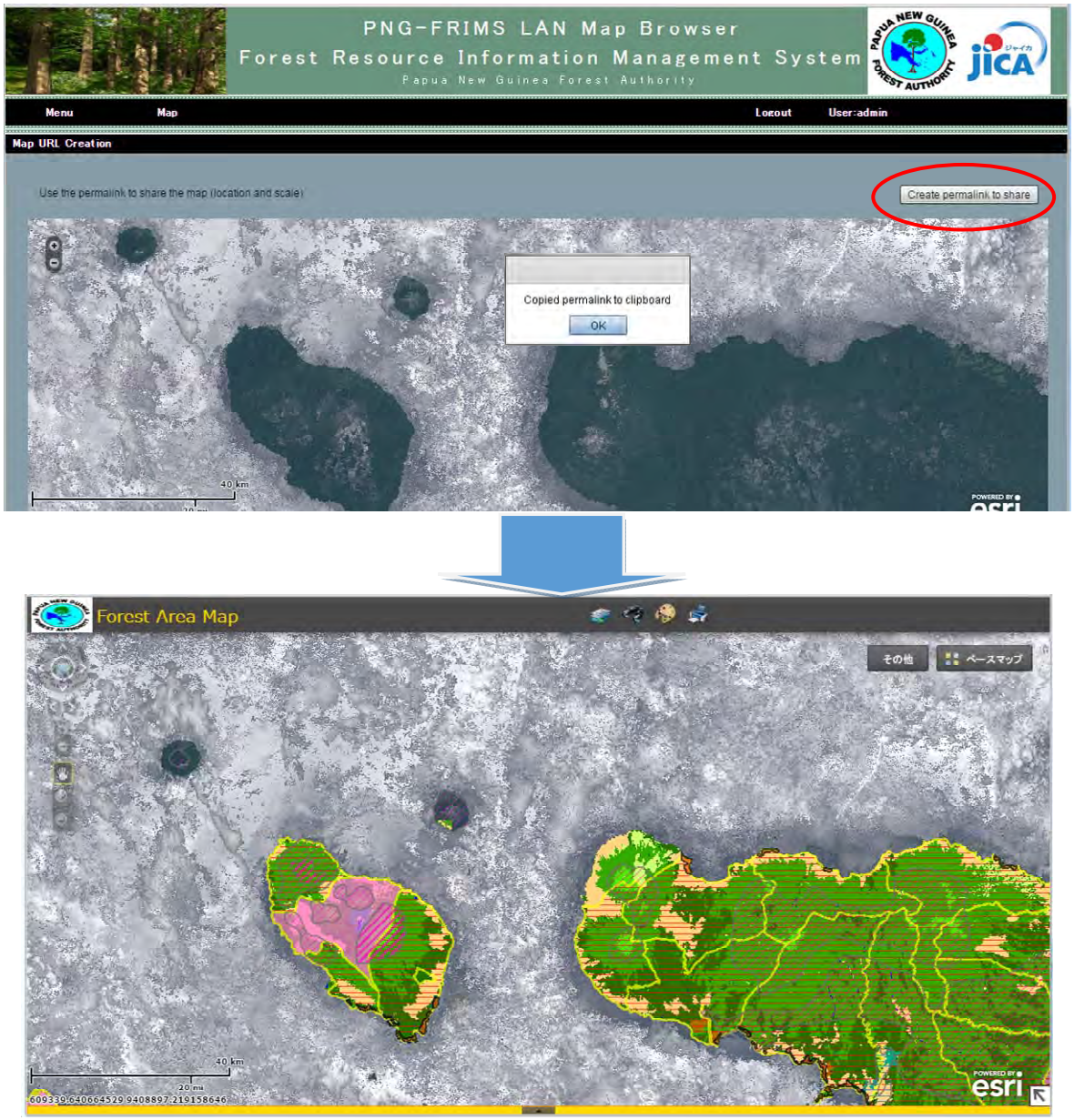
```
<add key="ReadURL_ViewURL" value="http://172.20.7.10:6080/arcgis/rest/services/MAP/AGP2014/MapServer" />
```

- Set the map for sharing among PNGFA officers (91 line from the top)

e.g.

```
<add key="ReadURL_Permalink" value="http://172.20.7.10/flexviewers/ConcessionAreaMap/" />
```

Please see the next chapter "3.3.2" showing more detailed information.



3.3.2 Shared Map setting

LAN Map is managing user access by the gateway “portal site”. The portal site provides users with several map services without letting them know map URLs. By doing so, LAN Map makes it possible to allow only authorized users to view maps published and reduce forest information leak by protect URL of each map service. Basic policy of LAN Map operation is to hide the URLs to prevent users from guessing URLs.

On the other hand, there is a requirement to share the URL to reach a same map among officers or other systems such as DSS (Decision Support System) in PNGFA HQ.

For example, DSS has no map but text information such as name of set-ups. However, if DSS has a field for storing URL which LAN Map provides, users of DSS can open the map related to location of the interested set-ups by clicking the URL.

Administrator of LAN Map needs to define two kinds of maps for the Shared Map.
One is a map which users and other systems can view, and whose URL is open to everyone.
The other is a map to get the coordinates of the point of interest. The URL issued by LAN Map will include the coordinates for displaying the shared map.

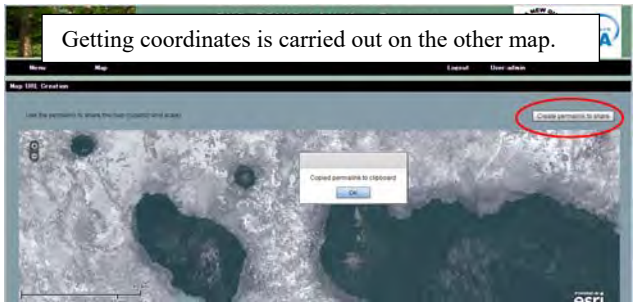
In order to set the maps for sharing among users and getting the coordinates of the point of interest, you needs to edit the following configuration file.
C:¥inetpub¥wwwroot¥FRIMS-LAN-Map¥Web.config

1. Set the map for sharing among PNGFA officers (91 line from the top)

You need to set the URL which will be open to everyone as value of "ReadURL_Permalink".
e.g.
<add key="ReadURL_Permalink"
value="http://pngfa-hq-srv3/flexviewers/ConcessionAreaMap/" />

2. Set the map for getting the coordinates (88 line from the top)

You need to set the restURL of the map. You can confirm the restURL at the ArcGIS 10.2.2 for server 'Services Directory'.
e.g.
<add key="ReadURL_ViewURL"
value="http://pngfa-hq-srv3:6080/arcgis/rest/services/MAP/AGP2014/MapServer" />



3.3.3 Trace a user who printed maps on LAN Map

There is a risk to forest information leak on the printing function of LAN Map.
Although it would be better to show a footnote including a computer name and login user name on the map printed with LAN Map, unfortunately, it is not possible to do that because the printing function is running on JICA server. So the footnote always shows "pngfa-hqsrv3" and "server_admin".

For the time being, the following ways is adopted to monitor users who printed maps.

- The footnote is able to show the date and time when the printing function of LAN Map is executed.
- LAN Map is recording user access history.
- Administrator can guess who printed a map of LAN Map with the above information.

(1) Preparation

Footnote setting on map layouts which are registered with the folder "C:¥Program Files¥ArcGIS¥Server¥Templates¥ExportWebMapTemplates" under PNGFA-HQ-SRV3 is needed.
"Dynamic text" is text placed on a map layout that changes based on the current properties of the map document.
There are seven types of dynamic text, "Date" and "Time" can be used for the foot note of the printing function of LAN Map.

Date: Returns the current date and has a default format of MM/dd/yyyy (example: 01/01/1001)
Time: Returns the current time and has a default format of hh:mm tt (example: 01:17 PM)
http://resources.arcgis.com/en/help/main/10.2/#/na/00s90000000v000000/
After the preparation of footnote setting, maps printed out from LAN Map show date and time.

(2) Check user access log of the Portal Site, which is a gateway system of LAN Map

User access log is stored in the folder "C:¥inetpub¥wwwroot¥FRIMS-LAN-Map¥log" under PNGFA-HQ-SRV3. The log file is created once per day.

(Example)

2017-06-02 14:47:03,351 [8] INFO ForestManagementSystem.BasePage - ,login,Patrick Laa,Inventory & Mapping,,

2017-06-02 14:49:41,922 [10] INFO ForestManagementSystem.BasePage - ,logout,Patrick Laa,Inventory & Mapping,,

The above information will be a clue to specify the origin of map printed.

Attachment

- Attachment1: PNG-FRIMS Installation Manual
- Attachment2: FIMS User Guide
- Attachment3: FIPS User Guide
- Attachment4: Simple manual on LAN Map on PNGFA's Intranet

Annex 2

Manual on Updating the Forest Base Map

Manual on Updating Forest Base Map

April 2019

Papua New Guinea Forest Authority (PNGFA)

Japan International Cooperation Agency (JICA)

FOR INTERNAL USE ONLY

Manual on Updating Forest Base Map

April 2019

Papua New Guinea Forest Authority (PNGFA)

Japan International Cooperation Agency (JICA)

Manual on Updating Forest Base Map

The information in this document is subject to change without notice

1st Edition published April 26, 2019

PNG Forest Authority (JICA Project)

Address: P.O.Box 5055, Boroko, National Capital District, Papua New Guinea

JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html

Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

Authors: Perry Malan, Jehu Antiko, Patrick Laa, Ayako Ochi, Takahiro Koide, Masamichi Haraguchi

Acknowledgments

The manual is based on process of developing a nationwide Forest Base Map 2012 which was built on GIS & RS system installed at PNGFA. The original forest base map was founded as forest inventory and mapping system (FIMS). However, the FIMS has not been updated since 1996 and had various practical issues to PNGFA. Thus, the PNG Forest Base Map 2012 was developed as a main layer of the improved version of FIMS known as PNG Forest Resource Information Management System (PNG-FRIMS) in 2014. The PNG-FRIMS was advanced under PNGFA-JICA Project in which Kokusai Kogyo Co., Ltd. (KKC) of Japan was contracted by JICA to improve, develop and implement the system to its current status.

The PNG Forest Base Map is a large system of complete national coverage. It has taken nearly ten years to implement since its initial conception. Thus, the purpose of this manual is to document the methods, procedures, workflows, guides, and processes of its development and its features. It would not have been possible to achieve that goal without the full and continuing support of PNGFA Counterparts namely; Perry Malan (Senior Cartographer GIS & RS), Jehu Antiko and Patrick La'a (Cartographers GIS & RS) and JICA Project Experts namely; Ayako Ochi, Takahiro Koide, Yasuyuki Okada and Masamichi Haraguchi of KKC of Japan.

Acronyms

AGLB	Above-Ground Living Biomass
AGP	Annual Greenest Pixel
ALOS	Advanced Land Observing Satellite
ALP	Annual Logging Plan
BGLB	Below-Ground Living Biomass
CEPA	Conservation and Environment Protection Authority
CU	Census Unit
DEM	Digital Elevation Model
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCA	Forest Clearance Authority
FDD	Forest Development Directorate
FIMS	Forest Inventory Mapping System
FMU	Forest Mapping Unit
FMU	Forest Monitoring Unit
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
FRI	Forest Research Institute
FWP	Forest Working Plan
GEE	Google Earth Engine
GeoSAR	Geostationary Orbiting Search And Rescue
GPS	Global Positioning System
ILG	Incorporated Land Group
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
LLG	Local Level Government
LULUCF	Land Use, Land Use Change and Forestry
MASP	Mapping Agriculture Systems of PNG
MRA	Mineral Resource Authority
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index

NEFC	National Economic and Fiscal Commission
NFI	National Forest Inventory
NIR	Near Infra-Red
NMB	National Mapping Bureau
NSO	National Statistical Office
PAD	Project Allocation Directorate
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PINFORM	PNG International Tropical Timber Organization Natural Forest Model
PNG-FRIMS	PNG Forest Resource Information Management System
PNGFA	Papua New Guinea Forest Authority
PNGRIS	Papua New Guinea Resource Information System
PSP	Permanent Sample Plots
RAMS	Road Asset Management System
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
REL	Reference Emission Level
SABL	Special Agriculture and Business Leases
SAR	Synthetic Aperture Radar
SRTM	Shuttle Radar Topography Mission
UNFCCC	United Nations Framework Convention on Climate Change
UPNG	University of Papua New Guinea
USGS	United States Geological Survey

Abbreviations of Papua New Guinea Province

WES	Western
GUL	Gulf
CEN	Central
NCD	National Capital District
MIL	Milne Bay
ORO	Oro
SHP, SHY	Southern Highlands
HLA	Hela
ENG	Enga
WHP, WHY	Western Highlands

JIW, JWK	Jiwaka
SIM	Chimbu
EHP, EHY	Eastern highlands
MOR	Morobe
MAD	Madang
ESP, ESK	East Sepik
WSP, WSK	West Sepik
MAN	Manus
NIP, NIR	New Ireland
ENB	East New Britain
WNB	West New Britain
ARB	Autonomous Region of Bougainville

Table of Contents

1. Executive Summary

1-1. Introduction

JICA-PNGFA Project 2011-2014 (Phase 1)

Japan International Cooperation Agency (JICA) and PNG Forest Authority (PNGFA) implemented a capacity development project since 2011 to 2014 combined with the Japanese Grant Aid Program that provided the project with remote sensing data and GIS equipment. The project set up a PNG Forest Resource Information Management System (PNG-FRIMS) based on a GIS system with remote sensing technology.

JICA-PNGFA Project 2014-2019 (Phase 2)

The new JICA-PNGFA project commenced in August 2014 and will terminate in August 2019. The new project aims to enhance capacity of PNGFA to continuously update forest information and to fully operationalize and utilize PNG-FRIMS for promoting sustainable forest management and for addressing climate change.

Development History of Forest Base Map

Before the project 2011-2014, national level Forest Base Map was created as at 1975 and had not been updated since minor update in 1996. This outdated map based on legacy technology caused various practical problems to PNGFA. Responding to this situation, The PNG Forest Base Map 2012 was initially developed as a main layer of the PNG-FRIMS in 2014. Following the successful completion of the project 2011-2014, new project 2014-2019 commenced for realizing the full operationalization of the PNG-FRIMS. The improvement and finalization of the Forest Base Map 2012 was taken over by this new JICA- PNGFA Project 2014-2019 and completed in February 2016.

1-2. Objectives

This manual was developed as a contribution from JICA-PNGFA Project activities to clarify work and responsibility sharing for updating data for forest cover map, as a part of forest resource monitoring. To this end,

(a) process and methods for updating forest cover map are clarified, and

(b) workflow (standard annual work plan) as new assignment for Inventory & Mapping branch is to be defined.

The manual was developed based on the following guide:

(a) The cartographer team of Inventory & Mapping branch is set as target user of this manual.

(b) Distinction between (i) automated process by tools (ex. ArcGIS) and (ii) human interpretation work by operators are made clearly.

(c) What and how the Project tackled (and will address) issues faced during the course of Project activities will be described.

(d) The indicator 2-4 'Guidelines of the forest planning' is to refer this manual. (The workflow for revising national forest plan will refer to and define the use of this manual in the workflow.)

1-3. Structure of the manual

The Forest Base Map indicates basis of forest cover map in PNG, which was developed in the Phase 1 Project and revised in the Phase 2 Project, and called the "Forest Base Map 2012". Past forest cover maps in 2000 and 2005 were created for two pilot provinces, West New Britain (WNB) and West Sepik (WSP), from the Forest Base Map 2012. Furthermore forest cover map in 2015 was also created based on the Forest Base Map 2012 for entire PNG.

Structure summary of the manual is the following:

(a) Specifying envisaged workflow (standard annual work plan) as new assignment for Inventory & Mapping branch

(b) Specifying development process and methods for Forest Base Map 2012 and forest degradation driver of forest cover map in chapter 3

(c) Specifying development process and method for the forest cover map in the past (2000, 2005) in chapter 4

(d) Specifying development process of updated (revised) forest cover map in future (2015) in chapter 5

(e) Above (b) to (d) also include technical knowledge on GIS, remote sensing and data input as well as operational tips of application programs, as necessary for the works in the above process.

(f) With aiming at future update and future trend of technical innovation, issues faced through the work process, to be noted or to be likely considered are also stated.

(g) Output summary of above (b) to (d) and additional technical knowledge and operation instructions related to the works are also shown in Annex.

Forest cover map is desired to be updated at fixed regular intervals, say 5-year or 10-year. Although new technologies will probably come out in the future, the manual is expected to be some help when PNGFA will update forest cover map combining new technologies in the future.

2. Workflows: Update of forest cover map (Forest Base Map)

2-1. Overarching structure

The Forest Cover Maps were created by JICA-PNGFA Project team. The Maps created in the Project activities were:

(a) the Forest Base Map 2012 for entire PNG,

(b) the Forest Cover Maps 2000, 2005, and 2011 (revised ver.) for WNB and WSP,

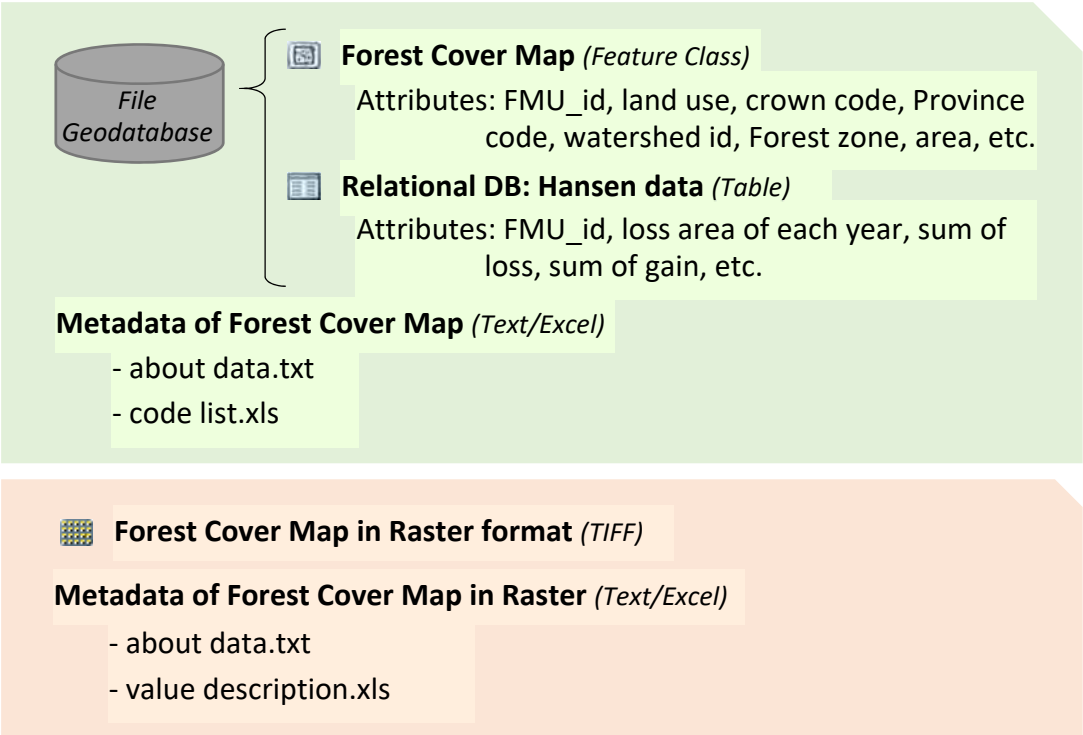
(c) the Forest Cover Map 2015 for entire PNG.

A forest cover map should be updated at fixed regular intervals, say 5-year or 10-year.

Overarching structure of the database and Cartographer team's workflows of updating forest cover map are illustrated in this chapter.

Forest Cover Map database

The database of each Forest Cover Map is composed of (1) Forest Cover Map (Feature Class in File Geodatabase), (2) relational database of Hansen data (Table in File Geodatabase), (3) Forest Cover Map in Raster format, and (4) metadata of each Forest Cover Map.



Forest Cover Map (in File Geodatabase) has many attributes such as FMU_id, land use, crown code, Province code, watershed id, Forest zone, area, etc. (see to chapter 3) Relational database of Hansen data has attributes such as FMU_id, loss area of each year, sum area of loss, sum area of gain, etc. Relational database can be linked to Forest Cover Map by "FMU_id" field. Forest Cover Map in File Geodatabase is powerful, but too large in data size to show lightly. Therefore, Forest Cover Map in Raster format was also prepared for display. Metadata for each Forest Cover Map was also prepared to specify data content.

PNG-FRIMS database

The Forest Cover Maps are stored in PNG-FRIMS database, which contains four principal types of data, including information to be used for updating forest cover map:

- **Logging Concession Information**;
- **Constraints and Land Use**;
- **Forest Base/Cover Maps**; and
- **Base/topography**.

Overview of PNG-FRIMS database is shown below.

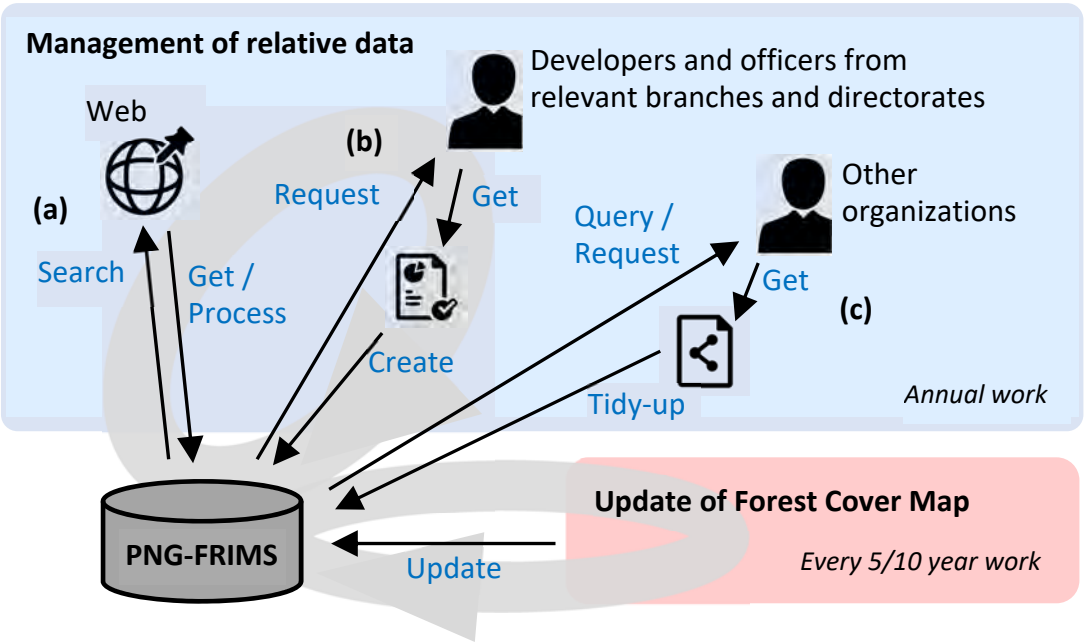
Logging Concession Information	Concession Area, Logged Area, Planned Area, Buffer zone Topographic info: Existing road, River/ Stream, Contour Facility info: Bridge/ Culvert, Campsite, Gravel pit, Log landing, Building, etc.
Constraints and Land Use	Managed condition: Forest Clearing Authority (FCA), Plantation, Protected Area, Mining operation area Natural condition: Slope (Extreme/ Relief), Altitude (Extreme), Inundation (Extreme/ Serious), Mangrove
Forest Base/ Cover Maps	Data: Forest Base Map 1.1 (2012) Time-series forest cover maps (2000/ 2005/ 2011) (WNB/ WSP, as of 29th Mar 2019) Forest cover map 2015 (benchmark map) Old vegetation (FIMS Forest Mapping Unit) Collect Earth Landuse change Assessment (Point Sampling) Permanent Sample Plots (PSP), © Forest Research Institute (FRI) All rights reserved. Database of PNG International Tropical Timber Organization Natural Forest Model (PINFORM), © 1998 FRI All rights reserved. Attributes: Vegetation area, Tree crown size, Forest Zone, Timber volume, Carbon stock, Degradation driver, etc.
Base/ Topography	Satellite imagery: RapidEye (2011), Landsat Annual Greenest Pixel (AGP) (1990/ 1995/ 2000/ 2005/ 2010/ 2011/ 2014/ 2015), PALSAR (2010/ 2011) Topomap (scale = 1:100,000, Raster) Topography: 5m mesh Digital Elevation Model (Airborne Radar in 2006 from National Mapping Bureau), Hillshade, Slope, Contour (10m), Watershed (made from Geostationary Orbiting Search And Rescue (GeoSAR)) Global Dataset: Hansen data (Tree cover loss/ lossyer/ gain) Main road (time-series), River, Incorporated Land Group and Clan boundary/ Settlement/ Local Level Government & District boundary/ Province-Region boundary (PNG Census 2000 and 2011), etc.

Database stores not only PNGFA data but also global dataset and the information from other organizations, which are updated and kept fresh periodically.

2-2. Workflows and timeline

Works related to updating forest cover map in Inventory & Mapping Branch and proposed workflows and timeline are described below.

Management of relative data	*Annual*
(a) Obtain and process satellite imagery and GIS data for updating Forest Cover Map	Data: LANDSAT AGP, Hansen data, main road, etc.
(b) Collect necessary information and data from developers and officers in other branches and directorates, and update regular PNGFA data	Data: logging information, FCA, plantation
(c) Confirm condition of update of data from other organizations, and get latest data if needed	Data: Protected area, Census data, etc.
Update of Forest Cover Map	*Every 5 or 10 year*
(1) Study new technologies and relevant data for updating Forest Cover Map, and plan procedures of updating Forest Cover Map	
(2) Prepare and arrange relevant data	
(3) Conduct analytical process for updating Forest Cover Map	
(4) Assess and modify updated Forest Cover Map, if needed	
(5) Tidy-up new data sets and revise database	
(6) Prepare processed data for input to LAN-Map, PNG-FRIMS	
(7) Prepare designed maps for provision	



Proposed timeline: Management of relevant data (annual)

	1	2	3	4	5	6	7	8	9	10	11	12
(a) LADSAT AGP												
(a) Hansen data												
(a) main road												
(b) logging info												
(b) FCA												
(b) plantation (Qf)												
(b) plantation (Qa) (Other than FCA)												
(c) other data												

: data request

* Timeline depends on responses from data providers.

Proposed timeline: Update of Forest Cover Map (FCM) (Every 5 or 10 year)

	1	2	3	4	5	6	7	8	9	10	11	12
(1) Study method												
(2) Prepare data												
(3) Update FCM												
(4) Assess map												
(5) Tidy-up data												
(6) Finish data												
(7) Prepare maps												

2-3. Operating procedures

Operating procedures and policies of each work shown in the above section are indicated below.

Management of relative data

(a) Obtain and process satellite imagery and GIS data

Satellite imagery (LANDSAT AGP[1])

Download satellite imagery annually.

For downloading and processing Landsat images and SAR, refer to **Annex D**: Manual for downloading and Processing Landsat Images and **Annex E**: Manual for downloading and processing SAR. For procedure to obtain this imagery, refer to **Annex F**: Manual to use Google Earth Engine.

Hansen data

Download and process Hansen data when it is released on the web site. Currently it has been released about once a year.

For procedure to obtain Hansen data, refer to **Annex G**: Arrangement of Global Forest Change data published by Hansen et al.

Main road

After inputting satellite imagery in the database, create or update new main road data which were built in the previous year. The digitizing should be implemented frequently (eg. once a year) because it is hard to find old road by satellite imagery.

For procedure of digitizing road network, refer to **Annex H**: Digitizing road network utilizing LANDSAT imagery.

(b) Collect and update necessary information and data from developers and officers from relevant branches and directorates

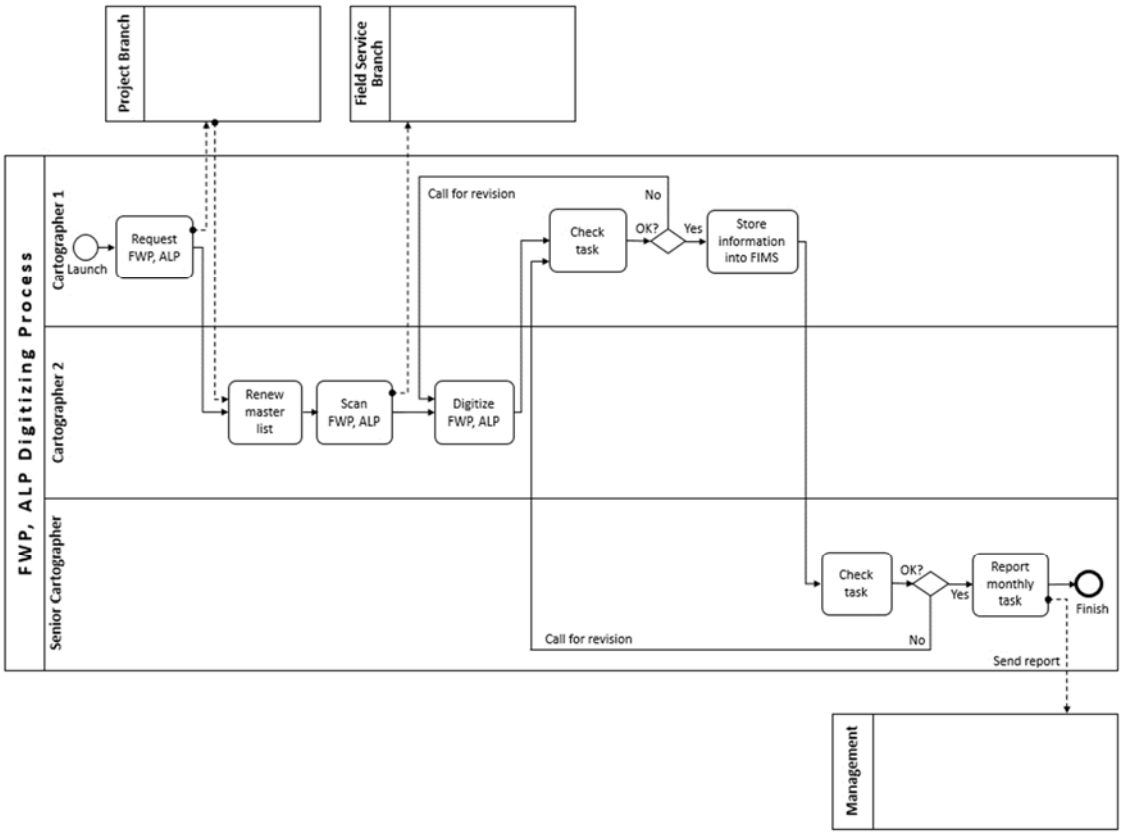
Logging information

Collect logging information from Project branch or storage room twice a year. If hard copies, scan hard copies and digitize. If soft copies, convert files to .shp files. Check the task if revision is required. Then store information in PNG-FRIMS database.

Work flow diagram of digitizing logging information in Forest Working Plan (FWP) and Annual Logging Plan (ALP) is shown below.

[1] Annual Greenest Pixel: mosaicked imagery including all the scenes in each year beginning from the first day of the year and continuing to the last day of the year obtained by specified satellite(s) with the greenest pixel on top, where the greenest pixel means the pixel with the greatest value of the Normalized Difference Vegetation Index (NDVI).

Work Flow Diagram of Digitizing FWP, ALP (Preferable Situation: To-Be Process)



FCA

Collect FCA information from Project Allocation Directorate (PAD) or storage room twice a year. If hard copies, scan hard copies and digitize. If soft copies, convert files to .shp files. Check the task if revision is required. Then store information in PNG-FRIMS database.

Plantation (Qf)

Collect Plantation (Qf) information from Forest Development Directorate (FDD) once a year. If hard copies, scan hard copies and digitize. If soft copies, convert files to .shp files. Check the task if revision is required. Then store information in PNG-FRIMS database.

Plantation (Qa) (Other than FCA)

Collect Planation (Qa) information other than FCA from outside of PNGFA once a year. If hard copies, scan hard copies and digitize. If soft copies, convert files to .shp files. Check the task if revision is required. Then store information in PNG-FRIMS database.

(c) Confirm and get latest updated data from other organizations

Protected area

Make inquiries about condition of update of protected area data to the Conservation and Environment Protection Authority (CEPA) annually, and ask for latest version if needed.

Format of data should be in .shp file.

Census data

Ask for new Census data to the National Statistical Office (NSO) when it is released.

Format of data should be in .shp file.

Update of Forest Cover Map

(1) Study new technologies and relevant data, and plan procedures of updating Forest Cover Map

This manual shows the operating procedures and analytical processes which the Project team conducted in creating the Forest Cover Maps. Future Forest Cover Maps can be created in the track of these methods, but new technologies and data are progressing rapidly. Therefore, the officers should study new technologies and data which can be used for updating the Forest Cover Maps, and decide methods to update. It should be highly considered if there are any methods to improve the issues revealed in the previous activities (see to chapter 3-3, 3-5 and 5-3).

(2) Prepare and arrange relevant data

Main data is updated annually as shown in previous section. Other data to be used are collected and arranged based on the method decided in (1).

(3) Conduct analytical process for updating Forest Cover Map

New Forest Cover Map is created on the basis of the method decide in (1).

Newly edited and created data should be checked for GIS data topology. As for topology check, refer to **Annex I**: Manual of topology check.

(4) Assess and modify updated Forest Cover Map, if needed

It is better to assess the created Forest Cover Map if there are appropriate reference data such as National Forest Inventory (NFI) data. As for accuracy assessment, refer to chapter 3-2. Also, it is better to check the differences between the previous map and the new map.

As for map comparison, refer to chapter 4-2. These confirmations are of service to find features and conditions of the map as well as some errors which had occurred throughout the work.

If there are any errors through the work or downside, they should be fixed.

(5) Tidy-up new data sets and revise database

A data set of the new Forest Cover Map, including metadata, is stored into the database.

As for raster data creation, refer to **Annex M**: Procedure to create raster data (Geo-TIFF) with colormap file.

(6) Prepare processed data for input to LAN-Map, PNG-FRIMS

New data is prepared for input to LAN-Map, PNG-FRIMS, which PNGFA officers can browse the data in their browser.

(7) Prepare designed maps for provision

Map layouts for the new Forest Cover Map are prepared by utilizing the existing map layouts for the Forest Base Map, and exported to PDF format in order to provide the designed maps.

The following data are provided from PNGFA (as of March 2019).

Paper map 'PNG Forest Base Map 2012' by computer prints

Coverage	Size	Scale	Price
National	A0, A1, A2, A3, A4	1:1,600,000 to 6,400,000	K150, 100, 50, 40, 20
Province	A0, A1, A2, A3, A4	1:150,000 to 2,200,000	K150, 100, 50, 40, 20

Note: Price in this table subject to change without further notice.

Digital format

Format*	Coverage	Fit to print on or scale at	Suitable medium	Price**
PDF	National	A3	CD-ROM	K50
	Province	A3		K50
TIFF	Province	To be used from 1:50,000 to 25,000		K20***

Note*: Provision of other digital format map may be arranged and admitted for government and academic institutions for public and research purposes principally for mutual information exchange

basis subject to agreement of Minutes of Understanding or other appropriate form of written consent.

Note**: Price in this table subject to change without further notice.

Note***: TIFF format may be shared subject to a written consent of usage and copyright credit obligation and citation with acknowledgement to PNGFA and JICA in case of further use in a publication, academic work and any other type of use of the data. A decision on this manner of distribution is made by the PNGFA and JICA according to the nature of the data and its usefulness for the social development of PNG as an information social infrastructure.

2-4. Essential specification / Structure of data and folder

Essential specifications of data, not only the Forest Cover Maps but also PNG-FRIMS database, are shown the table below.

Data Category	Data	Description (Attribute / Source)	Method of Update	
			Frequency	Proposed Method (Data Source)
Logging Concession Information	Concession area	Areas acquired from expired, current, or proposed concessions (FMA/TRP/LFA).	When acquired	If hard copies, scan hard copies and digitize. If sof copies, convert files to .shp files.
	Planned area (Set-ups / Coupes; annual working plan)	Areas not entered and not harvested. As per Annual Logging Plan (ALP).	Twice a year	If hard copies, scan hard copies and digitize. If sof copies, convert files to .shp files.
	Logged over area (Set-ups)	Areas entered and harvested. As per ALP.	Twice a year	
	Logged_NotLandUse	Areas logged and left to regenerate.	Twice a year	If hard copies, scan hard copies and digitize. If sof copies, convert files to .shp files.
	Logged_LandUse	Areas logged and subsequently converted to other forms of non-forest forms of land use.	Twice a year	
	Landuse (LandUse_NotLogged)	Areas cleared (but not logged commercially) and subsequently converted to other non-forest land use.	Twice a year	

	Logging information (Stripline, Buffer zone)	Logging information such as striplines and buffer zones as identified in the ALP.	Twice a year	If hard copies, scan hard copies and digitize. If sof copies, convert files to .shp files.
	Topographic information (Logging road, River / Stream, Contour)	Topographic information as identified in ALP.	Twice a year	If hard copies, scan hard copies and digitize. If sof copies, convert files to .shp files.
	Facility information (Bridge / Culvet, Campsite, Gravel pit, Log landing)	Facility information as identified in ALP.	Twice a year	If hard copies, scan hard copies and digitize. If sof copies, convert files to .shp files.
Constraints and Land Use	**Managed condition:**			
	FCA	Boundary of FCA. The developer submits 5-years plan before starting the clearance inside the boundary."	Every time after approval of the 5-years plans	If hard copies, scan hard copies and digitize. If soft copies, convert files to .shp files.
	Plantation	Compartment boundary in the Plantation Plan.	Once a year	Refer to FDD. If hard copies, scan hard copies and digitize. If soft copies, convert files to .shp files.
	Protected area	Protected Area under the Flora and Fauna Act (eg. Wildlife Management Areas, National Parks, Catchment Management Areas) from CEPA.	Every year	Refer to CEPA for updated data to get the latest version.
	Mining operation area	Mining operation area from Mineral Resource Authority (MRA).	Every year	Refer to MRA for updated data to get the latest version.

Constraints and Land Use	**Natural condition:**			
	Extreme Altitude	Land over 2400m altitude.	-	Processed Shuttle Radar Topography Mission (SRTM)30. Refer to the JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.5'.
	Extreme Slope (Extreme / Serious)	Extreme: land with over 30 degree dominant slope. Serious: land with dominant slope of 20-30 degrees and sub-dominant slope over 30 degrees and with high to very high relief.	-	
	Inundation (Extreme / Serious)	Extreme: land permanently or near permanently inundated extending over more 80% of the area of that land. Serious: land permanently or near permanently inundated extending over 50-80% of the area of that land.	-	Processed Papua New Guinea Resource Information System (PNGRIS) 2008 data. Refer to the JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.5'.
	Karst	Land with polygonal karst landform.	-	
	Mangrove	Land covered by mangroves.	Every 5 years (when to update forest cover map)	Extract "Mangroves" from a updated forest cover map. Refer to the JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.5'.
Forest Base / Cover Maps	Forest Cover Map:	Time-series forest cover maps. Only the map which was created in JICA-PNGFA Forestry Project initially as a base map are called Forest Base Map. Data has been developed in both vector and raster formats. Attribute: vegetation type, sub-vegetation type, tree crown size, Forest Zone, catchment no., province,	Every 5 years	Develop from the Forest Base Map by interpreting LANDSAT images, Hansen data, etc. Refer to this manual. As for DD driver attribute, refer to chapter 3-4 as well. Timber volume is to be replaced

		timber volume, DD driver, etc.		referring the results of the NFI survey.
Forest Base / Cover Maps	Forest Cover Map 2015	Forest cover map in 2015.	-	Developed from the Forest Base Map by interpreting LANDSAT images, Hansen data, etc. Refer to chapter 5.
	Forest Base Map 2012	Initial map of time-series forest cover maps. Forest cover map developed by referring satellite imagery in 2010 and 2011. This map are called the `Forest Base Map 2012'. Latest version is ver. 1.1 (as of December 2017).	-	Developed by analysis of RapidEye and PALSAR imagery and so on. Refer to chapter 3.
	Forest Cover Map 2011	Forest cover map in 2011 revised from the Forest Base Map. Maps of WNB (West New Britain) and WSP (West Sepik) have been developed as of December 2017.	-	Developed from the Forest Base Map by interpreting LANDSAT images, Hansen data, etc. Refer to chapter 4.
	Forest Cover Map 2005	Forest cover map in 2005. Maps of WNB and WSP have been developed as of December 2017.	-	
	Forest Cover Map 2000	Forest cover map in 2000. Maps of WNB and WSP have been developed as of December 2017.	-	
	Old Forest Inventory Mapping System (FIMS) vegetation	An area of forest or other vegetation type mapped as a unique polygon in the 1:100,000 forest inventory mapping series. A main layer in former FIMS.	-	-

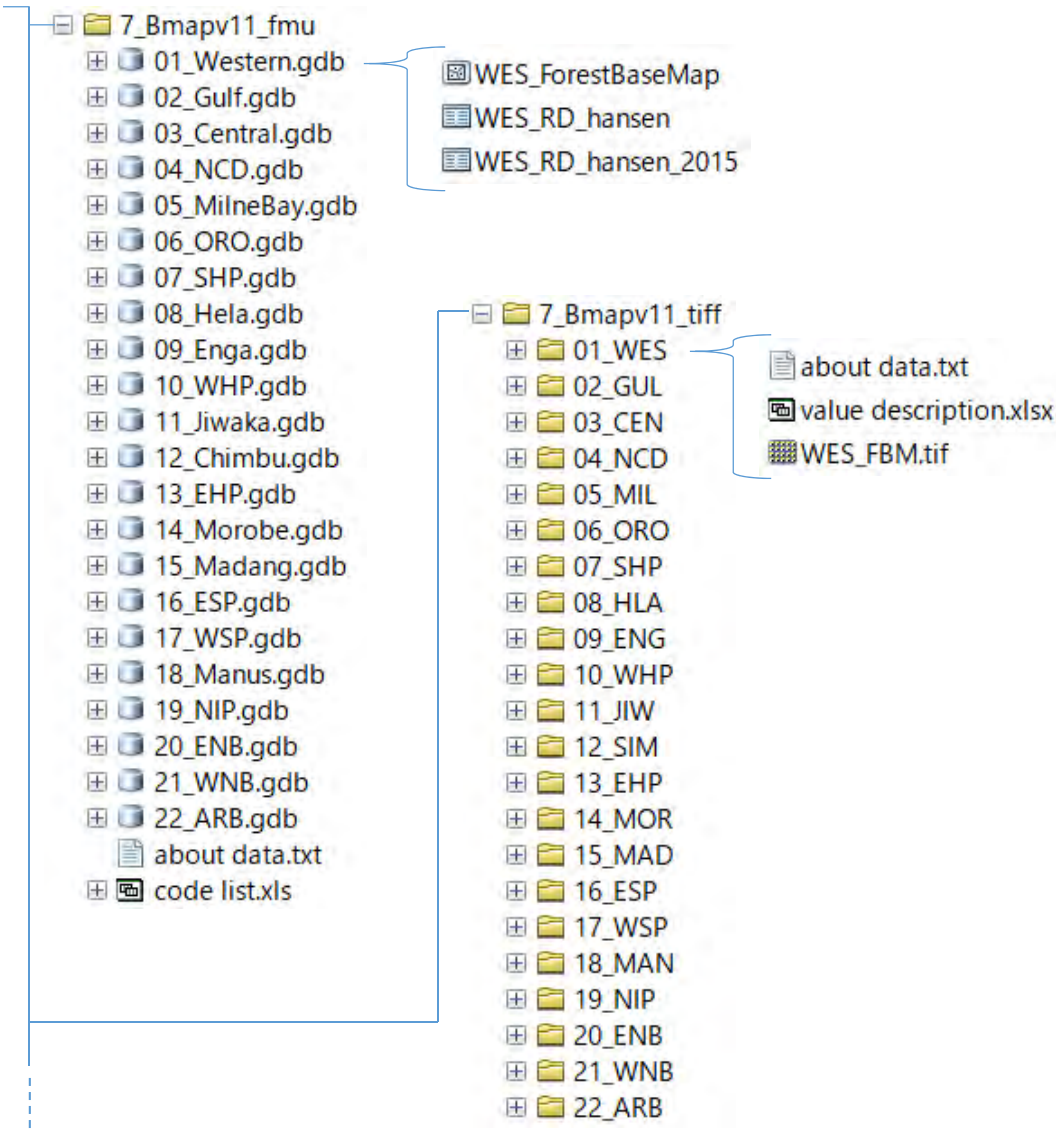
Forest Base / Cover Maps	Collect Earth Landuse change Assessment (Point Sampling) 2000-2015	Annual forest and land use assessment data used for Forest Reference Level (2001-2013) and BUR Technical Annex (REDD+ Results Report) 2014-2015. Data is also used as pre-inventory for Multi-purpose NFI. The assessment is completed (under report preparation) as of March 2019.	Every two years (for BUR: biennial update report)	Satellite image interpretation per about 4km systematic sampling grid using Collect Earth (Google Earth high resoluton satellite image and AGP of Landsat in Google Earth Engine (GEE)
	PSP	Time series of forest volume data in PSP plots. © FRI All rights reserved.	Depend on FRI	Data will be generated by FRI. It is necessary for PNGFA-HQ to consider how to get new data timely.
	Database of PINFORM	A model to estimate forest regrowth rate developed by FRI and International Tropical Timber Organization (ITTO). © 1998 FRI All rights reserved.	Depend on FRI	FRI may improve the model using new dataset from PSP.
Base/ Topography	**Satellite imagery:**			
	RapidEye (2010 / 2011)	RapidEye imagery in 2011. Spatial resolution: 5 m. Number of bands: 5.	-	-
	LANDSAT AGP (1990 / 1995 / 2000 / 2005 / 2010 / 2011 / 2014 / 2015)	Mosaicked LANDSAT imagery including all the scenes in each year with the greenest pixel on top, where the greenest pixel means the pixel with the greatest value of the NDVI. Spatial resolution: 30 m. Number of bands: 7-11.	Once a year	Computed by Google Earth Engine. Refer to Annex F.
	PALSAR (2010 / 2011)	Imagery generated from SAR (Synthetic Aperture Radar). Spatial resolution: 10 m.	-	-

		Bands: HH, HV, HH/HV.		
Base/ Topography	Topomap	Topographic Survey map. Scale = 1:100,000. Total number of maps: 280.	-	Scaned Topographic Survey map.
	Topography:			
	5 m mesh Digital Elevation Model (DEM)	GeoSAR, Airborne Radar in 2006 from National Mapping Bureau (NMB).	-	-
	Hillshade	Hillshade in PNG.	-	Processed GeoSAR DEM.
	Slope	Slope in PNG.	-	
	Contour (10 m / 50 m)	10 m and 50 m interval contour in PNG.	-	
	Watershed	Watershed in PNG.	-	
	Global Dataset:			
	Hansen data (Tree cover / loss / lossyear / gain)	Data published annually by Hansen et al., University of Maryland. Data includes information of tree cover in 2000, tree cover gain area since 2000, tree cover loss area since 2000, and tree cover loss area in each year since 2000. Data site: “Global Forest Change” (http://earthenginepartners.appspot.com/science-2013-global-forest)	Once a year	Download data from the site of "Global Forest Change", and arrange data as relational database of forest cover maps. Refer to Annex G.
	Main road (time-series)	Main road: ~2000, 2000~2005, 2005~2011, 2011~2015.	Once a year	Digitize LANDSAT AGP. Refer to Annex H.
	Road	Road in PNG.	-	-
	River	River in PNG.	-	-
	Incorporated Land Group (ILG) and Clan boundary	ILG information as collected by Acquisition branch.	-	-

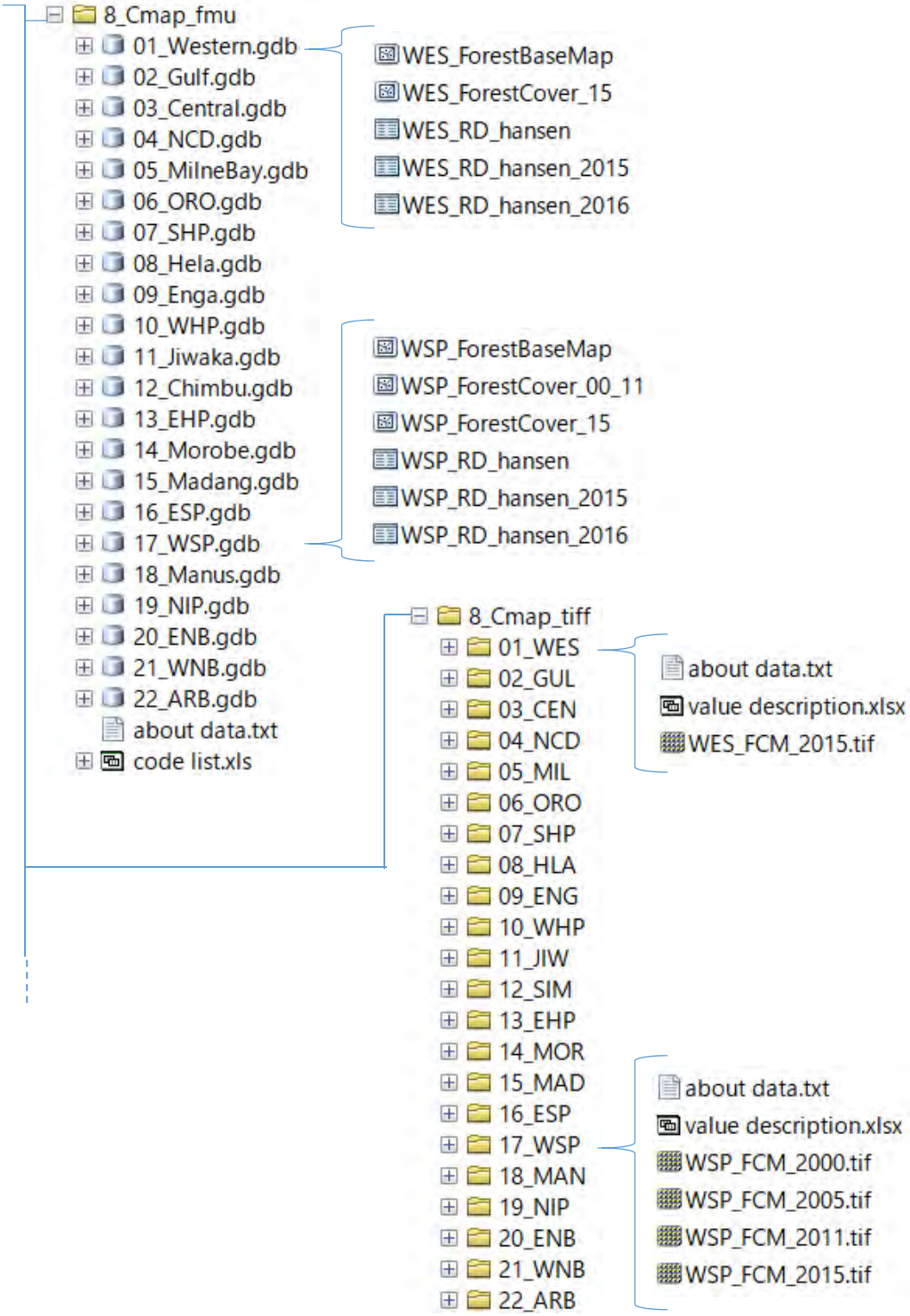
Base/ Topography	Province boundary (PNGFA use)	Province boundary used in the JICA-PNGFA Forestry Project. Province boundaries have been created from province boundary data of PNG Census 2011. But boundary between Jiwaka and Western highlands and boundary between Hela and Southern highlands have been fixed by PNGFA. Coastal lines have been created from RapidEye imagery used to create the Forest Base Map.	-	-
	Province boundary	Province-Region Boundary. Data source: PNG Census 2000 and 2011 from NSO.	-	-
	District boundary	District Boundary. Data source: PNG Census 2000 and 2011 from NSO.	-	-
	Local Level Government (LLG) boundary	LLG Boundary. Data source: PNG Census 2000 and 2011 from NSO.	-	-
	Settlement	Census Unit. Data source: PNG Census 2000 and 2011 from NSO.	-	-

Appearance of data and folder structure of the Forest Cover Maps in ArcGIS are shown below for reference.

Forest Base Map 2012



Forest Cover Map 2000, 2005, 2011 revised, 2015



Reference

JICA and PNGFA, 2017, 'Papua New Guinea Forest Base Map 2012 - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.2'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

JICA and PNGFA, 2018, 'Papua New Guinea Forest Resource Information Management System - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.3'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

JICA and PNGFA, 2019, 'Constraints data - Natural condition layers in the PNG-FRIMS - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.5'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

Annex D. Manual for downloading and Processing Landsat Images

Annex E. Manual for downloading Processing SAR

Annex F. Manual to use Google Earth Engine

Annex G. Arrangement of Global Forest Change data published by Hansen et al.

Annex H. Digitizing of road network utilizing LANDSAT imagery

Annex I. Manual of topology check

Annex M. Procedure to create raster data (Geo-TIFF) with colormap file

3. Forest Base Map 2012

3-1. Process and methods of developing the Forest Base Map 2012

In order to cope with challenging conditions including rugged terrain, vast forest area, very poor road connection and landowner issue (97% of the land in PNG is customary owned by clans), Forest Base Map 2012 was developed using optical satellite imagery (RapidEye), Rader satellite data (ALOS-PALSAR[2]) and other existing data. Significant improvements such as up-to-date information, finer segmentation size, forest/non-forest delineation including water area etc. are seen in the newly developed Forest Base Map 2012.

Data input and process

Satellite observation data used for developing the PNG Forest Base Map 2012 include RapidEye (optical sensor, captured in 2010 and 2011) and ALOS-PALSAR (radar sensor, captured in 2007 and 2010). Airborne radar information shared from the PNG National Mapping Bureau (NMB) was also utilized as data for elevation from sea level.

Classification and its coding system of forest and other land-cover used in the Forest Base Map 2012 was developed by integrating classification code necessary for PNGFA work and classes discernible from satellite imageries on the basis of the land cover classification and code registered in Forest Inventory Mapping System (FIMS) (Hammermaster & Saunders, 1995 and McAlpine, and Quigley, 1998,). 'Alpine grassland' and 'Subalpine grassland' were picked up from 'Grassland and Herbland' according to the elevation from sea level. 'Forest plantation' and 'Plantation other than forest plantation' are newly added to the Forest Base Map 2012. Details of the classification and coding system are illustrated in next section.

Segmentation and object-based classification of the land cover was done by using a software 'eCognition' for satellite imagery analysis as well as a software 'R' for statistical analysis of the segments. For this analysis, we utilized RapidEye satellite imageries (five bands), NDVI generated from analysis on RapidEye data, elevation data shared from NMB (five meter mesh), and slope and watersheds (or catchment boundaries) generated from analysis on NMB elevation data.

Automated classification of the segments were done for forest and other vegetation by 'eCognition' and 'R', after calculating 'feature parameters' of each segment by using statistical value including average and standard deviation of various parameters of all pixels in each

[2] ALOS-PALSAR: The Advanced Land Observing Satellite (ALOS) "DAICHI" equipped with Phased Array type L-band Synthetic Aperture Radar (PALSAR) launched by Japan Aerospace Exploration Agency (JAXA) in 2006.

segment. The classification was done by multi-stage classification following a forest classification flowchart tailored for this work, by using parameters including Brightness, Green, Near Infra-Red (NIR), NDVI, elevation from DEM, and slope.

Where we encountered with difficulty by cloud cover on optical RapidEye imageries, we interpolated forest/ non-forest distinction by utilizing PALSAR radar data.

Correction by human interpretation was made where we found automated classification is difficult for some classes (Larger Urban Centres, Bare Areas, Cropland/ Agriculture land, Woodland, Savanna, and Scrub) or obvious error classification made by automated process. The human interpretation was supported by photographs taken by digital camera on hand-held Global Positioning System (GPS) terminal from helicopter, verification by ground truthing, mobilization of existing knowledge, and literature study.

'Forest Plantation' was distinguished from 'Plantation other than forest plantation' by referring to plantation boundaries data owned by PNGFA. 'Forest Plantation' indicated on the Forest Base Map is not necessarily corresponding to the actual distribution of forest plantations since PNGFA does not have every boundary information of forest plantations which are often managed by private sectors.

Some classes (Cropland/ Agriculture land, Forest Plantation, and Plantation other than forest plantation) are delineated by human interpretation relying on local knowledge of PNGFA officers and staffs attached to Area and Provincial Forestry Offices by utilizing RapidEye imageries and geo-referenced photographs taken by handheld GPS terminal. The PNGFA officers and staffs used ultrahigh resolution satellite imageries on Google Earth and Bing Map, existing information on cropland (Mapping Agriculture Systems of PNG, MASP and Papua New Guinea Resource Information System, PNGRIS), and data on DEMs.

Typology of forests and other land use

P	Low altitude forest on plains and fans – below 1000 m	Sc	Scrub
H	Low altitude forest on uplands – below 1000 m	G	Grassland and herbland
L	Lower montane forest – above 1000 m	Ga	Alpine grassland – above 3200 m
Mo	Montane forest – above 3000 m	Gi	Subalpine grassland – above 2500 m
B	Littoral forest	O	Cropland/Agriculture land
D	Dry seasonal forest	Qa	Plantation other than forest plantation
Fri	Seral forest	Qf	Forest plantation
Fsw	Swamp forest	Z	Bare areas
M	Mangrove forest	U	Larger urban centres
W	Woodland	E	Lake & larger rivers
Sa	Savanna		

Appropriate scale of use

The ground resolution of the RapidEye imageries used for the development of the Forest Base Map 2012 data is five (5) meters (re-sampled from original six point five (6.5) meters) meanwhile it is ten (10) meters for PALSAR used for interpolating cloud cover area. The mapping scale is between 1/25,000 and 1/50,000 for the data development while minimum mapping polygon size is 1 hectare. Therefore, this map should be used at a scale between 1/25,000 and 1/50,000 with noting the constraint of location accuracy described in the next section.

Limitations of location accuracy and geographical coverage

Location accuracy: The location accuracy of the Forest Base Map 2012 is equal to that of orthorectified dataset of LANDSAT (Land Satellite) developed by United States Geological Survey (USGS) because the specification was designed in accordance with LANDSAT, taking account of the conditions of reference data available for PNG and future updating of data. According to the limitation of the resolution of LANDSAT, location error of plus or minus thirty (30) meters may have been included. Due to this limitation, it should be noted that the ground based positioning by GPS has higher location accuracy than that of this map.

Coverage: This map is developed for utilizing on purpose of forest management by the PNGFA. Therefore, the map does not exhaustively cover some small islands and other areas where forest management operation by PNGFA are not currently conducted. On the other hand, the Forest Base Map includes a part of Australian territory in Western (WES) Province and Solomon Islands territory in Autonomous Region of Bougainville (ARB) Province. Thus, it is specified in the provincial code attribute, "P_Code_n", of the Forest Base Map whether polygon is contained in which province or "outside PNG".

Delineation of Cropland/Agriculture land: Since conditions of crop land varies depending on applied practice and cropping cycle, local knowledge and supplementary information is prerequisite for their interpretation and classification at much localized level. According to that nature, the map does not exhaustively cover all cropland and agriculture land.

Classification among Woodland, Savanna, and Scrub: The accurate delineation, verification and monitoring of boundaries of Woodland, Savanna, and Scrub cannot be done as long as relying on interpretation and classification solely on satellite imageries. The savanna, particularly in PNG, only occurs in areas limited to the southern region under specific climatic and ecological conditions. The Scrub in PNG is also specifically defined as a low-rise forest vegetation comprised of specific tree species. Taking these conditions into account, these three classes are identified on the Forest Base Map 2012 by referring to FIMS and localities.

Distinction between P (Low Altitude Forest on Plains and Fans, Plain-Forest) and H (Low Altitude Forest on Uplands, Hill-Forest): The distinction between ‘P’ and ‘H’ type forest are made according to incline (or slope) in the Forest Base Map 2012. We are aware that the distribution of ‘P’ and ‘H’ are significantly different between the Forest Base Map 2012 and FIMS in Western Province where plains are dominant and topography is relatively gentle. This difference occurred mainly because the FIMS development process took account of composition of tree species as well. After consultations within JICA Project Team (comprised of PNGFA officers and JICA experts), we decided to keep the methodology for the Forest Base Map 2012 as it is because the classification depending on slope is important and useful information for forest management operations. The slope is often a main determinant of efficiency and practicability of the logging operations as it determines maneuverability of heavy machineries in field.

Outputs of the Forest Base Map 2012 are shown in **Annex A**.

3-2. Accuracy assessment of the Forest Base Map 2012

It is highly improbable that a land cover map obtained by image classification perfectly represents the actual land cover distribution on the ground; rather, such a map is highly likely to contain errors and biases. The Project tried to provide accuracy information about the Forest Base Map so that it can PNGFA (users) could properly use for estimating forest covers and forest cover changes. However, there was not adequate ground truth data to validate accuracy of the Forest Base Map when it was revised, but there was pre-inventory data of NFI surveyed using Collect Earth[3] supported by the Food and Agriculture Organization of the United Nations (FAO) Project[4]. Therefore, the project tried to get a grasp of features of the Forest Base Map by comparing it with the NFI pre-inventory data before finalizing the Map.

Outline of accuracy assessment

Step 1: Studying NFI pre-inventory data (reference data) in detail

- To know condition of the data to decide assessment procedure

Step 2: Considering correspondence of the land cover class of the NFI pre-inventory data with that of the Forest Base Map

- To compare these data to clarify issues if any

Step 3: Accuracy assessment of the Forest Base Map comparing with NFI pre-inventory data

- To figure out condition and issues of the map to examine and determine what improvement should be performed if necessary

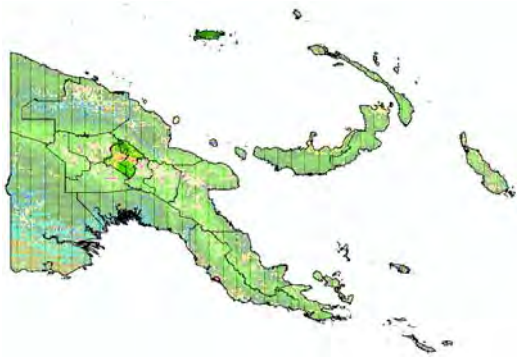
[3] Collect Earth: A tool that enables data collection through Google Earth. In conjunction with Google Earth, Bing Maps and Google Earth Engine, users can analyze high and very high resolution satellite imagery. http://www.openforis.org/tools/collect-earth.html

[4] "Papua New Guinea Multipurpose National Forest Inventory" project supported by FAO with EU funds

NFI pre-inventory data surveyed by Collect Earth

Forest Base Map ver. 1.0

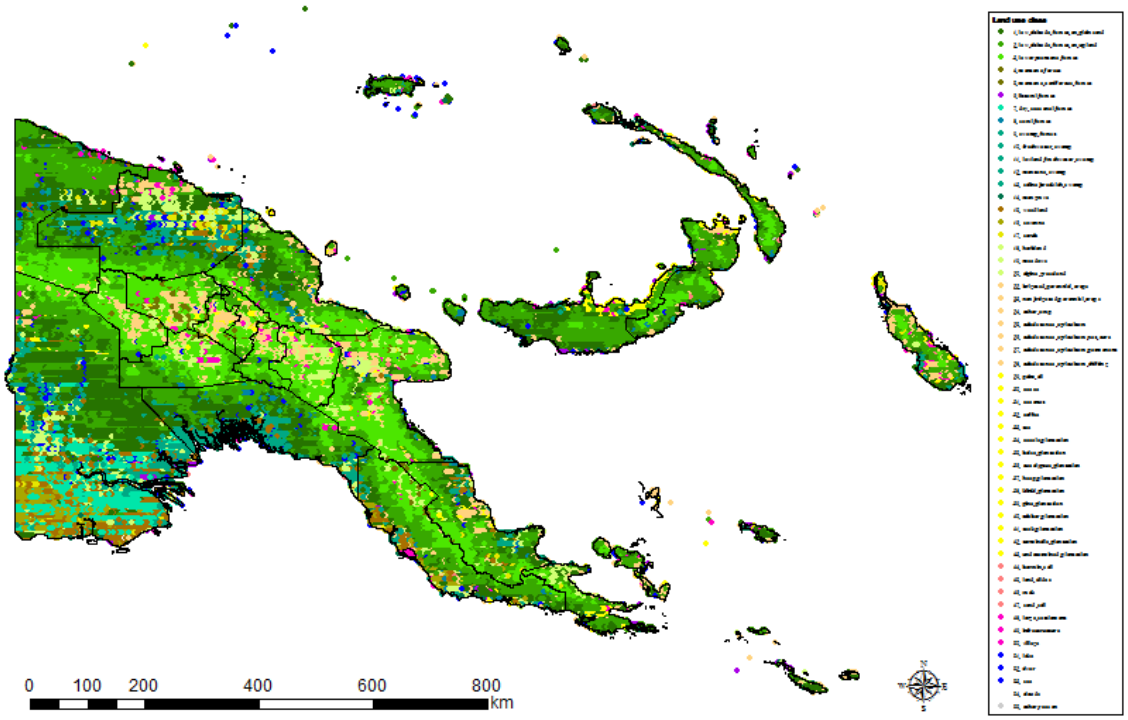
NFI Pre-inventory data



	Basemap	Sampling Point
Spatial Coverage	**Wall-to-wall by polygons** Segmentation < 1ha (100x100m)	**Sampling plots** Points every 4km x 4km 1ha unit with 25 check points
Satellite	Rapid Eye	LANDSAT, Digital Globe, Rapid Eye, SPOT, etc.
Land cover class	21 classes including agricultural land and plantation	**class:**6 grouping categories; Forest, Grassland, Cropland, Wetland, Settlement, Other, with 54 detailed classes

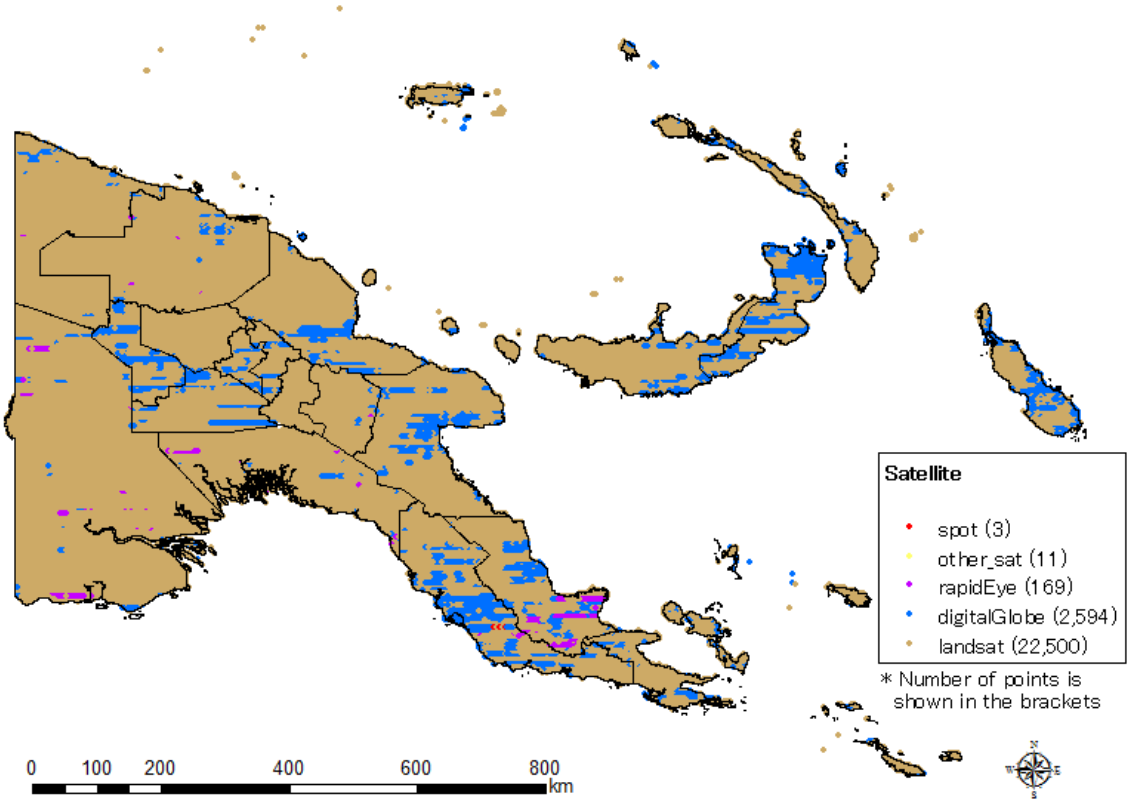
Land cover class of NFI pre-inventory data in each province

	Land use class	WES	GUL	CEN	NCD	MIL	ORO	SHP	HLA	ENG	WHP	JIW	SIM	EHP	MOR	MAD	ESP	WSP	MAN	NIP	ENB	WNB	ARB	Sum
Forest	low_altitude_forest_on_plainsand	1,274	551	217		167	204	26		1	11	2			95	345	551	421	174	89	152	301	77	4,658
	low_altitude_forest_on_upland	811	527	480		235	364	275	62	30	40	167	59	31	369	414	490	799	132	216	347	511	138	6,497
	lower_montane_forest	145	93	355		75	255	300	328	329	313	437	145	300	719	256	121	322		55	144	33	49	4,774
	montane_forest	3		17			17	6	9	67	22	37	6	9	23	12	2	4						234
	montane_coniferous_forest		1	7				2	1		4	6		1	16	2	1	2						43
	littoral_forest	22		4		17	1								2	4	5		2	7	3	11	3	81
	dry_seasonal_forest	752																						752
	seral_forest	32	30	24			7	3							9	34	18	16	3	4	11	1	1	193
	swamp_forest	364	179	22		2	38	2			4				11	43	302	94	17	7	4	14	16	1,119
Wetland	freshwater_swamp	197	41	6			22	2			1				3	19	150	15	6	1	1	1	3	466
	lowland_freshwater_swamp	3	140	23																				166
	montane_swamp							11			6													17
	saline_brackish_swamp	16	32	7													8		1	1		1	4	70
Forest	mangrove	24	47	22		17	8								1		9	3	10	13	2	16	6	178
	woodland	554	18	62		1	46							1	4	17	92	14	4			1	3	817
	savanna	313	5	80	1		3																	402
	scrub	29		6		6	11	1		4	7	2	2	5	23	16	63	9			1	4	9	196
Grassland	herbland	71	19	68		73	37	40	24	19	32	29	12	82	115	54	124	23	7	6	7	3	5	843
	meadows	212	13	7		4	13	7	11	1	5	1		3	24	19	85	4		2	2		1	414
	alpine_grassland	1		16			4	12	4	20	26	19	3	28	23	4		5						165
Cropland	irrigated_perennial_crops			1																				1
	non_irrigated_perennial_crops		1	1				1	1		2	3												9
	other_crop	2	1	1		8		9	6		20	17			4	3					8			79
	subsistence_agriculture			45		59																		104
	subsistence_agriculture_not_sure	3	1				3	2	2	11	9	1	2	4	11	11	7	4	1	5		4	5	86
	subsistence_agriculture_permanent	1	3	1		1	6	13	24	12	103	12		4	12	18	38	5	4	4	20	2	15	298
	subsistence_agriculture_shifting	24	11	23		29	98	48	53	91	190	176	63	82	201	130	72	22	36	52	28	15	93	1,537
	palm_oil					10	17								3	5				7	4	95		141
	cocoa											4			2				2		4		7	19
	coconut			6		10	1								3	9	1		2	1	28	3	16	80
	coffee			1				1		5	42	34	1	3	1									88
	tea										11	9			1									21
Forest	acacia_plantation															1								1
	balsa_plantation	3																			1			4
	eucalyptus_plantation					1														2				3
	hoop_plantation														1									1
	kiinki_plantation														2									2
	pine_plantation							1																1
	rubber_plantation	18		4																				22
	teak_plantation			1																				1
	terminalia_plantation					2																		2
	undetermined_plantation																				2			2
Other land	barrein_soil	1		2							1	1			1						1	1	1	9
	land_slides						1								1									2
	rock	1													1	1								3
	sand_soil	2	1																1	2			1	7
Settlement	large_settlement	3	1	2	14		1	2		1	7	4	1	5	7	2	4		1	1	1	6	2	65
	infrastructure		2			2		2		2	1	2		1	1	1		4	1		1	1	1	22
	village	7	5	4		6		8	2	5	17	7	13	12	15	23	32	12	8	9	5	3	18	211
Other land	lake	38		1					1	1					4	6	23	1	1				1	77
	river	62	36	5			10	1	3	5	4	4	5	1	16	11	32	11	2	2	1	7	1	219
	sea	3	1	3		10									1				17	7	1	5	4	52
	clouds	2										2									2	3		9
	other_reason		1	1				4				2								2	1			11
	Sum	4,993	1,754	1,525	15	735	1,167	779	531	604	878	977	312	572	1,725	1,460	2,230	1,790	432	495	782	1,042	480	25,278



Satellite utilized for NFI pre-inventory data

Landcover Category	Landsat	SPOT	RapidEye	DigitalGlobe	Other	Sum
Forest	17,939	3	157	1,876	10	19,985
Grassland	1,278		6	138		1,422
Cropland	2,024		2	437		2,463
Settlement	235			63		298
OtherLand	292			25		317
WetLand	683		4	34		721
NoData	49			21	1	71
Sum	22,500	3	169	2,594	11	25,277



Notes:

- The NFI pre-inventory data might contain errors and biases.
- Class categories between the Forest Base Map and the NFI pre-inventory data are not exactly the same, especially swamp (wetland).

- The difference of these data have to be understand and considered when comparing them.
- All sampling plots which overlap the Forest Base Map are used for accuracy assessment because only points utilized high resolution satellite are not enough.

Comparison of forests and other land use classification

IPCC Category	Forest Base Map No	Code	Class	NFI Land use class
Forest	1	P	Low Altitude Forest on Plains and Fans	low_altitude_forest_on_plains and
	2	H	Low Altitude Forest on Uplands	low_altitude_forest_on_upland
	3	L	Lower Montane Forest	lower_montane_forest
	4	Mo	Montane Forest	montane_forest
	4	Mo	Montane Forest	montane_coniferous_forest
	5	D	Dry Seasonal Forest	dry_seasonal_forest
	6	B	Littoral Forest	littoral_forest
	7	Fri	Seral Forest	seral_forest
	8	Fsw	Swamp Forest	swamp_forest
	15	M	Mangrove	mangrove
	20	Qf	Forest Plantation	acacia_plantation
				balsa_plantation
				eucalyptus_plantation
				hoop_plantation
				klinki_plantation
				pine_plantation
				rubber_plantation
				teak_plantation
				terminalia_plantation
				undetermined_plantation
Woodland	9	W	Woodland	woodland
Savanna	10	Sa	Savanna	savanna
Scrub	11	Sc	Scrub	scrub
Grassland	12	G	Grassland and Herbland	herbland
				meadows
	13	Ga	Alpine grassland	alpine_grassland
	14	Gi	Subalpine grassland	-

IPCC Category	Forest Base Map No	Code	Class	NFI Land use class
Cropland	16	O	Agricultural Land Use	irrigated_perennial_crops
				non_irrigated_perennial_crops
				other_crop
				subsistence_agriculture
				subsistence_agriculture_not_sure
				subsistence_agriculture_permanent
				subsistence_agriculture_shifting
	21	Qa	Plantation other than forest plantation	palm_oil
				cocoa
				coconut
				coffee
				tea
Wetland	-	-	-	freshwater_swamp
				lowland_freshwater_swamp
				montane_swamp
				saline_brackish_swamp
	17	E	Lakes and larger rivers	lake
				river
Other land	18	Z	Bare areas	barrein_soil
				land_slides
				rock
				sand_soil
Settlement	19	U	Larger urban centres	large_settlement
				infrastructure
				village
-	22	Es	Sea	sea
	-	-	-	clouds
	-	-	-	other_reason

* As for Intergovernmental Panel on Climate Change (IPCC) category, refer to '2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use'[5].

Accuracy assessment

The Project assessed classification accuracy and correction for biases in area estimates using the error matrix.

Verifying the accuracy of classification results

- The validity of the classification results should be verified.
- This is accomplished by creating an **error matrix** from **verification data** obtained by **ground**

[5] https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

truths.

- **Overall accuracy**, **user's accuracy**, **producer's accuracy**, and the **kappa coefficient** are often used as **indices of accuracy**.
- **About 50 samples**, at least, are required per class for accuracy verification.
- The area biases are evaluated and corrected by using an error matrix.

Ground truth

- Field survey data on land covers, forest types, and forest biomass collected for the purpose aiding in the analysis of remote sensing data is called ground truths.
- These data can be used as **training data** in the classification process or as **verification data** for evaluating the results of the classification.
- Ground truths can be collected by random sampling or by stratified sampling. Stratified sampling is often preferable when funds or human resources are limited.
- Another consideration is the possibility of limited access to some parts of the forest, which can lead to biases if fewer samples are collected in less accessible places.

Error matrix and accuracy indicators

- A point is correctly classified if the map class (i.e., the land cover class assigned by the classification procedure) is identical to the reference class (i.e., the real land cover class at that point on the ground). Conversely, a point is wrongly classified if the map class is not identical to the reference class.
- **Overall accuracy (O.A.)**: The ratio of the correctly classified area on the map
- **User's accuracy (U.A.)**: The ratio of the area correctly classified into reference class i to the total area classified into map class i
- **Producer's accuracy (P.A.)**: The ratio of the area correctly classified into map class j to the total area of reference class j
- **Kappa coefficient**: An overall classification accuracy indicator, which takes into account the effect of coincidentally correct classification

		Reference				
		Class A	Class B	Class C	Total	User's accuracy
Map	Class A	500	200	25	725	69.0%
	Class B	150	380	60	590	64.4%
	Class C	20	120	185	325	56.9%
	Total	670	700	270	1640	
	Producer's accuracy	74.6%	54.3%	68.5%		

Overall accuracy *A* 64.9%

500/(500+150+20)*100

500/(500+200+25)*100

(500+280+185)/1640*100

A target accuracy of *A* >= 85% is typical for many land cover mapping projects.

For more detail on accuracy evaluation and ground truth, refer to 'REDD-plus COOKBOOK - How to Measure and Monitor Forest Carbon -'[6].

GIS operation for accuracy assessment

1. Prepare simple NFI pre-inventory data for saving memory space.

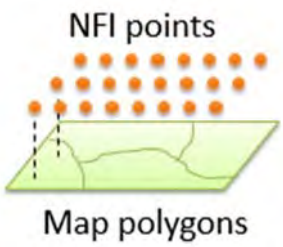
1-1. Delete fields of NFI pre-inventory data besides ID field (unique code field) and land cover code.

1-2. Select points only in target area and export the points to create new NFI pre-inventory data for target area.

Tips:

- **Selection** menu > **Select By Location…**
- Right click NFI layer in TOC > **Data** > **Export Data…**
- Exported data should be projected data

2. Join the Forest Base Map with NFI pre-inventory data spatially.



2-1. Join the table of the Forest Base Map to the table of NFI pre-inventory data spatially.

Tips:

- Right click NFI layer in TOC > **Joins and relates** > **Joins…**
- Join data from another layer based on spatial location

2-2. Export the joined table to .dbf file.

[6] https://www.ffpri.affrc.go.jp/redd-rdc/en/reference/cookbook/redd_cookbook_all_low_en.pdf

3. Make an error matrix table from the exported .dbf file.

Tips:

- Use **PivotTable**[7] function in Excel

Results of accuracy assessment

Accuracy evaluation of land cover categoly in PNG (Forest, Non-forest)

		NFI			
		Forest	Non-forest	Total	U.A.
Map	Forest	18333	1545	19878	92%
	Non-forest	1612	3606	5218	69%
	Total	19945	5151	25096	
	P.A.	92%	70%		

O.A.	87%

Accuracy evaluation of land cover categoly in PNG (6 categolies)

			NFI							
			Forest	Non-forest						
			Forest	Grassland	Cropland	Wetlands	Other land	Settlements	Total	U.A.
Map	Forest	Forest	18333	323	719	415	6	82	19878	92%
	Non-forest	Grassland	491	802	179	303	7	20	1802	45%
		Cropland	1063	273	1541	47	2	174	3100	50%
		Wetlands	53	19	2	209		2	285	73%
		Other land	5	4		3	2	1	15	13%
		Settlements		1	1			14	16	88%
		Total	19945	1422	2442	977	17	293	25096	
		P.A.	92%	56%	63%	21%	12%	5%		

O.A.	83%

Wetlands: P.A. 21%, U.A. 73%

Settlements: P.A. 5%, U.A. 88%

Accuracy evaluation of forest base map in PNG

				NFI															
				Forest													Non-forest	Total	U.A.
				P	H	L	Mo	D	B	Fri	Fsw	M	Qf	W	Sa	Sc			
Map	Forest	P	Low Altitude Forest on Plain	2446	1138	4		40	21	70	309	31	16	65	9	18	362	4529	54%
		H	Low Altitude Forest on Uplar	1122	4820	109			9	47	18		4	17	6	17	336	6505	74%
		L	Lower Montane Forest		58	4208	74						2			16	266	4624	91%
		Mo	Montane Forest			19	186									6	28	239	78%
		D	Dry Seasonal Forest	121	8			207	1	5	47			65	3	3	20	480	43%
		B	Littoral Forest	8					6		3	1		7			2	27	22%
		Fri	Seral Forest	17	18	11			1	4	11	1		5			14	82	5%
		Fsw	Swamp Forest	297	38			48	6	22	314	11		90	15	11	169	1021	31%
		M	Mangrove	17				2	11	2	34	104		5	2		70	247	42%
		Qf	Forest Plantation	3	3	1			1				7	1		2	15	33	21%
		W	Woodland	267	33	1		325	5	16	247	7		307	115	40	198	1562	20%
		Sa	Savanna	5	1	1		34			8	3		77	132	8	54	323	41%
		Sc	Scrub	2	1	1	1	33			3			58	85	11	11	206	5%
	Non-forest			336	368	419	16	62	16	27	124	13	10	120	35	66	3606	5218	69%
	Total			4641	6486	4774	277	752	77	193	1118	171	39	817	402	198	5151	25096	
	P.A.			53%	74%	88%	67%	28%	8%	2%	28%	61%	18%	38%	33%	6%	70%		

O.A.	65%

[7] See **Annex K** for more information of PivotTable.

Accuracy evaluation of forest base map in PNG

					NFI																					
					Forest													Grassland		Cropland		Wetlan	Other	Settle	Total	U.A.
					Forest								Woodl	Savanna/Sc				Grassland		Cropland		Wetlan	Other	Settle		
					P	H	L	Mo	D	B	Fri	Fsw	M	Qf	W	Sa	Sc	G	Ga/G	O	Qa	E	Z	U		
Map	Forest	Forest	P	Low Altitude Forest on Plain	2446	1138	4		40	21	70	309	31	16	65	9	18	41		184	26	80		31	4529	54%
			H	Low Altitude Forest on Uplar	1122	4820	109			9	47	18		4	17	6	17	41		225	21	23	4	22	6505	74%
			L	Lower Montane Forest		58	4208	74						2			16	56	18	165	7	6	1	13	4624	91%
			Mo	Montane Forest			19	186									6	2	26						239	78%
			D	Dry Seasonal Forest	121	8			207	1	5	47			65	3	3	13				7			480	43%
			B	Littoral Forest	8					6		3	1		7			1			1				27	22%
			Fri	Seral Forest	17	18	11			1	4	11	1		5			3		2	3	5			82	5%
			Fsw	Swamp Forest	297	38			48	6	22	314	11		90	15	11	33		13	1	116		6	1021	31%
			M	Mangrove	17				2	11	2	34	104		5	2		1		3	2	62		2	247	42%
			Qf	Forest Plantation	3	3	1			1				7	1		2	1	1	11	2				33	21%
		Woodlan	W	Woodland	267	33	1		326	5	16	247	7		307	115	40	51		36	5	104		2	1562	20%
		Savan	Sa	Savanna	5	1	1		34			8	3		77	132	8	27		11		3	1	6	323	41%
		ann	Sc	Scrub	2	1	1	1	33			3			58	85	11	8		1		2			206	5%
	Grassland	asslan	G	Grassland and Herbland	83	44	45		53	3	7	72	4	1	98	24	36	689	20	162	15	303	7	19	1685	41%
			Ga/G	Alpine grassland/Subalpine g			7	12									2	23	70	2				1	117	60%
	Cropland		O	Agricultural Land Use	225	299	363	4	7	12	16	45	6	7	21	9	24	233	30	1211	132	47	2	165	2858	42%
		roplan	Qa	Plantation other than forest	13	6				1		1		2			2	10		66	132			9	242	55%
	Wetlands	atlan	E	Lakes and larger rivers	13	18	3		2		4	6	3		1	2	1	19		2		209		2	285	73%
	Other land	her la	Z	Bare areas	2	1	1										1	4				3	2	1	15	13%
	Settlements	tleme	U	Settlements and larger urbar														1		1				14	16	88%
				Total	4641	6486	4774	277	752	77	193	1118	171	39	817	402	198	1257	165	2095	347	977	17	293	25096	
				P.A.	53%	74%	88%	67%	28%	8%	2%	28%	61%	18%	38%	33%	6%	55%	42%	58%	38%	21%	12%	5%		

O.A.	60%

Map: W ⟷ NFI: D

Map: Qf, Qa (Plantation) ⟷ NFI: O

Fri: P.A. 2%, U.A. 5%

Map: Fsw, W, G ⟷ NFI: E

Fri usually locates near river which shape is long and thin

Map: Swamp woodland → W
Swamp grassland, Herbaceous swamp → G

- Forest/Non-forest → O.A. 87%

  *reference: Target accuracy in VCS → O.A. 80%
  Target accuracy in JNR → O.A. 75% (Under development)

- IPCC 6 categories → O.A. 83%

- Forest class/Non-forest → O.A. 65%

  *reference: Target accuracy in VCS → O.A. 70%

- Land cover class → O.A. 60%

- Wetlands: P.A. 21% (low), U.A. 73% (high)

  ✓ Accuracy of Wetlands categorized in the Map is good, but many Wetlands picked out in the NFI data cannot be categorized in the Map.

- Many Fsw, W, G classes of the Map are located in E of the NFI data.

  ✓ Fsw is swamp forest which is categorized in Forest in the Map. W includes swamp woodland. G includes swamp grassland and herbaceous swamp.

- Fri: P.A. 2% (low), U.A. 5% (low)

  ✓ Fri usually locate along rivers and its shape is long and thin, that's why it is difficult to be picked out.

- Settlements: P.A. 5% (low), U.A. 88% (high)
  - ✓ Accuracy of Settlements categorized in the Map is good, but small settlements are not picked out, that's why many Settlements picked out in the NFI data cannot be categorized in the Map.
- Many Qf, Qa classes of the Map are located in O of the NFI data.
  - ✓ It seems that it is difficult to divide between plantation (Qf, Qa) and O.
- Many W classes are located D of the NFI data.
  - ✓ It seems that it is difficult to divide between W and D.
- IPCC 6 categories in each province:
  - Cropland in Enga, Hela, Western Highlands and Jiwaka is high accuracy (especially P.A. is high), while cropland in Central, Western and especially West Sepik is low. >>> Are there any local features?
  - Wetlands in Gulf is low. >>> There are tangled rivers. Many swamp along rivers are picked out in the NFI data, but not in the Map.
- Checking mismatch points in the Map:
  - Mismatch points are not always error.
  - Ex: NFI small point located in Cropland is contained in Forest of the Map's big polygon created object base classification, because methods between the Map (wall to wall) and the NFI data (point) are different.

Detail results of accuracy assessment of the Forest Base Map 2012 are shown in **Annex J**.

3-3. Issues found in the Forest Base Map 2012 and way to address them

In this section, we describe (i) issues and points to keep in mind found in the Forest Base Map 2012, (ii) how the Project tackled them during the course of the Project activities, and (iii) future possible works toward improvements.

The Project team found the following issues through the process of developing the Forest Base Map 2012 and the analysis of accuracy assessment by comparing the NFI pre-inventory data.

(a) Distinguishing Woodland (W), Savanna (Sa), and Scrub (Sc)

In developing the Forest Base Map v 1.0, it was revealed that the thresholds to distinguish Woodland, Savanna and Scrub was not robust even among PNGFA officers. Also, it turned out that separating Savanna and Scrub utilizing analyzed satellite imagery (RapidEye) was difficult.

The extent of savannas is limited by climatic and environmental conditions, and human-induced fires. On the other hand scrub is low-height forest composed of particular species. These differences in where each are likely to be located were used to determine the distribution of savanna and scrub in the Forest Base Map based on the FIMS map.

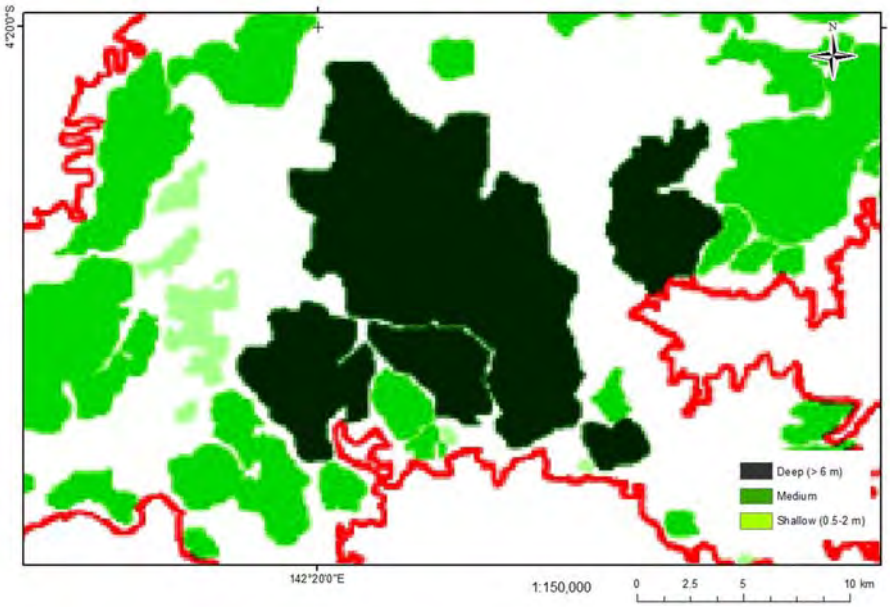
Although Woodland was rather distinguished from Savanna and Scrub from analysis of satellite imagery, it was difficult to separate Savanna and Scrub, so consolidation of those classes was one of the options. However, the Project team decided to keep the classification based on FIMS map and not to consolidate the classifications even though uncertainties of the classification remained.

(b) Detecting wetland-forest

An issue raised when developing the Forest Base Map v 1.0 was that more precise land cover information on the FIMS map was simplified into rough information on the Forest Base Map which lost some information from the FIMS map such as wetland information. Additionally, the accuracy on information about wetland distribution on the FIMS map was not satisfactory. Moreover, in the accuracy assessment with NFI pre-inventory data, it was pointed out that wetlands located in forest et al. were not picked out enough comparing Wetlands based on IPCC definition because definition of land cover class of the Forest Base Map is based on FIMS/PNGRIS, whose wetlands class is only “Lake & larger rivers”.

The project was expected to examine how to grasp distribution of wetland because this information is important for judging the possibility of forest operations and for being referred to in order to select candidate areas of activities to conserve their characteristic ecosystems.

Therefore, the Project team examined methodology to detect wetland-forest utilizing remote sensing data around April Salome, East Sepik (ESP) Province where distribution of peatland, deeply related with existence of wetland forest, was precisely investigated (see to the figure below).

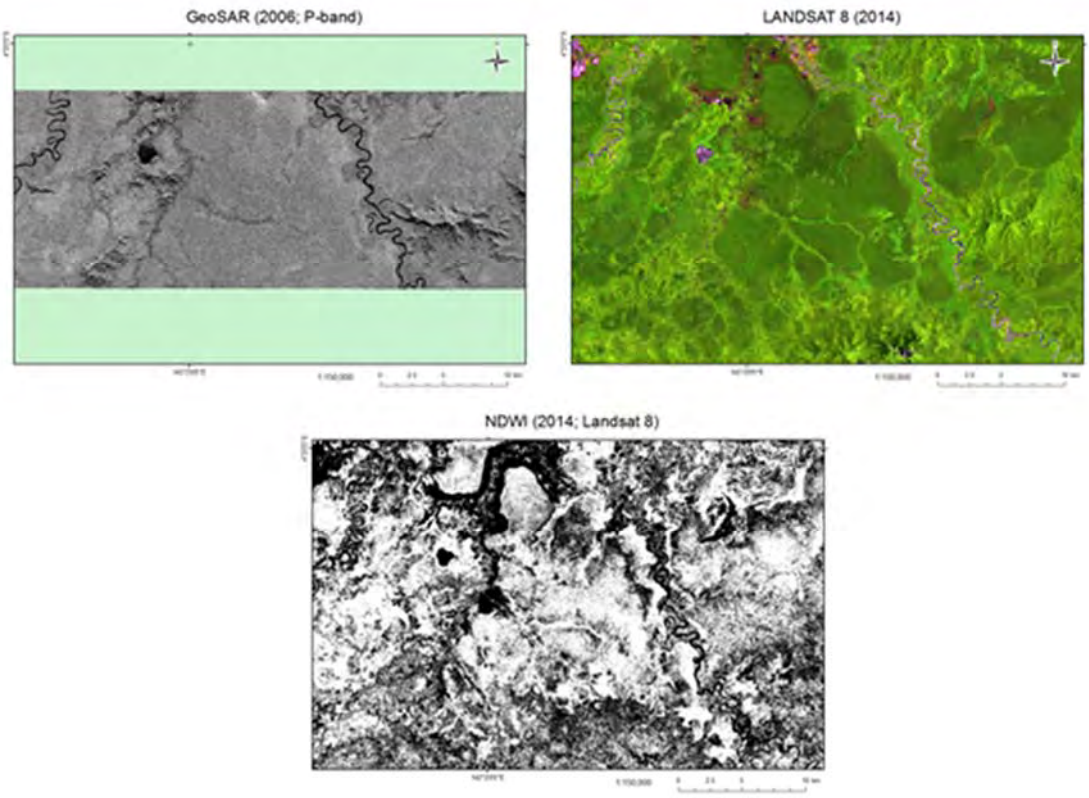


Distribution of peatland around April Salome[8]

GeoSAR data is airborne data utilizing P-band microwave to observe ground features. This data was expected to be used for effectively detecting wetland forest because P-band microwave, which has relatively longer wavelength, can penetrate the crown of forest and monitor forest floor directly. However, it was not easy to distinguish wetland forest, which is likely to be distributed on peatland, and other forests using GeoSAR (the figure below, upper left). A false color composite of LANDSAT-8 (R: Band 6, G: Band5, B: Band 4) looks capable of helping estimate peat distribution (the figure below, upper right). On the other hand, Normalized Difference Water Index (NDWI) calculated from LANDSAT-8 imagery could not show significant difference between inside and outside of peatland area (the figure below, lower).

This suggests that digitizing work or object-based segmentation referring LANDSAT-8 imagery is one of the options to detect wetland forest using remote sensing data. However, because ground survey is necessary to ensure accuracy of the information, it is difficult to investigate distribution of wetland forest targeting the whole of PNG. Practically speaking, updating the Forest Base Map to integrate wetland information referring the information on FIMS should come first. And as necessary, the accuracy of the information should be enhanced locally, digitizing or object-based segmentation of remote sensing data such as LANDSAT-8 imagery and ground survey.

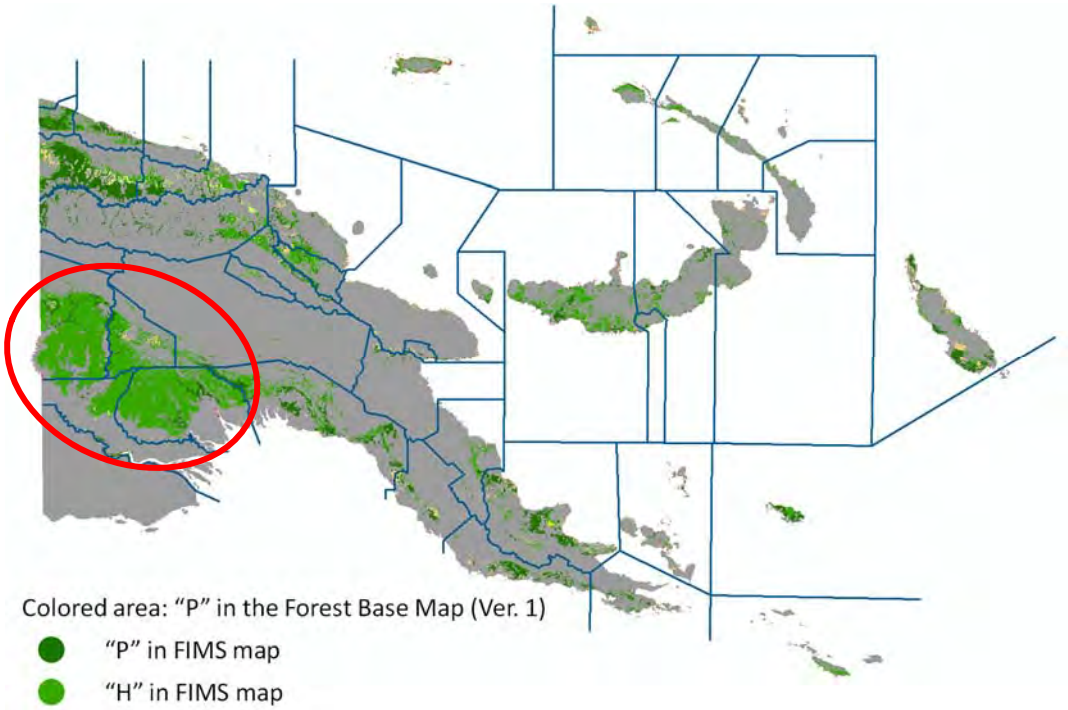
[8] Extracted from Pokana and Joseph, 2013, 'Papua New Guinea's status on peatland initiative'



Imagery around April Salome; GeoSAR (upper left), LADSAT-8 (upper right), NDVI (lower)

(c) Dividing plain forest (P) and hill forest (H) in Western (WES) province

In developing the Forest Base Map v 1.0, it was known that the distribution pattern in Low altitude forest on plains and fans (P) and Low altitude forest on uplands (H) in existing FIMS and the new Forest Base Map were completely different (see to the figure below). In the Project, the causes of this discrepancy were examined and the necessity of revision of the Forest Base Map was discussed.



Comparison between distribution pattern in P forest in the Forest Base Map and that in various forest types in FIMS map

The colored part in the map is the area where P forest is distributed in the Forest Base Map. The dark green part is P forest both in the Forest Base Map and FIMS map and the light green part is P forest in the Forest Base Map and H forest in FIMS map. The blue lines indicate the boundaries of each forest zones. Discrepancy between the Forest Base Map and FIMS map is obvious in the four forest zones circled by a red line.

As a result of analysis, it was revealed that the relationship between slopes of the forests and tree composition in this region was different from that in the other regions in PNG. When the existing FIMS was made, P and H were distinguished from tree composition. In developing the Forest Base Map v 1.0, the Forest Base Map was developed from satellite imagery and it was not possible to distinguish tree composition of the forests using the imagery. Comparing the distribution pattern in P and H in FIMS and the steepness of the polygons in developing the Forest Base Map, the Project team decided to define low altitude forest, which is located on slopes with a gradient less than 6º, as P, and the opposite, that is slopes with a gradient greater than 6°, as H. However, tree species composing "H" in the other region are distributed even in lower slope areas in this region. This can be the main reason why distributions in P and H are different between the Forest Base Map and FIMS map in this region.

The JICA expert team raised the following two options to PNGFA as policies to update the Forest Base Map:

(1) The definition of P and H in the Forest Base Map is not changed (use 6º as the threshold)

(2) Change P in the four forest zones around the WES Province to H if the area was H in FIMS map

The team recommended option (1) if PNGFA considers the slope information to be more important than the tree composition information. Otherwise option (2) was recommended.

Project manager and most of the other officers believed slope information was more useful than tree composition information even though there might be a relationship between tree composition information and flood plain distribution, which could be important information for logging operations. Also, they recognized that the current distribution pattern of each tree species in the zones was actually not clear because most of the forests in the zones were disturbed after FIMS map development. As a result, option (1) was chosen as their collective opinion.

The advantage of this choice is that the slope of the site in low altitude forest is clearly known from the vegetation code and the vegetation code is easy to identify from the slopes in the future when non-forest polygons in low altitude areas change to forest polygons. On the other hand, tree species expected to exist in the site according to the vegetation code may not actually be there.

(d) Extracting Cropland/Agriculture land (O)

In developing the Forest Base Map v 1.0, it was known that it is hard to extract all of Cropland/Agriculture land (O) since the limitations of satellite imagery and other related information. It was also revealed that some Cropland/Agriculture lands were not extracted in the Forest Base Map when creating the past Forest Cover Maps and the Forest Cover Map 2015. Therefore, it is necessary to pay attention to this point when utilizing the Forest Base Map 2012.

The Forest Cover Map 2015 was created based on the Forest Base Map 2012, which was shown in chapter 5-1. It should be a more accurate map than the Forest Base Map since new satellite imagery and new technologies were able to be used when creating the Forest Cover Map 2015. In the future a renewed forest cover map will be created based on the Forest Cover Map 2015, but at that time it will be possible to use further satellite imagery and new technologies, so a renewed forest cover map should be more accurate.

(e) Extracting Settlement

It was known that many settlements located cropland et al. are not divided since it is hard to detect small settlements from analysis of satellite imagery. In addition definition of land cover class of the Forest Base Map is based on FIMS/PNGRIS, whose Larger urban centres (U) class does not cover small settlements.

In the Project activities, settlements were improved somewhat with reference to Census Village in cropland information and the assistance of region officers' knowledge they attended the Project workshop. Nonetheless, the Forest Base Map does not cover so much of 'Settlements' as compared with NFI pre-inventory data.

(f) Extracting and distinguishing Forest plantation (Qf) and Plantation other than forest plantation (Qa)

'Forest Plantation' was distinguished from 'Plantation other than forest plantation' by referring to plantation boundaries data owned by PNGFA. 'Forest Plantation' indicated on the Forest Base Map is not necessarily corresponding to the actual distribution of forest plantations since the plantation data did not cover every boundary information of forest plantations.

Therefore, it is recommended that Inventory & Mapping branch obtain forest plantation information from FDD regularly and digitize it to piece out GIS data, which could be helpful when updating forest cover maps in the future.

(g) Coverage of the Forest Base Map

The following points were known for the coverage of the Forest Base Map, especially small islands, as a result of comparing the Forest Base Map with other existing data such as province data of Census 2011 published by NSO, FIMS map, and province data of Geobook[9].

(1) Country boundaries between existing data have some differences, especially around small islands.

(2) The Forest Base Map does not cover all small islands.

(3) The Forest Base Map includes islands of Australia territory and Solomon Islands.

As a result of the discussions in the Project team, ways to cope with the aforementioned points were decided as follows:

[9] University of Papua New Guinea (UPNG) Remote Sensing Centre, 2010, 'PNG Geobook'. UPNG, Port Moresby, Papua New Guinea

- Boundary of the Forest Base Map, which was created from RapidEye imagery, is just maintained since other existing boundaries are not necessarily accurate,
- Small islands which are not included in the Forest Base Map do not have forests, those are mainly rock reef, under the jurisdiction of PNGFA, and thus they will not be newly created. Notes about small islands are inserted in metadata of the Forest Base Map.
- Islands of Australia territory and Solomon Islands are maintained with "outsidePNG" description in the attribute table of the Forest Bae Map to indicate their territory.

(h) Quality and accuracy assessment of the Forest Base Map

In the Project activities, accuracy assessment of the Forest Base Map was implemented by comparing NFI pre-inventory data to get a grasp of features of the Forest Base Map (see to chapter 3-2). In the future, a renewed forest cover map to be created by PNGFA could be assessed its quality and accuracy using NFI data which is currently in progress.

3-4. Process and methods of developing forest degradation drivers of forest cover map

The tropical rain forest in PNG plays an important role in many aspects, contributing to the national economy through timber exports, rich biodiversity and mitigation of climate change; however an alarming rate of forest loss and degradation have been reported in recent decades. Generally, Deforestation and forest Degradation (DD) are said to be caused by timber harvesting, clearing forests to develop cropland, and natural disasters such as forest fires and floods. For PNGFA to figure out distribution of intact (primary) forest, create forest plans, and manage natural forests in a sustainable manner, it is essential to understand the process of DD through identifying and quantifying DDs and their drivers using a map-based method.

In the Project, PNGFA staff and JICA experts (the Project team) studied DD drivers in three steps: The Project team began by defining terminology such as land use classes, land transition and its drivers (see **section (1)** below). The Project team then examined useful data sources (see **section (2)** below) and availability of satellite images. Finally the Project team established operational procedure and criteria of detecting land transition in forest area (see **section (3)** below) and conducted analyses of DD drivers.

The Forest Mapping Unit (FMU) used in the formerly developed FIMS indicates timber volume value among other attributes. The new PNG-FRIMS (see Fact Sheets No.2 & 3) includes the Forest Base Map, which also includes timber volume and forest disturbance information, as one of its

map contents. The Forest Base Map gives information on where intact (primary) forest may be, versus where forest disturbance has already taken place, etc. for forest management and planning, through a redefined the Forest Monitoring Unit (FMU)[10].

The Forest Base Map covers the whole of PNG and shows forest information as of 2012. Statistical DD driver analysis was conducted to additionally produce Forest Cover Maps for 2000 and 2005 of West New Britain (WNB) Province and West Sepik (WSP) Province and for 2015 of entire PNG, also included in PNG-FRIMS.

The Project team then assessed the effectiveness of the methodology used by the Project team by comparing results to DD drivers identified by the "Collect Earth" tool by UN-REDD, noting the differences (see **section (4)**) and lessons learned (see **chapter 3-5**).

(1) Definitions of land use classes, land transition and its drivers

Definitions of land use (LU) classes

Prior to defining LU transition and its drivers, LU classes and its strata were defined, based on IPCC's six land use categories.

LU classes (IPCC*)	LU strata
Forest land (Natural Forest)	Primary forest
	Logged over forest
	Non-logged degraded forest (driven by activities other than formally planned logging, such as fuelwood collection, gardening, small scale logging for mobile sawmills)
Forest land (Plantation Forest)	Open-canopy plantation (premature or harvested)
	Closed-canopy plantation (mature)
Cropland	Annual crops (herbaceous)
	Perennial plantations (ligneous)
Grassland	Shrub (not defined in the Forest Base Map)
	Grassland
Settlements	Infrastructure (other than roads)
	Road

* IPCC categories 'Wetlands' and 'Other Land' not shown in this table.

[10] FMU (Forest Monitoring Unit) is a minimum polygon of forest cover on a map, used as a unit of data management in PNG-FRIMS. FMU is delineated by Province boundaries, Forest Zone, Catchment area, Land use class, forest type including crown.

Definitions of land transition and its drivers

This set of typology and definitions takes into consideration technical limitations associated to Remote Sensing analysis. Some definitions were deliberately simplified to facilitate analyses of drivers.

Deforestation

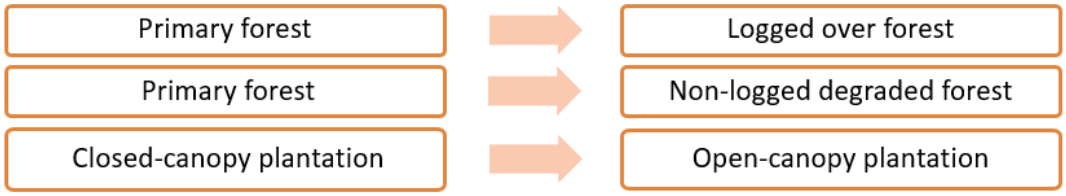
Deforestation is a land transition; for example, "Forest land" class is converted to other LU classes such as “Crop land,” driven by drivers such as "Subsistence agriculture".

Forest land → Another land use class

Initial LU class/ strata	Driver	Final LU class/ strata
Forest land/ whichever strata	Subsistence agriculture	Cropland/ Annual crops Grassland/ Shrub Grassland/ Grassland
	Commercial agriculture	Cropland/ Perennial plantations
	Large fire	Grassland/ Grassland
	Mineral extraction	Settlements/ Infrastructure
	Road construction	Settlements/ Road
	City expansion & settlements	Settlements/ Infrastructure

Degradation

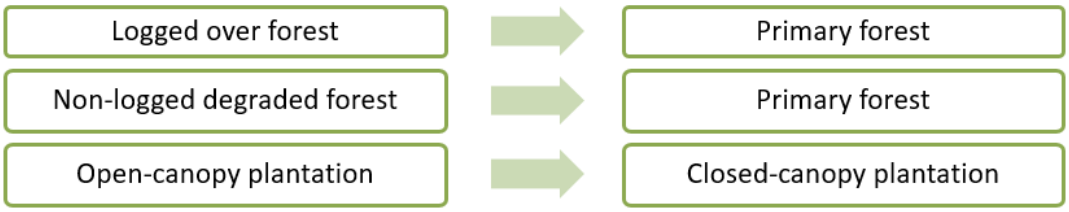
Degradation is a land transition where “Primary forest" strata is converted to other LU strata under “Forest land” class, or "Closed-canopy plantation" is converted to "Open-canopy plantation”.



Initial Forest land strata	Driver	Final Forest land strata
Primary forest	Authorized selective logging	Logged over forest
Primary forest	Wood collection (non-authorized logging + fuel wood collection)	Non-logged degraded forest
Primary forest	Gardening (shifting agriculture) through slash and/or burn (including small fires)	Non-logged degraded forest
Closed-canopy plantation	Logging in forest plantations	Open-canopy plantation
Primary forest	Grazing (usually happens in Grassland, yet may have a potential of forest degradation)	Grassland/ Shrub Grassland/ Grassland

Regeneration

Regeneration is a "positive" land transition under "Forest land" class where "Logged over forest" or "Non-logged degraded forest" is converted to "Primary forest", or "Open-canopy plantation” is converted to "Closed-canopy plantation”.



Initial Forest land strata	Driver	Final Forest land strata	Area type
Logged over forest	Assisted regeneration/Natural regeneration	Primary forest	Managed by PNGFA programme in logging concessions
Non-logged degraded forest	Natural regeneration	Primary Forest	Not in concessions
Open-canopy plantation	Plantation	Closed-canopy Plantation	Managed by PNGFA or private sector

Reforestation

Reforestation is a "positive" land transition where LU class such as "Grassland" or "Cropland" is converted to "Forest land (Plantation forest)" by plantation activities.

Grassland or Cropland → Forest land

Initial LU class/ strata	Driver	Final Forest land strata	Area type
Grassland/ Shrub	Plantation	Forest land (Plantation forest)	Managed by PNGFA or private sector
Grassland/ Grassland			
Cropland/ Perennial plantations			

General scale of degradation associated with each driver

The general scale of degradation associated with each potential DD driver was used to determine the smallest size of "Hansen loss"[11] areas for which drivers will be analyzed and interpreted manually. That cut-off was determined to be 20 ha, according to the analysis below.

Drivers	Associated scale	Notes and information for analysis
Mining / Extractive industry	Generally > 50 ha Sometimes > 30 ha	Deforestation caused by constructing pipelines for oil and gas. Forest areas are cleared for facility construction including the construction of townships with workers compounds, schools, hospitals, administrative centers and recreational areas.
Road construction	Generally 40 to 60 ha	Normal width: 40 m road line corridor (20 m on either sides) Normal road length added per year: 10,000 to 15,000 m 40x (10,000 to 15,000) = 400,000 to 600,000 m^2 per annum
Facility construction (e.g. School)	Generally 2 ha	Schools and logging camps are usually around 2 ha in size. Schools are usually constructed in the village and most schools are not detected as Hansen Loss. Facility construction usually appear along the road, grassland, and other non-forest lands.
Agricultural plantation associated with FCA	Generally > 50 ha	Most activities via FCA occur at a larger scale than 50 ha. Developer can clear forests up to 1,000 ha a year.

[11] "Hansen loss" data is a dataset developed by Hansen, et al. (2013), showing yearly forest reduction since 2001 based on an algorithm to extract areas where decrease of vegetation taller than 5 m was occurring, utilizing imagery of LANDSAT 7 and LANDSAT 8.

Logging (and logging roads)	Generally 20 to 40 ha	The maximum width allowed for main logging roads, which logging trucks and other vehicles will use, is 40 m. Spur roads are also considered to be logging roads but are not commonly used by vehicles. Normal road length added per year: 5 to 10 km for main logging roads. 40 x (5,000 to 10,000) = 200,000 to 400,000 m^2 per annum
Disasters	Generally 5 ha	Main types of disasters in PNG are landslides, from flood and soil erosion especially along the Highlands Highway, or earthquakes (in ENB). The latter could happen in natural forest but hard to identify.
Subsistence agriculture	Generally 1 to 5 ha	Definition: shifting and permanent agriculture, cultivation, and gardening, occurring within 5 to10 km from Census Unit. *The 2010 Census Information is available from the National Statistics Office. Some of this information is already stored in PNG-FRIMS.
	1 ha for non-commercial crops	Size of agricultural land for non–commercial crops is usually 1 ha.
	5 ha for cash crops	Agriculture for cash crops (e.g. cocoa, cacao, etc.) is usually 5 ha.
Fire	1 to 5 ha	Difficult to obtain actual information as the Natural Disaster Office doesn't publish datasets. Natural fires are rare in PNG and thus fires are usually man-made. Major causes are: - Preparation for gardening (1 to 5ha) - Hunting fire in grassland (1 to 5ha) to chase animals - Accidental or careless fire (1 to 5ha) from smoking, cooking, etc.

It is noted that DD Drivers such as **facility construction**, **disaster**, **subsistence agriculture** and **fire** may not be identifiable through the analysis of DD Drivers, however:

- Hansen Loss due to facility construction is not so common.
- Fire will be identified by the FireWatch PNG[12].
- Distinction between 'disaster' and 'subsistence agriculture' drivers can be made using information and assumptions presented below (see notes on subsistence agriculture).

Characteristics of other activities, listed below, may facilitate the association of drivers to the

[12] Web service which provides information of when and where fire occurred. The website has been produced by UPNG Remote Sensing Centre with the financial assistance of the EU. http://fire.pngsdf.com/home.php

remaining Hansen Loss points:

Drivers	Notes and useful information for analysis
Plantations	Replanting periods for each species type are useful in identifying plantations. Forest plantations: Kamerere: 20 years, Teak: 30 to 40 years, Klinkii: 30 to 35 years, Acacia: 8 to 10 years, Pinus spp.: 30 to 35 years, and Hoop: 30 to 35 years Plantations other than forest plantations: Cocoa: 20 to 30 years (upper trees are remaining), Oil palm: 20 years, Rubber: 30 years, and Coconut: 50 years
Settlements	Normally built in non-forest areas and very unlikely detected as Hansen Loss points

The activities, below, cannot be tied to a particular scale of deforestation, but are nevertheless identified as drivers:

Drivers	Notes and useful information for analysis
Grazing	Usually happens in Grassland
Wood collection	Dead trees & twigs are normally collected from gardening site
Logging	Logging data is assumed to be entered as forest working plans, and the volume subtracted in FIMS. Small logging could be operated with chainsaws and portable sawmills.
Building materials collection	People cut down and collect living trees for building materials.

<u>Notes on subsistence agriculture</u>

Definition: Shifting and permanent agriculture cultivation and gardening; occurs within 5 km from Census Unit (CU)

Means to identify small agriculture patches

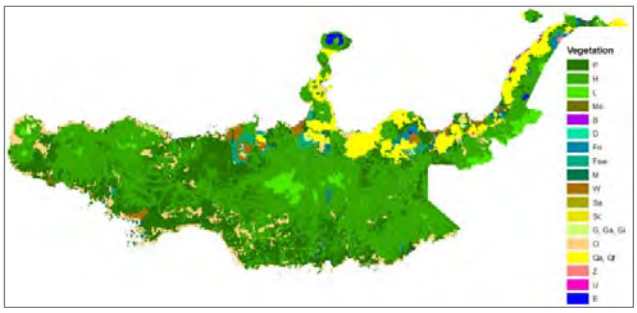
- Hansen Loss larger than 1 to 5 ha, that is adjacent to the Forest Base Map Land use class "Cropland/Agriculture land" but not in characteristic shapes of mining, road, other facilities, plantation, or logging.
- A set of expedient criteria for classifying Hansen Loss data is shown below.

Distance from CU	Size of Hansen Loss data	Disturbance type
No longer than 5 to 10 km	5 to 20 ha	Commercial agriculture
	Up to 1 to 5 ha	Small agriculture patches
	Less than 1 ha	Other disturbance

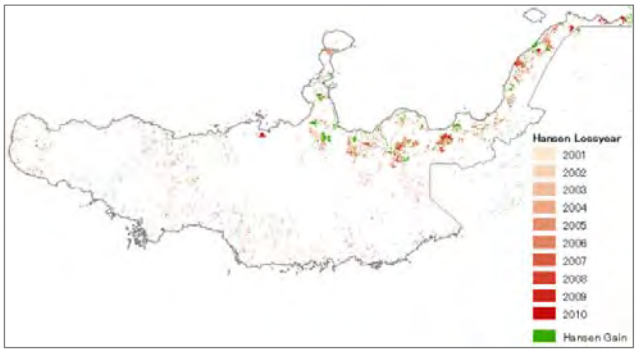
(2) Information used for DD driver identification

The following information was identified as useful for the identification of DD drivers.

Forest Base/Cover Maps: Forest cover information in PNG. Driver information was added to each FMU.



Hansen Data (Lossyear/Gain): Annual pixel-by-pixel representation of deforestation areas. Used for identifying the location of both deforestation and degradation.



Logged over areas: Dataset created by the Project, marking logged over areas under the assumption that logging activities take place within a 500 m buffer from road data in 2000, 2005 and 2011.

Mining: Boundaries of mining activity by the Mineral Resource Authority.

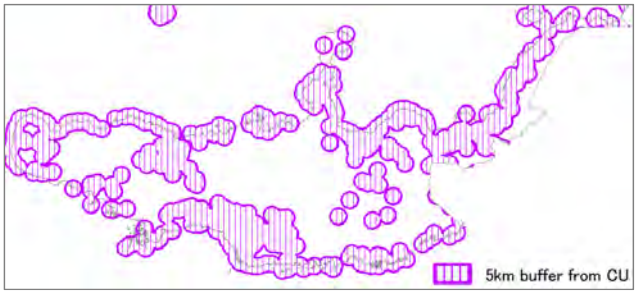
Plantation: Plantation data (Qf/Qa) from the Forest Base Map.

Subsistence agriculture: Agriculture data (O) from the Forest Base Map.

Boundary of Special Agriculture and Business Leases (SABL): Areas permitted for development for agricultural purpose leasing customarily-owned land.

Boundaries of Forest Clearance Authority (FCA): Areas of forest clearance by developers within SABL boundaries.

Concession Area: Timber concession boundaries.



Census Unit: Representative point of settlements. Used for creation of 5 km buffer zone.

FireWatch PNG: Data obtained from a web site (http://fire.pngsdf.com/home.php) developed by the University of Papua New Guinea with the support of the European Union (EU).

(3) Detection and analysis of forest area changes and their drivers

Method

The definitions of DD drivers as discussed in section (1) above, were used in combination with available satellite imagery and other data listed in section (2), to analyze forest area changes and their drivers, based on presence or absence of Hansen Loss polygon and its size.

DD drivers for Hansen Loss polygons larger than 20 ha in targeted years 2001-2010 were identified by visual observation utilizing LANDSAT imagery, RapidEye Imagery (2011), and Google Earth.

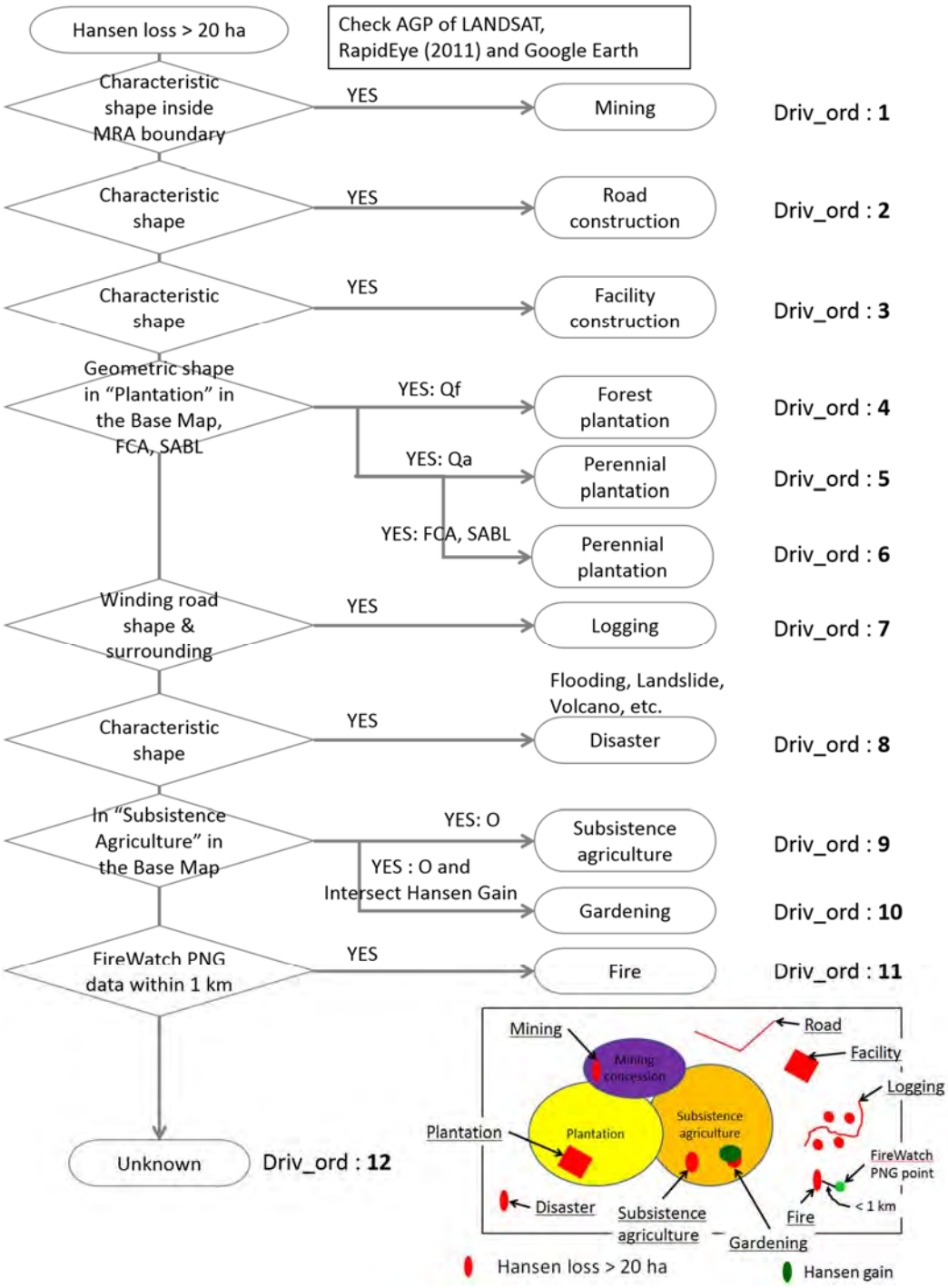
The drivers were identified using the key-out method according to the rules shown in the **flowchart (a)**. Using this method, drivers are exclusive to each other, and multiple operators will identify the same driver for the same deforestation area.

The flowchart started with drivers that are more obvious and easily identifiable, such as mining activities and plantations, and then progressed to drivers that are more difficult to interpret via satellite imagery, such as fires.

The driver "unknown" was assigned to deforestation areas for which no driver could be identified until the end of the flowchart.

The description of the DD driver (e.g. “Mining”) was added to each FMU of the Forest Base Map, as well as past forest cover maps.

(a) Flowchart of driver analysis for Hansen Loss polygons larger than 20 ha

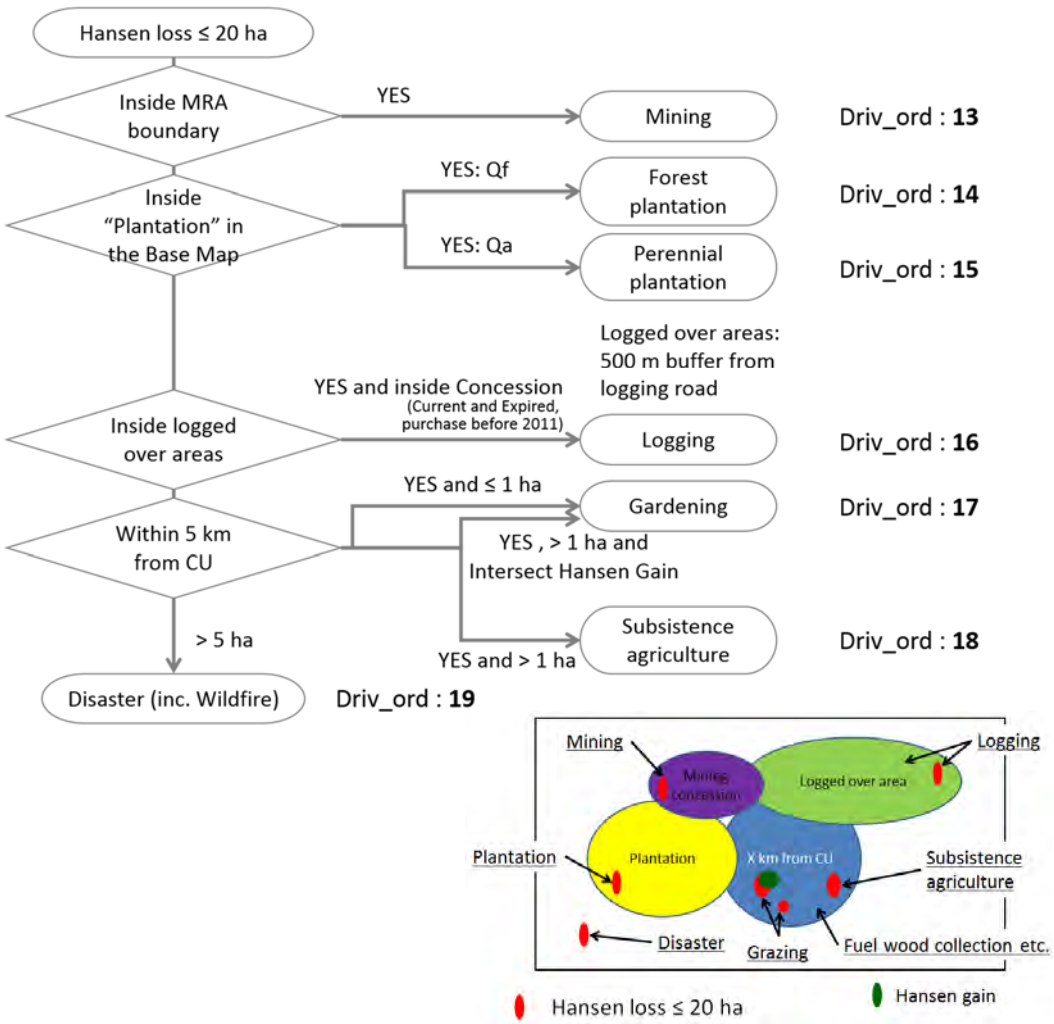


The Hansen Loss polygons 20 ha or smaller in targeted years 2001-2010 were automatically classified to DD driver using GIS data.

The drivers were identified according to the rules shown in the **flowchart (b)**.

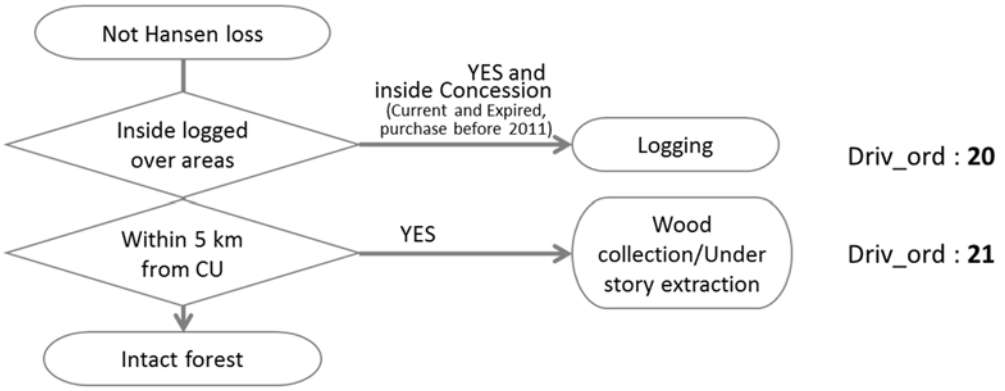
The description of the DD driver (e.g. "Mining") was then added to each FMU of the Forest Base Map, as well as past forest cover maps. The identification of drivers of Hansen Loss polygons larger than 20 ha (see **flowchart (a)** above) was conducted earlier, chronologically. When a FMU overlapped with two or more Hansen Loss polygons, the driver identified and entered earlier was prioritized.

(b) Flowchart of driver analysis for Hansen Loss polygons 20 ha and smaller



Following the above steps, each remaining FMU polygon that indicated change in Land use class/ strata pointing to DD, but without driver information from Hansen Loss, was analyzed according to the **flowchart (c)**, and its driver information was added to FMU directly.

(c) Flowchart of driver analysis for map polygons which do not intersect Hansen Loss



Analysis of other forest cover maps

Although work procedure is described for the Forest Base Map here, driver analysis can be conducted on past forest cover maps and future forest cover maps using the same methodology, but using different datasets which are for targeted years.

Driver analysis was conducted on past forest cover maps for WNB and WSP provinces, and forest cover map of 2015 for entire PNG, using the datasets below.

Data used for the Forest Cover Map 2005:

Hansen Loss polygon for 2001-2004, logging road data before 2005, concession purchase before 2004, and Qf, Qa and O in the forest cover map 2005 data.

Data used for the Forest Cover Map 2000:

Logging road data before 2000 and concession purchase before 1999.

Data used for the Forest Cover Map 2015:

Hansen Loss polygon for 2001-2014, logging road data before 2015, concession purchase before 2014, and Qf, Qa and O in the forest cover map 2015 data.

Procedure

Drivers are developed in a forest cover map in accordance with the following steps.

Step 1: Data preparation

- To collect and arrange all needed data to be used for DD analysis

Step 2: Identify drivers of large Hansen Lossyear polygons (> 20 ha)

- To identify drivers of Hansen Lossyear polygons larger than 20 ha for whole nation by image interpretation in accordance with flowchart (a) above

Step 3: Identify drivers of small Hansen Lossyear polygons (<= 20 ha)

- To identify drivers of Hansen Lossyear polygons 20 ha and smaller than 20 ha by each province by GIS analysis in accordance with flowchart (b) above

Step 4: Merge Hansen Lossyear polygons for each province

- To merge two of Hansen Lossyear polygons identified drivers in step 2 and step 3 by each province

Step 5: Input driver for each FMU

- To input driver in an attribute table of the forest cover map for each FMU using Hansen Lossyear polygons in step 4

Step 6: Input driver for each FMU without Hansen Loss

- To identify driver using some data without Hansen Lossyear polygons for each FMU

Step 7: Input driver by join table

- To complete developing driver in the attribute table to input driver name, since only driver number (Driv_ord) is used in the steps above

1. Data preparation

1-1. Prepare the following data.

Data	Work folder	File name
Forest Base Map	¥02_ana¥21_WNB.gdb (copy from the folder: 31_ForestMap¥ver.1¥7_Bmapv11_fmu)	WNB_ForestBaseMap
Hansen lossyear	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_clp_z55.shp
Province boundary	42_Boundary¥Province_updated2014	Province_2014_z55.shp

* Work folder of the operation: 31_ForestMap¥tmp_works_dd

1-2. Prepare the following reference data necessary for identifying drivers.

Reference data	Work folder	File name	For use in	
			Step 2	Step 3
Mining	¥01_data_arg¥Mining	ML_06May_merge_utm55.shp	Yes	Yes
Forest plantation (Qf) polygon in the Forest Base Map	¥01_data_arg¥FBM_Qf_Qa¥21_WNB	WNB_FBMrev_Qf_Qa.shp * For WNB, use the revised version	(Yes)	Yes
Plantation other than forest plantation (Qa) polygon in the Forest Base Map			(Yes)	Yes
FCA and SABL polygon	¥01_data_arg¥FCA ¥01_data_arg¥SABL	FCA_mer_utm55.shp SABL_utm55.shp	Yes	
Subsistence agriculture (O) in the Forest Base Map	¥01_data_arg¥FBM_O¥21_WNB	WNB_FBMrev_O.shp * For WNB, use the revised version	(Yes)	
500 m buffer from logging road (2000, 2000-2005, 2005-2011)	¥01_data_arg¥LoggingRoad¥21_WNB	Road2011_WNB_500mbuf_sng * Need roads adjacent to the target province		Yes
Concession (Current and Expired, purchase before 2010)	¥01_data_arg¥Concession	ConcessionArea_Cur_Exp_2011_z55.shp		Yes
5 km buffer from CU	¥01_data_arg¥CU¥04_fin	CU_5kmbuf_mer_sng_z55.shp		Yes
Hansen Gain	¥01_data_arg¥Hansen_gain	hansen_gfc2015_gain_z55.shp	Yes	Yes
FireWatch PNG[13]	¥00_data_org¥FireLocation¥cartodb-query	cartodb-query.shp	Yes	

*Data of 500 m buffer from logging road is created by adding 500 m buffer to the original road line data.

[13] FireWatch PNG was accessed on 03 April 2017 in the Project activities..

1-3. Prepare the following image data necessary for interpreting drivers.

Reference data	Work folder	For use in	
		Step 2	Step 3
Forest Base Map (Tiff)	31_ForestMap¥ver.1¥7_Bmapv11_tiff	Yes	
RapidEye imagery	01_Satellite¥RapidEye_2010¥06_mosaic¥Mosaic.gdb	Yes	
Landsat imagery	01_Satellite¥LANDSAT_XXXX	Yes	
Annual Greenest Pixel Landsat imagery	01_Satellite¥Annual_Greenest_Pixel¥GeoTIFF¥TOA	Yes	

2. Identify Drivers of large Hansen Lossyear polygons (> 20 ha)

Driver analysis of large polygons will be done **for whole nation** at once.

2-1. Open ArcMap, and add the following data.

- Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp")
- MRA boundary ("ML_06May_merge_utm55.shp")
- FCA boundary ("FCA_mer_utm55.shp")
- SABL boundary ("SABL_utm55.shp")
- Hansen gain ("hansen_gfc2015_gain_z55.shp")
- Fire Watch PNG data ("cartodb-query.shp")
- Forest Base Map
- RapidEye imagery in 2011
- LANDSAT imagery in 2000, 2005, 2011, and the latest year

2-2. From Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp"), select polygons that are larger than area of 20 ha using *Select by Attribute*, and export selected features as "hansen_gfc2015_lossyear_20ha_z55.shp".

Data	Work folder	File name
Hansen lossyear	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_clp_z55.shp
Hansen lossyear (>20 ha)	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_20ha_z55.shp

2-3. Add field named "**Driv_ord**" (data type: long) to "hansen_gfc2015_lossyear_20ha_z55.shp".

2-4. For each polygon of "hansen_gfc2015_lossyear_20ha_z55.shp", input the driver order number to the "Driv_ord" field according to the following steps by reference to **flowchart (a)**.

Refer to LAMDSAT AGP, RapidEye (2011), Google Earth data for the analysis.

Also refer to "Driver interpretation card" (**Annex L**).

Driv_ord	Driver
1	Mining
2	Road construction
3	Facility construction
4	Forest plantation
5	Perennial plantation
6	Perennial plantation (2)
7	Logging
8	Disaster
9	Subsistence Agriculture
10	Gardening
11	Fire
12	Unknown

1) When the Hansen lossyear polygon ("hansen_gfc2015_lossyear_20ha_z55.shp") is inside **MRA boundary** ("ML_06May_merge_utm56.shp") and a huge deforested area connected with road is visible on the imagery around the polygon area, enter **1** in the "Driv_ord" field.

2) If not 1), and the polygon has a characteristic long and narrow shape representing **roads**, enter **2** in the "Driv_ord" field.

3) If not 2), and the **town or airport** is visible on the imagery around the polygon area, enter **3** in the "Driv_ord" field.

4) If not 3), and the polygon is inside **"Forest plantation" (Qf)** of the Forest Base Map, and has a geometric shape, enter **4** in the "Driv_ord" field.

5) If not 4), and the polygon is inside **"Perennial plantation" (Qa)** of the Forest Base Map and has a geometric shape, enter **5** in the "Driv_ord" field.

6) If not 5), and the polygon is inside **FCA** ("FCA_mer_utm55.shp") or **SABL** ("SABL_utm55.shp"), and has a geometric shape, enter **6** in the "Driv_ord" field.

* It should be classified as Perennial plantation for now, because the actual substance of FCA and SABL cannot be known. However distinguish from the Perennial Plantation (2) classified by the Forest Base Map Qa, because in the future it might became possible to classify them.

7) If not 6), and the polygon has a **winding road** shape or surrounding, enter **7** in the "Driv_ord" field.

8) If not 7), and the polygon has a characteristic shape that is caused by **flooding, landslide and volcano**, enter **8** in the "Driv_ord" field.

9) If not 8), and the polygon is inside the **"Substance agriculture" (O)** of the Forest Base Map, enter **9** in the "Driv_ord" field.

10) Select **"Substance agriculture"** polygons ("Driv_ord" = 9), and for those polygon intersects **Hansen gain** ("hansen_gfc2015_gain_z55.shp") using *Select Layer by Location*, enter **10** in the "Driv_ord" field.

    *Make sure to change the selection type to "Subset selection" when using *Select Layer by Location*.

11) If not 10), and the polygon is **inside 1 km buffer** from the **Fire Watch PNG** data ("cartodb-query.shp"), enter **11** in the "Driv_ord" field.

    *For 11) make sure the year of fire match with the year of Hansen loss.

12) If not 11) enter 12 in the "Driv_ord" field.

2-5. From "hansen_gfc2015_lossyear_20ha_z55.shp", select changes for each province. Use *Select Layer by Location* to select polygons intersect each selected province ("Province_2014_z55.shp"), and export selected features as "WNB_2015_lossyear_20ha_s56.shp".

Data	Work folder	File name
Hansen lossyear (>20 ha) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_2015_lossyear_20ha_s56.shp

2-6. Change the projected coordinate system accordingly to the following table.

No.	Province	Coordinate	No.	Province	Coordinate
01	WES	S54	12	SIM	S55
02	GUL	S54	13	EHP	S55
03	CEN	S55	14	MOR	S55
04	NCD	S55	15	MAD	S55
05	MIL	S55	16	ESP	S55
06	ORO	S55	17	WSP	S54
07	SHP	S54	18	MAN	S55
08	HLA	S54	19	NIP	S56
09	ENG	S54	20	ENB	S56
10	WHP	S54	21	WNB	S56
11	JIW	S54	22	ARB	S57

2-7. For each province, from "WNB_2015_lossyear_20ha_s56.shp", select changes for targeted year of 2001-2011 ("GRIDCODE" <= **10**), and export selected features as "WNB_2011_lossyear_20ha_s56.shp"

Data	Work folder	File name
Hansen lossyear (>20 ha, 2000-2011) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_**2011**_lossyear_20ha_s56.shp

3. Identify Drivers of small Hansen Lossyear polygons (<= 20 ha)

Driver analysis of small polygons will be done **by each province**.

3-1. Open ArcMap, and add the following data.

- Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp")
- Province boundary ("Province_2014_z55.shp")
- 5 km buffer from CU ("CU_5kmbuf_mer_sng_z56.shp")
- Hansen gain ("hansen_gfc2015_gain_z56.shp")
- Logged over areas ("Road2011_WNB_500mbuf_sng")
- Concession area ("ConcessionArea_Cur_Exp_2011_z56.shp")
- "Forest plantation" area of the Forest Base Map ("WNB_FBMrev_Qf_Qa.shp")
- MRA boundary ("ML_06May_merge_utm56.shp")

3-2. From Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp"), select polygons that are 20 ha or smaller using *Select Layer by Attribute*, and export selected features as "hansen_gfc2015_lossyear_0_20ha_z55.shp".

3-3. From "hansen_gfc2015_lossyear_0_20ha_z55.shp", select changes for each province. Use *Select Layer by Location* to select polygons intersect each selected province ("Province_2014_z55.shp"), and export selected features as "WNB_2015_lossyear_0_20ha_s56.shp".

*Make sure to change the projected coordinate system accordingly to each province.

3-4. Add field named "**Driv_ord**" (data type: long) to "WNB_2015_lossyear_0_20ha_s56.shp"

3-5. From "WNB_2015_lossyear_0_20ha_s56.shp", select changes for targeted year of 2001–2011 ("GRIDCODE" <= 10), and export selected features as "WNB_2011_lossyear_0_20ha_s56.shp".

Data	Work folder	File name
Hansen lossyear (0-20 ha)	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_0_20ha_z55.shp
Hansen lossyear (0-20 ha) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_2015_lossyear_0_20ha_s56.shp
Hansen lossyear (0-20 ha, 2000-2011) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_**2011**_lossyear_0_20ha_s56.shp

3-6. For each polygon of "WNB_2011_lossyear_0_20ha_s56.shp", input the driver order number to the "Driv_ord" field according to the following steps. The entire flow is visualized in **flowchart (b)**.

*The actual process will start from the bottom of the flow to the top, in order to overwrite the drivers in lower order.

Driv_ord	Driver
13	Mining
14	Forest plantation
15	Perennial plantation
16	Logging
17	Gardening
18	Subsistence agriculture
19	Disaster

1) Input **99** in the "Driv_ord" field of Hansen lossyear polygon ("WNB_2011_lossyear_0_20ha_s56.shp").

2) For the polygon of area **larger than 5 ha** ("area_ha" > 5), enter **19** in the "Driv_ord" field.

3) When the polygon intersects **5 km buffer** from **Census Unit** ("CU_5kmbuf_mer_sng_z56.shp"), enter **18** in the "Driv_ord" field.

4) When 3), and the polygon intersects **Hansen gain** ("hansen_gfc2015_gain_z56.shp"), enter **17** in the "Driv_ord" field (*Select layer by Location*).

   *Make sure to change the selection type to "Subset selection" when selecting the polygon using *Select layer by Location*.

5) When 3), and the polygon is **smaller than 1 ha** ("Driv_ord" = 18 AND "area_ha" <= 1), enter **17** in the "Driv_ord" field.

6) When the polygon intersects **logged over areas** ("Road2011_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2011_z56.shp"), enter **16** in the "Driv_ord" field.

   *Make sure to include the road information of the adjacent province.

   *Make sure to change the selection type to "New selection" before selecting the polygons intersect logged over areas, and change again to "Subset selection" when selecting the polygons intersect concession area using *Select layer by Location*.

7) When the polygon intersects "**Perennial plantation" (Qa)** in the Forest Base Map ("WNB_FBMrev_Qf_Qa.shp"), enter **15** in the "Driv_ord" field.

   *Make sure to change the selection type to "New selection" before selecting the polygons intersect Perennial plantation using *Select layer by Location*.

8) When the polygon intersects **"Forest plantation" (Qf)** in the Forest Base Map ("WNB_FBMrev_Qf_Qa.shp"), enter **14** in the "Driv_ord" field.

9) When the polygon intersects **MRA boundary** ("ML_06May_merge_utm56.shp"), enter **13** in the "Driv_ord" field (*Select layer by Location*).

4. Merge Hansen Lossyear polygons for each province

4-1. Add the following data on ArcMap.

- Hansen lossyear (>20 ha) data for 2001-2010 ("WNB_2011_lossyear_20ha_s56.shp")

- Hansen lossyear (<=20 ha) data for 2001-2010 ("WNB_2011_lossyear_0_20ha_s56.shp")

4-2. Merge two Hansen lossyear data for small and large area ("WNB_2011_lossyear_20ha_s56.shp" and "WNB_2011_lossyear_0_20ha_s56.shp") and export data to analysis folder as "WNB_2011_lossyear_20ha_s56.shp"

Data	Work folder	File name
Hansen lossyear with driver info (2000-2011) in Province	¥02_ana¥21_WNB¥FBM_2011	WNB_2011_lossyear_s56.shp

5. Input driver for each FMU

In this step, the driver will be added to each FMU by overlaying Hansen lossyear polygon. For those FMUs including more than two Hansen lossyear polygons, the lower (high priority) value of "Driv_ord" will be applied. For the same value of "Driv_ord", a lossyear polygon with the lowest (former) year takes the priority.

5-1. Add the following data on ArcMap.

- Forest Base Map ("WNB_ForestBaseMap")

  * For WNB, use "WNB_ForestCover_00_11" because the value was revised.

- Hansen lossyear data ("WNB_2011_lossyear_s56.shp")

5-2. Add field named "**kari**" (data type: long) to Hansen lossyear data ("WNB_2011_lossyear_s56.shp").

5-3. Using *Calculate Field*, input number which contains both driver order information and the year of Hansen loss to "**kari**" field.

Equation: **[Driv_ord] * 100 + [GRIDCODE]**

5-4. Select polygons with "kari" field **larger than 9000** ("kari" > 9000), and input **9999** to the selected features.

**Close the Map document and open ArcMap (new Map document) again to avoid ArcGIS bug.*

5-5. Using *Identity*, overlay Hansen lossyear polygon ("WNB_2011_lossyear_s56.shp") and the Forest Base Map ("WNB_ForestBaseMap") and save outputs to FBM_2011 folder as "WNB_FBM_Driv_iden.shp".

*Arc Info license is required for using *Identity*.

Data	Work folder	File name
Forest Base Map overlayed Hansen lossyear	¥02_ana¥21_WNB¥FBM_2011	WNB_FBM_Driv_iden.shp

5-6. Open the attribute table of "WNB_FBM_Driv_iden.shp", and select polygons without driver information (**"kari" = 0**) and input **9999** to the "**kari**" field.

5-7. Right click on the "**FMU_id**" field to choose "**Summary**". Summarize the minimum value of "kari" field for each FMU. Save the summary table as "FMU_DrivOrd.dbf".

*This operation is done for identifying the driver with the lowest order for each FMU.

Data	Work folder	File name
Summary table	¥02_ana¥21_WNB¥FBM_2011	FMU_DrivOrd.dbf

5-8. Add the following three fields to the Forest Base Map ("WNB_ForestBaseMap").

Field	Name	Data type	Length
Driver	Driv_11	Text	50
Driver order	Drv_Ord_11	Long integer	
Year	Y11	Long integer	

5-9. Using *Join table*, join summary table ("FMU_DrivOrd.dbf") to the Forest Base Map ("WNB_ForestBaseMap") using "**FMU_id**" field as join field.

5-10. Input driver order information to "**Drv_Ord_11**" field by calculating the following equation using *Calculate Field*.

Equation: **([FMU_DrivOrd_1.Min_kari] - Right ([FMU_DrivOrd_1.Min_kari], 2)) / 100**

5-11. Input year information to "**Y11**" field by calculating the following equation using *Calculate Field*.

Equation: **2000 + Right ([FMU_DrivOrd_1.Min_kari], 2)**

5-12. Select polygons without year information (**Y11 = 2099**) and input **9999** to the "**Y11**" field.

5-13. Remove joined table.

6. Input driver for each FMU without Hansen loss

6-1. Open ArcMap, and add the following data.

- Forest Base Map ("WNB_ForestBaseMap")
- Logged over areas for 2000 ("Road2000_WNB_500mbuf_sng")
- Logged over areas for 2005 ("Road2000_2005_WNB_500mbuf_sng")
- Logged over areas for 2011 ("Road2005_2011_WNB_500mbuf_sng")

  *Year information will be added to the drivers identified by logged over areas.

- Concession area ("ConcessionArea_Cur_Exp_2011_z56.shp")
- 5 km buffer from CU ("CU_5kmbuf_mer_sng_z56.shp")

6-2. For each polygon of the Forest Base Map ("WNB_ForestBaseMap"), input the driver order number to the "Drv_Ord_11" field according to the following steps by reference to **flowchart (c)**.

*Make sure not to overwrite the polygon which already has a driver information from Hansen loss.

Order	Driver
20	Logging
21	Wood collection/Understory extraction

*Grazing is excluded from this analysis, because it usually happens in grassland.

1) When the polygon of the Forest Base Map ("WNB_ForestBaseMap") does not have driver information (**Driv_Ord_11= 99**) and intersects the **logged over areas** ("**Road2000**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2000_z56.shp"), enter **20** in the "**Drv_Ord_11**" field, enter **2000** in the "**Y11**" field.

   *Make sure the change the selection type to "Subset selection" when selecting the polygon using *Select Layer by Location*.

2) When the polygon does not have driver information (**Drv_Ord_11= 99**) and intersects the **logged over areas** ("**Road2000_2005**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2005_z56.shp"), enter **20** in the "**Drv_Ord_11**" field, enter **2005** in the "**Y11**" field.

3) When the polygon does not have driver information (**Drv_Ord_11= 99**) and intersects the **logged over areas** ("**Road2005_2011**_WNB_500mbuf_sng") and **concession area**

("ConcessionArea_Cur_Exp_2011_z56.shp"), enter **20** in the "**Drv_Ord_11**" field, enter **2011** in the "**Y11**" field.

4) If not 1) - 3) (**Drv_Ord_11= 99**), and the polygon intersects **5 km buffer** from **Census Unit** ("CU_5kmbuf_mer_sng_z56.shp"), enter **21** in the "**Driv_ord_11**" field.

7. Input driver by join table

7-1. Join DriverTab table (DriverTab$) using "Driv_ord_11" as join field, and input the driver to "**Driv_11**" field. ([DriverTab$.Driver])

7-2. Those polygons with "-" in "Driver" field are considered as intact forest.

7-3. Remove joined table.

Procedure (Forest Cover Map 2005)

For reference, work procedure for the Forest Cover Map 2005 is also described here. Driver analysis for Forest Cover Map 2005 is done **by each province**.

1. Data preparation

1-1. Prepare the following reference data necessary for identifying drivers.

Data	Work folder	File name
Mining	¥01_data_arg¥Mining	ML_06May_merge_utm56.shp
Forest plantation (Qf) polygon in the forest cover map **2005**	¥01_data_arg¥FBM_Qf_Qa¥21_WNB	WNB_**FCM05**_Qf_Qa.shp
Plantation other than forest plantation (Qa) polygon in the forest cover map **2005**	¥01_data_arg¥FBM_Qf_Qa¥21_WNB	
FCA and SABL polygon	¥01_data_arg¥FCA ¥01_data_arg¥SABL	FCA_mer_utm56.shp SABL_utm56.shp
500 m buffer from logging road (**2000**, **2000-2005**)	¥01_data_arg¥LoggingRoad¥21_WNB	Road**2005**_WNB_500mbuf_sng * need roads adjacent to the target province
Concession (Current and Expired, purchase before **2004**)	¥01_data_arg¥Concession	ConcessionArea_Cur_Exp_**2005**_z56.shp

5km buffer from CU	¥01_data_arg¥CU¥04_fin	CU_5kmbuf_mer_sng_z56.shp
Hansen Gain	¥01_data_arg¥Hansen_gain	hansen_gfc2015_gain_z56.shp
FireWatch PNG	¥00_data_org¥FireLocation¥cartodb-query	cartodb-query.shp

*Data in grey cells are already prepared for Forest Base Map.

2. Prepare Hansen lossyear data for 2005 and identify Drivers

2-1. Open ArcMap, and add the following data.

- Hansen lossyear (>20 ha) data ("WNB_2015_lossyear_20ha_s56.shp")
- Hansen lossyear (<=20 ha) data ("WNB_2015_lossyear_20ha_s56.shp")
- 5 km buffer from Census Unit ("CU_5kmbuf_mer_sng_z56.shp")
- Hansen gain ("hansen_gfc2015_gain_z56.shp")
- Logged over areas ("Road2005_WNB_500mbuf_sng")
- Concession area ("ConcessionArea_Cur_Exp_2005_z56.shp")
- "Forest plantation" area of the forest cover map 2005 ("WNB_FCM05_Qf_Qa.shp")
- MRA boundary ("ML_06May_merge_utm56.shp")

2-2. From large Hansen lossyear data ("WNB_2015_lossyear_20ha_s56.shp"), select changes for targeted year of 2001–2004 ("GRIDCODE" <= 4), and export selected features as "WNB_2005_lossyear_20ha_s56.shp"

2-3. From small Hansen lossyear data ("WNB_2015_lossyea_0_20ha_s56.shp"), select changes for targeted year of 2001–2004 ("GRIDCODE" <= 4), and export selected features as "WNB_2005_lossyear_0_20ha_s56.shp"

Data	Work folder	File name
Hansen lossyear (>20 ha, 2000-2005) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_2005_lossyear_20ha_s56.shp
Hansen lossyear (0-20 ha, 2000-2005) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_2005_lossyear_0_20ha_s56.shp

*For the <= 20 ha polygons, driver information have to be re-identified.

2-4. For each polygon of "WNB_2005_lossyear_0_20ha_s56.shp", input the driver order number to the "Driv_ord" field according to the following steps, using the prepared data. The entire flow is visualized in **flowchart (b)**.

Driv_ord	Driver
13	Mining
14	Forest plantation
15	Perennial plantation
16	Logging
17	Gardening
18	Subsistence agriculture
19	Disaster

1) Input **99** in the "Driv_ord" field of Hansen lossyear polygon ("WNB_2005_lossyear_0_20ha_s56.shp").

2) For the polygon of area **larger than 5 ha** ("area_ha" > 5), enter **19** in the "Driv_ord" field.

3) When the polygon intersects **5 km buffer** from **Census Unit** ("CU_5kmbuf_mer_sng_z56.shp"), enter **18** in the "Driv_ord" field.

4) When 3), and the polygon intersects **Hansen gain** ("hansen_gfc2015_gain_z56.shp"), enter **17** in the "Driv_ord" field (*Select layer by Location*).

   *Make sure to change the selection type to "Subset selection" when selecting the polygon using *Select layer by Location*.

5) When 3), and the polygon is **smaller than 1 ha** ("Driv_ord" = 18 AND "area_ha" <= 1), enter **17** in the "Driv_ord" field.

6) When the polygon intersects **logged over areas** ("Road2005_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2005_z56.shp"), enter **16** in the "Driv_ord" field.

   *Make sure to include the road information of the adjacent province.

   *Make sure to change the selection type to "New selection" before selecting the polygons intersect logged over areas, and change again to "Subset selection" when selecting the polygons intersect concession area using *Select layer by Location*.

7) When the polygon intersects "**Perennial plantation" (Qa)** in the Forest Cover Map 2005 ("WNB_FCM05_Qf_Qa.shp"), enter **15** in the "Driv_ord" field.

   *Make sure to change the selection type to "New selection" before selecting the polygons intersect Perennial plantation using *Select layer by Location*.

8) When the polygon intersects **"Forest plantation" (Qf)** in the Forest Cover Map 2005 ("WNB_FCM05_Qf_Qa.shp"), enter **14** in the "Driv_ord" field.

9) When the polygon intersects **MRA boundary** ("ML_06May_merge_utm56.shp"), enter **13** in the "Driv_ord" field (*Select layer by Location*).

3. Merge Hansen Lossyear polygons for each province

3-1. Add the following data on ArcMap.

- Hansen lossyear (>20 ha) data ("WNB_2005_lossyear_20ha_s56.shp")
- Hansen lossyear (<=20 ha) data for 2005 ("WNB_2005_lossyear_0_20ha_s56.shp")

3-2. Merge two Hansen lossyear data for small and large area.

Data	Work folder	File name
Hansen lossyear with driver info (2000-2005) in Province	¥02_ana¥21_WNB¥FBM_2005	WNB_2005_lossyear_s56.shp

4. Input driver for each FMU

In this step, the driver will be added to each FMU. For those FMUs including more than two Hansen lossyear polygons, the lower value of "Driv_ord" will be applied.

4-1. Add the following data on ArcMap.

- Forest Base Map ("WNB_ForestBaseMap")

  * For WNB, use "WNB_ForestCover_00_11" because the value was revised.

- Hansen lossyear data ("WNB_2005_lossyear_s56.shp")

4-2. Add field named "**kari**" (data type: long) to Hansen lossyear data ("WNB_2005_lossyear_s56.shp").

4-3. Using *Calculate Field*, input number which contains both driver order information and the year of Hansen loss to "**kari**" field.

Equation: **[Driv_ord] * 100 + [GRIDCODE]**

4-4. Select polygons with "kari" field **larger than 9000** ("kari" > 9000), and input **9999** to the selected features.

**Close the Map document and open ArcMap (new Map document) again to avoid ArcGIS bug.*

4-5. Using *Identity*, overlay Hansen lossyear polygon ("WNB_2005_lossyear_s56.shp") and the

Forest Base Map ("WNB_ForestBaseMap") and save outputs to FCM_2005 folder as "WNB_FBM_Driv_iden.shp".

*Arc Info license is required for using *Identity*.

Data	Work folder	File name
Forest Base Map overlayed Hansen lossyear	¥02_ana¥21_WNB¥FBM_2005	WNB_FCM_Driv_iden.shp

4-6. Open the attribute table of "WNB_FCM_Driv_iden.shp", and select polygons without driver information (**"kari" = 0**) and input **9999** to the "**kari**" field.

4-7. Right click on the "**FMU_id**" field to choose "**Summary**". Summarize the minimum value of "kari" field for each FMU. Save the summary table as "FMU_DrivOrd.dbf".

*This operation is done for identifying the driver with the lowest order for each FMU.

Data	Work folder	File name
Summary table	¥02_ana¥21_WNB¥FCM_2005	FMU_DrivOrd.dbf

4-8. Add the following three fields to the Forest Base Map ("WNB_ForestBaseMap").

Field	Name	Data type	Length
Driver	Driv_05	Text	50
Driver order	Drv_Ord_05	Long integer	
Year	Y05	Long integer	

4-9. Using *Join table*, join summary table ("FMU_DrivOrd.dbf") to the Forest Base Map ("WNB_ForestBaseMap") using "**FMU_id**" field as join field.

4-10. Input driver order information to "**Drv_Ord_05**" field by calculating the following equation using *Calculate Field*.

Equation: **([FMU_DrivOrd_1.Min_kari] - Right ([FMU_DrivOrd_1.Min_kari], 2)) / 100**

4-11. Input year information to "**Y05**" field by calculating the following equation using *Calculate Field*.

Equation: **2000 + Right ([FMU_DrivOrd_1.Min_kari], 2)**

4-12. Select polygons without year information (**Y05 = 2099**) and input **9999** to the "**Y05**" field.

4-13. Remove joined table.

5. Input driver for each FMU without Hansen loss

5-1. Open ArcMap, and add the following data.

- Forest Base Map ("WNB_ForestBaseMap")
- Logged over areas for 2000 ("Road2000_WNB_500mbuf_sng")
- Logged over areas for 2005 ("Road2000_2005_WNB_500mbuf_sng")

*Year information will be added to the drivers identified by logged over areas.

- Concession area ("ConcessionArea_Cur_Exp_2005_z56.shp")
- 5 km buffer from Census Unit ("CU_5kmbuf_mer_sng_z56.shp")

5-2. For each polygon of the Forest Base Map ("WNB_ForestBaseMap"), input the driver order number to the "Drv_Ord_05" field according to the following steps by reference to **flowchart (c)**.

*Make sure not to overwrite the polygon which already has a driver information from Hansen loss.

Order	Driver
20	Logging
21	Wood collection/Understory extraction

*Grazing is excluded from this analysis, because it usually happens in grassland.

1) When the polygon of the Forest Base Map ("WNB_ForestBaseMap") does not have driver information (**Driv_Ord_05= 99**) and intersects the **logged over areas** ("**Road2000**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2005_z56.shp"), enter **20** in the "**Drv_Ord_05**" field, enter **2000** in the "**Y05**" field.

   *Make sure the change the selection type to "Subset selection" when selecting the polygon using *Select Layer by Location*.

2) When the polygon does not have driver information (**Drv_Ord_05= 99**) and intersects the **logged over areas** ("**Road2000_2005**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2005_z56.shp"), enter **20** in the "**Drv_Ord_05**" field, enter **2005** in the "**Y05**" field.

3) If not 1) or 2) (**Drv_Ord_05= 99**), and the polygon intersects **5 km buffer** from **Census**

Unit ("CU_5kmbuf_mer_sng_z56.shp"), enter **21** in the "**Driv_ord_05**" field.

6. Input driver by join table

6-1. Join DriverTab table (DriverTab$) using "Driv_ord_05" as join field, and input the driver to "**Driv_05**" field. ([DriverTab$.Driver])

6-2. Those polygons with "-" in "Driver" field are considered as intact forest.

6-3. Remove joined table.

Procedure (Forest Cover Map 2000)

For reference, work procedure for the Forest Cover Map 2000 is also described here. Driver analysis for Forest Cover Map 2000 is done **by each province**.

1. Data preparation

1-1. Prepare the following reference data necessary for identifying drivers.

Data	Work folder	File name
500 m buffer from logging road (**2000**)	¥01_data_arg¥LoggingRoad¥21_WNB	Road**2000**_WNB_500mbuf_sng * need roads adjacent to the target province
Concession (Current and Expired, purchase before **1999**)	¥01_data_arg¥Concession	ConcessionArea_Cur_Exp_**2000**_z56.shp
5km buffer from CU	¥01_data_arg¥CU¥04_fin	CU_5kmbuf_mer_sng_z56.shp

*Data in grey cells are already prepared for Forest Base Map.

2. Input driver for each FMU

2-1. Open ArcMap, and add the following data.

- Forest Base Map ("WNB_ForestBaseMap")
- Logged over areas for 2000 ("Road2000_WNB_500mbuf_sng")

  *Year information will be added to the drivers identified by logged over areas.

- Concession area ("ConcessionArea_Cur_Exp_2000_z56.shp")
- 5 km buffer from Census Unit ("CU_5kmbuf_mer_sng_z56.shp")

2-2. Add the following three fields to the Forest Base Map ("WNB_ForestBaseMap").

Field	Name	Data type	Length
Driver	Driv_00	Text	50
Driver order	Drv_Ord_00	Long integer	
Year	Y00	Long integer	

2-3. Input **99** to "Driv_ord_00" field and **9999** to "**Y00**" field for all polygon.

2-4. For each polygon of the Forest Base Map ("WNB_ForestBaseMap"), input the driver order number to the "Drv_Ord_00" field according to the following steps.

Order	Driver
20	Logging
21	Wood collection/Understory extraction

*Grazing is excluded from this analysis, because it usually happens in grassland.

1) When the polygon intersects the **logged over areas** ("**Road2000**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2000_z56.shp"), enter **20** in the "**Drv_Ord_00**" field, enter **2000** in the "**Y00**" field.

   *Make sure the change the selection type to "Subset selection" when selecting the polygon using *Select Layer by Location*.

2) If not 1) (**Drv_Ord_00= 99**), and the polygon intersects **5 km buffer** from **Census Unit** ("CU_5kmbuf_mer_sng_z56.shp"), enter **21** in the "**Driv_ord_00**" field.

3. Input driver by join table

3-1. Join DriverTab table (DriverTab$) using "Driv_ord_00" as join field, and input the driver to "**Driv_00**" field. ([DriverTab$.Driver])

3-2. Those polygons with "-" in "Driver" field are considered as intact forest.

3-3. Remove joined table.

Outputs of forest degradation driver of the Forest Base Map 2012 and the Forest Cover Maps for 2000, 2005, and 2011 (revised ver.) are shown in **Annex A**.

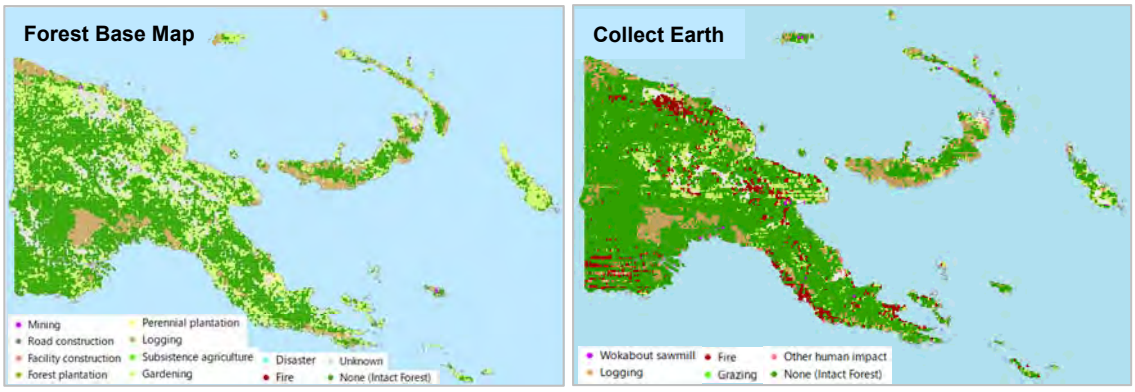
(4) Assessment of DD Driver Analysis using Collect Earth Data

Comparison of DD drivers identified in the Forest Base Map and Collect Earth

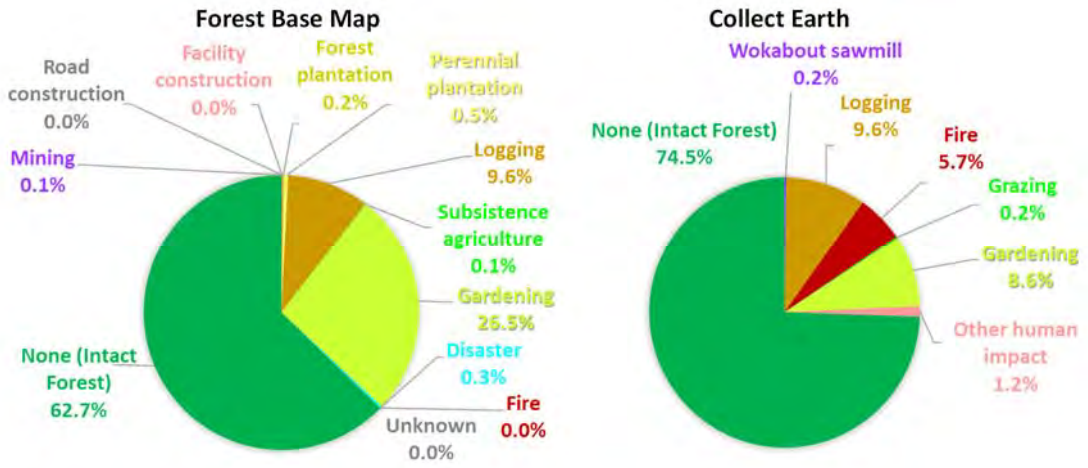
To assess the effectiveness of DD Driver analysis developed and conducted by the Project team, DD drivers identified on the Forest Base Map were compared with "impact type" identified by Collect Earth, by overlaying with Collect Earth plots.

Notes on methodology:

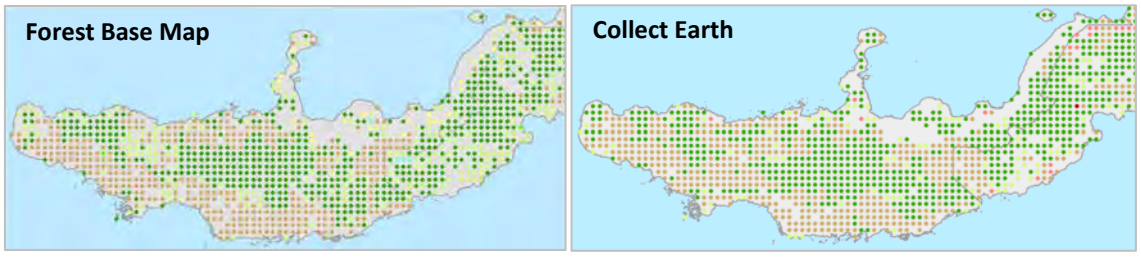
- Data from the revised forest cover map 2011 were used for WSP and WNB, and the Forest Base Map for other Provinces (hereinafter collectively referred to as "Forest Base Map").
- The comparison was conducted on geographical plots about which both Forest Base Map and Collect Earth data existed, that is, 25,122 plots out of 25,279 plots of Collect Earth data for PNG. The process further concentrated on the targeted land use class, Forest, for which 19,743 plots existed in the Forest Base Map and 19,292 plots in Collect Earth.
- In the full DD Driver analysis, areas within 5 km from Census Unit were marked as areas possibly affected by wood collection. However, for this assessment, wood collection is included into intact forest since impact of disturbance is presumed to be limited.
- Impact type in the Collect Earth data is determined by interpretation of satellite imagery. The Forest Base Map determines some drivers, such as Gardening, by inference (e.g. proximity to settlements), not actual image interpretation.



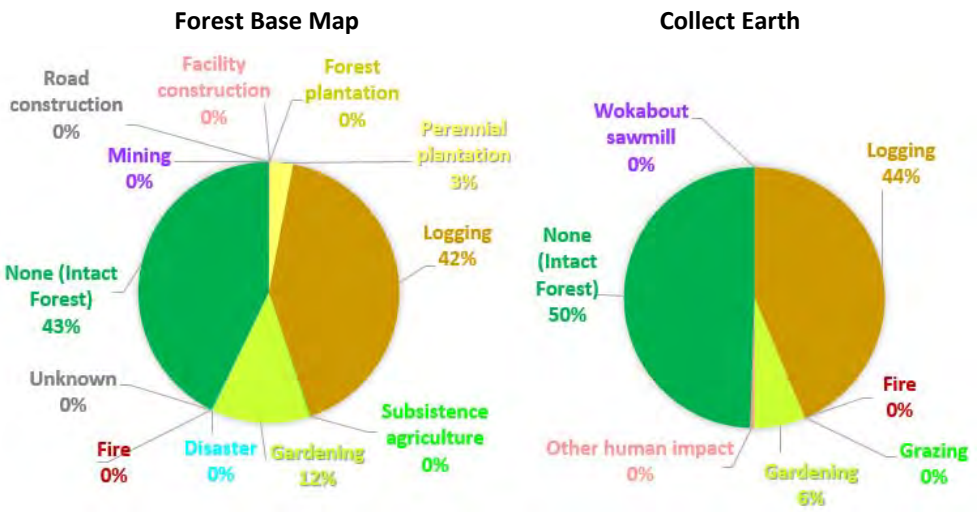
DD driver and impact type distribution (PNG)



DD driver and impact type composition (PNG)



DD driver and impact type distribution (WNB)

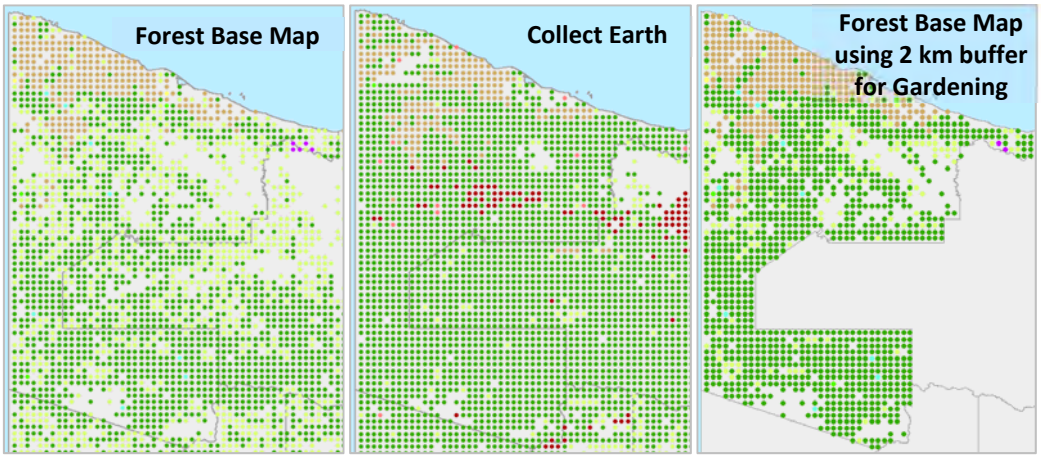


DD driver and impact type composition (WNB)

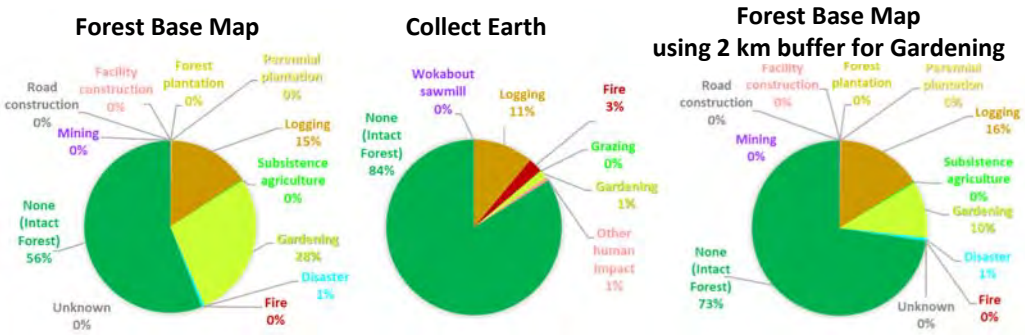
Box: Trial-basis adjustment in Garden driver parameters using WSP data

The cause of the prevalence of areas affected by Gardening as a DD driver in the Forest Base Map, immediately noticeable upon comparison with Collect Earth data, was investigated through a trial-basis adjustment of buffer distance used in the detection of the Gardening driver.

Under the original methodology, Hansen Loss polygons 20 ha or smaller and within 5 km from Census Unit was assigned to the Gardening driver, drawing from studies and discussion on general scale of degradation (see **section (1)** above). However, on a trial basis, the buffer distance of 2 km was applied to WSP data.



DD driver and impact type distribution (WSP)



DD driver and impact type composition (WSP)

3-5. Discussion and lessons learned in developing forest degradation drivers

The Project team designed a methodology of DD Driver analysis that makes possible a wall-to-wall mapping of the drivers of deforestation and forest disturbance in PNG. **This methodology maps DD drivers to FMU and allows the monitoring of the dynamic state of forests.**

In the methodology described in chapter 3-4, forest disturbance is recorded either as present or absent in an FMU, a binary value (i.e. either black and white, and no shades of grey). If desired, it is possible to capture the level of disturbance (i.e. the shades of grey) by analyzing the ratio of Hansen Loss areas in an FMU in future analyses.

The methodology can be applied to past forest cover map data, but care must be taken when comparing across years and datasets. As shown in the analysis of past Forest Cover Maps of WNB and WSP, care should be taken in noting, and accounting for, for limitations in data in the interpretation process. Data limitations may translate to fewer types of identifiable DD drivers, and thus the absence of certain drivers purely as an artefact of methodology.

Overall the results of DD Driver analysis carried out by the Project team and impact data provided by Collect Earth (CE) corroborated each other. **Notable characteristics of the Forest Base Map that may be better understood through the comparative analysis are:**

- The ratio of area classified as intact (primary) forest, versus total area, is smaller in the Forest Base Map, compared to CE data. This is due to **the wall-to-wall and binary nature of the Forest Base Map dataset**; FMUs containing any amount of forest loss was classified as degraded area.
- Logging as a DD driver accounted for about the same ratio of forest degradation in both datasets. Fire accounts for a much smaller amount of forest degradation in the Forest Base Map compared to CE; due to the difficulty in identifying the Fire driver in the methodology used by the Project team.
- Gardening was identified as a much larger DD driver in the Forest Base Map, compared to CE data. This is because small patches of Hansen Loss areas, which were not classified to preceding drivers in the methodology flowchart, and located within 5 km from a Census Unit, were classified to Gardening. Due to the wall-to-wall nature of the Forest Base Map, an FMU containing even small patches of disturbed area by Gardening is indicated as non-intact, non-primary forest in the DD Driver analysis. It should be understood that **FMUs marked as 'disturbed by gardening' in the Forest Base Map is not an area that is entirely turned into a garden, but rather, a forest area that contains disturbance by gardening activities**.

- Due to concerns that the initial methodology may have led to over-emphasis of Gardening as a DD driver, the Project team experimented with changing the buffer distance from 5 km to 2 km from a Census Unit. Even with distance set to 2km, Gardening still shows up as a driver of degradation over a much larger area, compared to CE data; the key lesson learned is that **care should be taken when using buffer analysis**. It should be noted, however, that there is also a possibility that CE data under-estimates Gardening as a driver, and that further analyses are necessary to solve the discrepancy.
- In such further analyses, it is also possible to adjust buffer distance by population size, region, landform, or other factors that may affect migration length. To determine the best methodology for detecting Gardening as a DD driver, a trial-and-verification process, where detection methods are verified by manual identification of Gardening based forest degradation for sample areas, may need to be conducted in the future.
- The Project team utilized Hansen Loss data in the analysis of DD drivers. This choice led to more areas classified as disturbed in comparison with other datasets such as Collect Earth, as Hansen Loss also captures naturally produced gaps, such as a fallen tree caused by wind.

An understanding of these characteristics of data and methodology is necessary for the appropriate use of the Forest Base Map. With such understanding, the Forest Base Map is already useful in identifying a mass of intact (primary) forest, estimating timber volume based on type of disturbance, and obtaining other meaningful information for forest management and the planning of logging activities. The DD Driver analysis was only a trial assessment preceding a full quantitative assessment; discussions and lessons derived are hoped to contribute to the development of better methods of forest resource data use.

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Annex A. Forest Base Map 2012 (ver.1.1): Forest Base Map 2012 (PNG)

Annex A. Forest Base Map 2012 (ver.1.1): Area of Forest Base Map 2012 (PNG)

Annex A. Forest Base Map 2012 (ver.1.1): Forest degradation driver map of Forest Base Map 2012 (PNG)

Annex A. Forest Base Map 2012 (ver.1.1): Area of forest degradation driver map of Forest Base Map 2012 (PNG)

Annex A. Forest Base Map 2012 (ver.1.1): Forest degradation driver map of Forest Cover Map 2000, 2005, 2005, and 2011 (WNB)

Annex A. Forest Base Map 2012 (ver.1.1): Area of forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WNB)

Annex A. Forest Base Map 2012 (ver.1.1): Forest degradation driver map of Forest Cover Map 2000, 2005, 2005, and 2011 (WSP)

Annex A. Forest Base Map 2012 (ver.1.1): Area of forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WSP)

Annex J. Accuracy assessment of the Forest Base Map

Annex K. Excel tips

Annex L. Driver Interpretation card

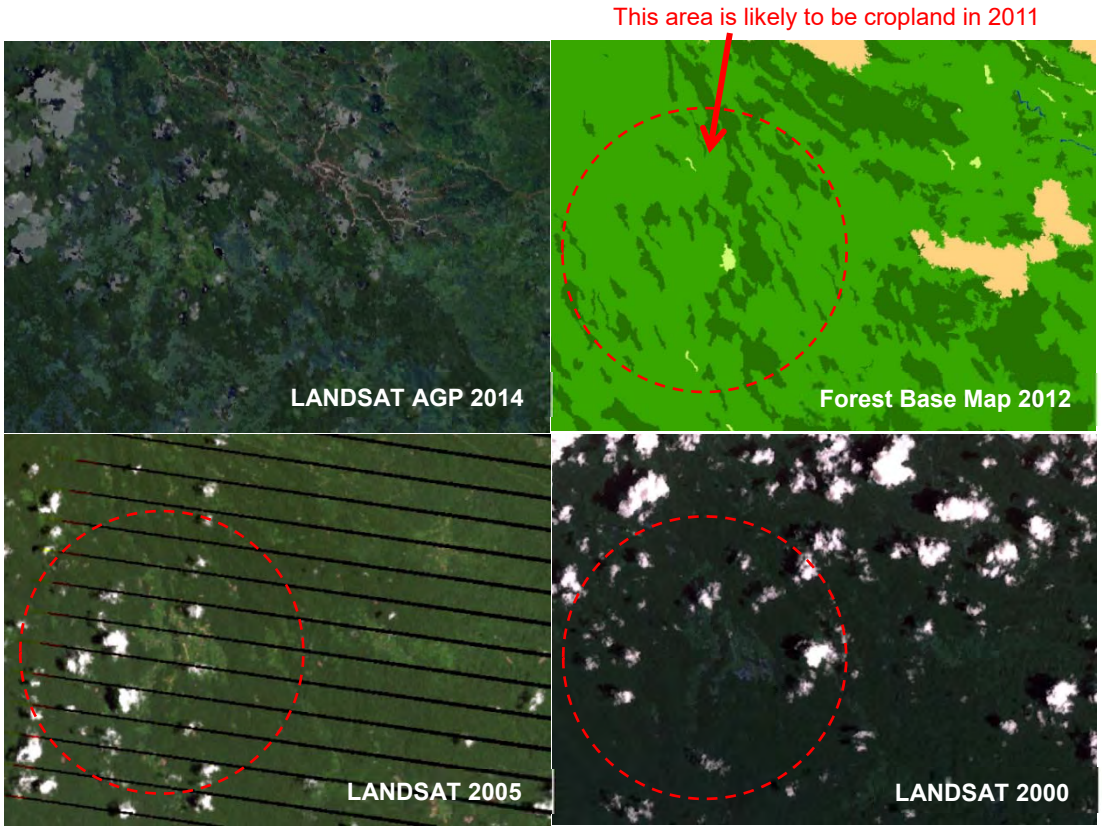
4. Forest Cover Map (Past)

4-1. Process and Methods of developing the Forest Cover Map 2000 / 2005

It is important to figure out where and how much forest resources are for a sustainable forest management. To get handle on the behavior of the forest is useful for a better forestry planning, monitoring and management. The Project team created past forest cover maps (2005, 2000) for two pilot provinces, WNB and WSP, to look into forest situation, say (a) where intact forest is, (b) how degraded forest has recovered, (c) how deforestation or forest degradation has expanded, and (d) if people run cyclic subsistence agriculture or not. Those data also can be useful information for addressing REDD+.

In this activities, past forest cover maps (2005, 2000) were created in order to compare the changes in forest cover over years. However, while reviewing the Forest Base Map with new reference data, we found some misclassifications in the Forest Base Map, and it turned out that it would be difficult to make comparisons over years using the Forest Base Map.

Therefore, while creating the past forest cover map of 2005, the Forest Base Map was revised as well. After completion of the revised Forest Base Map and forest cover map of 2005, forest cover map of 2000 was created.



Data input

- The Forest Base Map 2012
- LANDSAT / LANDSAT AGP: 1990, 2000, 2005, 2010, 2011, 2014
- Hansen gain / loss / lossyear data 2001-2014
- Old FIMS vegetation
- Logged over area
- Mining, Google Earth, etc.
- SRTM 30 (Slope)

Forests and other land use code

	Code	Description	Note
	P	Low altitude forest on plains and fans – below 1000 m	Slope ≦ 6
	H	Low altitude forest on uplands – below 1000 m	Slope ＞ 6
	L	Lower montane forest – above 1000 m	
	Mo	Montane forest – above 3000 m	
	B	Littoral forest	
	D	Dry seasonal forest	
	Fri	Seral forest	
	Fsw	Swamp forest	
	M	Mangrove forest	
	W	Woodland	
	Sa	Savanna	
	Sc	Scrub	
	G	Grassland and herbland	
	Ga	Alpine grassland – above 3200 m	
	Gi	Subalpine grassland – above 2500 m	
	O	Cropland/Agriculture land	
	Qa	Plantation other than forest plantation	
	Qf	Forest plantation	
	Z	Bare areas	
	U	Larger urban centres	
	E	Lake & larger rivers	
	Es	Sea (outside land)	

Procedure

Here, work procedures are shown by taking WNB province as an example.

1. Data preparation

- In ArcCatalog, copy the Forest Base Map file geodatabase (21_WNB.gdb in 7_Bmapv11_fmu) in the work folder.

  ** This will be used for creating past forest cover maps.*

- Copy the Forest Base Map feature class (WNB_ForestBaseMap) in the copied Forest Base Map file geodatabase (21_WNB.gdb), and rename it as "WNB_ForestCover_2005_00_11".

2. Preparation in ArcMap

- Open ArcMap, and add the following data.

  - The copied Forest Base Map (WNB_ForestBaseMap)
  - The past forest cover map to be edited (WNB_ForestCover_2005_00_11)
  - LANDSAT AGP in 1990, 2000, 2005, 2011, and the latest year for the target area
  - LANDSAT imagery in 1990, 2000, 2005, 2011, and the latest year for the target area
  - Hansen loss year, loss and gain
  - Old FIMS vegetation target area (All_PNG_Veg_region)
  - Concession (LandUse_NotLogged_Current, Logged_LandUse_Current, Logged_NotLandUse_Current, and ConcessionArea)
  - Slope (Slope_strm30_z55.tif)
  - Driver related data such as mining, road, etc.
  - Province (Province_2014_single)

- Set symbols of each layer. Suggested settings of symbols are listed below.

  - For "WNB_ForestCover_2005_00_11", import symbology from layer (ForestBaseMap_ver1.1_code.lyr)
  - Loss from 2001 to 2005, loss from 2006 to 2011 and loss after 2012 by using Hansen lossyear
  - Only land use area (O, Qa, Qf, Z and U) and grassland area (G, Ga and Gi) by using the Forest Base Map

- Add Three fields for past land use and revised land use 2011 in the attribute table of the past forest cover map (WNB_ForestCover_2005_00_11).

  Field name: lu11, lu05, lu00

  Field type: Text

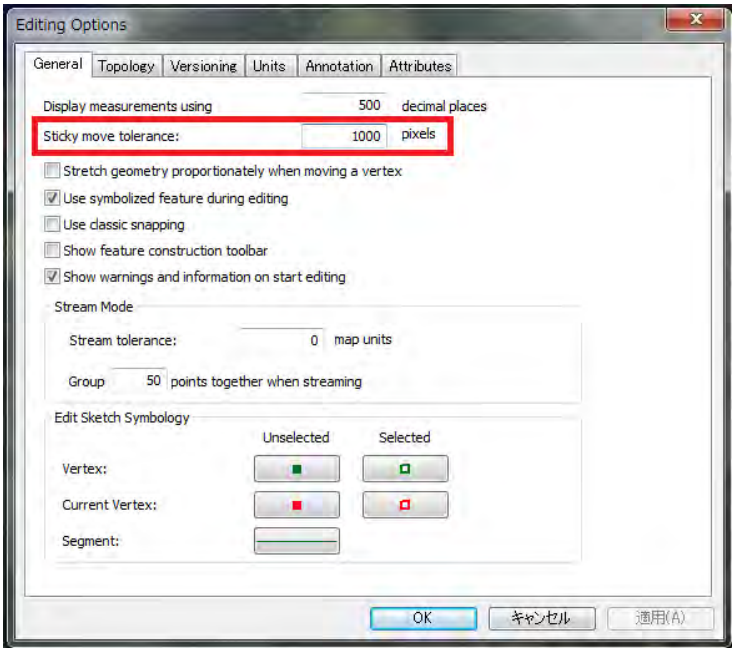
  Field length: 12

- Copy records of original land use in 2011 from “Landuse” field into “lu11” and “lu05” field.
- Fix the move tolerance to avoid moving the existing polygon (Tip 1).
- Fix the visible fields to show only the fields to be edited (Tip 2).

<Tip 1: How to fix the sticky move tolerance >

To avoid moving polygons, sticky move tolerance should be fixed before editing.

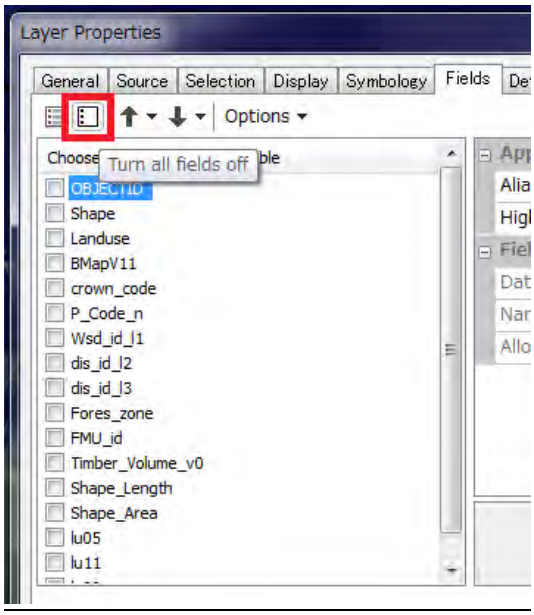
1. Left click on the “Editor” to open “Editing Options”.
2. Adjust “Sticky move tolerance” to more than 1000 pixels (the larger the number, the lower the risk of moving polygon), and click “OK”.



<Tip 2: How to show only the fields to be edited>

To avoid misinputs, it is better to hide the fields you are not editing.

1. Left click on the layer you are editing (WNB_ForestCover_2005_00_11) to open "Layer Properties".
2. On the "Fields" property, click "Turn all fields off" and then pick the fields you want to edit (ex. "lu05", "lu11". DO NOT turn on the "Landuse" field.).



3. Click "Apply" and then "OK".

3. Editing

- Refer to 2005 LANDSAT imagery, and cut the polygon at the area of changes bigger than about 1ha, and add its attribute (landuse code) in the "lu05" field. For detecting changes, also refer to the imagery of other years, Hansen lossyear, and concession layer, etc.
- If any obvious misclassification is found for 2011 Forest Base Map, edit "lu11" field.
- Typical changes are changes from forest (P~Sc) and grassland (G~Gi) to Cropland (O), Plantation (Qa, Qf) and other land used (Z, U), and from forest (P~Sc) to grassland (G~Gi). You can edit for the changes from glassland to forest if there are any, but this is expected to be rare. That is to say, you look at the whole area, but should especially pay attention to the cropland, plantation, and other land use area (O~U) in the Base Map, and confirm

how it was used in the past.

- Hansen data can be useful to find the changed area, although note that the loss and gain is also repeated inside the plantation.
- For the land use classification, refer to the texture of land use at the surrounding area. However, since “H” and “P” cannot be classified based on the texture, refer to the slope data. If a range of area with slope steeper than 6 is large within the target polygon, it should be “H”, and if it is most of the area is slope 6 or less, it should be “P” (also refer to the classification of surroundings).
- After completing 2011 base map and 2005 cover map, copy records of land use in 2005 from “lu05” field into “lu00” field. Create 2000 cover map by adding attributes to “lu00” field.

Matters to consider:

- ✓ Changes that are obvious in 1:50,000 scale is targeted.
- ✓ Zoom in when cutting or editing the polygons, because shape of some polygons is sometimes unexpected.
- ✓ If the shape of changed area is similar to FMU boundary, just add past land use code since many tiny polygons are not preferable. Do not mind the slight difference in shapes.
- ✓ Do not change the “lu11” field, unless the existing classification is obviously wrong.
- ✓ Some area is hardly visible. Ignore the area you are not sure about.
- ✓ Keep the consistence over year (ex. changes like “cropland→forest→cropland” is unlikely to happen).
- ✓ Logging road and forest degradation can be ignored. They are edited in another layer.
- ✓ NEVER merge polygons. Each polygon has their own ID and consistency is lost by merging them.

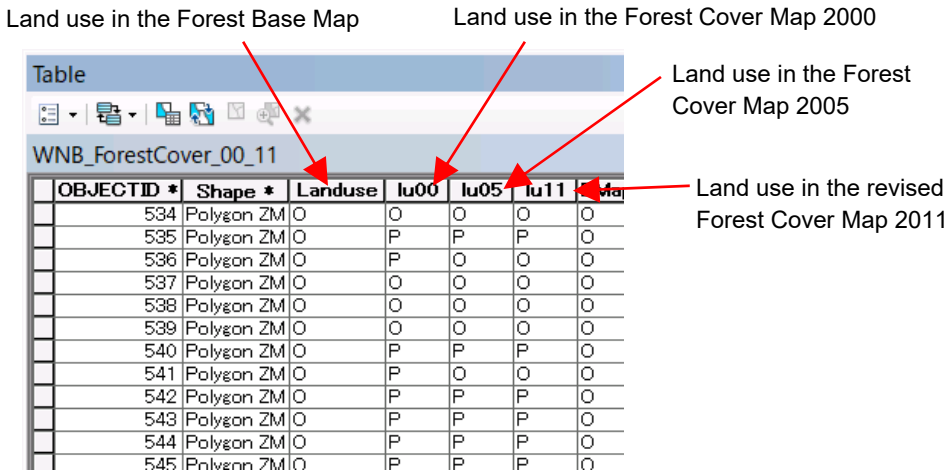
Outputs of the Forest Cover Map 2010, 2005 and 2011 (revised ver.) are shown in **Annex B**.

4-2. Forest cover change between 2000 - 2011

Forest cover change between 2000 - 2011 was figured out using created Forest Cover Map 2000 and 2005, and revised Forest Cover Map 2011.

Procedure

The past Forest Cover Maps were developed/managed in one file for each province in PNG-FRIMS database, so that the file contains all information of the past Forest Cover Maps.



OBJECTID *	Shape *	Landuse	lu00	lu05	lu11	Ma
534	Polygon ZM	O	O	O	O	O
535	Polygon ZM	O	P	P	P	O
536	Polygon ZM	O	P	O	O	O
537	Polygon ZM	O	O	O	O	O
538	Polygon ZM	O	O	O	O	O
539	Polygon ZM	O	O	O	O	O
540	Polygon ZM	O	P	P	P	O
541	Polygon ZM	O	P	O	O	O
542	Polygon ZM	O	P	P	P	O
543	Polygon ZM	O	P	P	P	O
544	Polygon ZM	O	P	P	P	O
545	Polygon ZM	O	P	P	P	O

1. Export the attribute table of the past Forest Cover Maps to .dbf file.
2. Make a table from the exported .dbf file to compare land use among 2000, 2005, and 2011 using PivotTable function in Excel.

Outputs of the Forest Cover change between 2000 - 2011 are shown in **Annex B**.

4-3. Issues found in the past Forest Cover Map and way to address them

In this section, we describe (i) issues and points to keep in mind found in the past Forest Cover Map, (ii) how the Project tackled them during the course of the Project activities, and (iii) future possible works toward improvements.

The Project team found the following issues through the process of developing the past Forest Cover Map based on the Forest Base Map 2012.

(a) Misclassifications of Cropland/Agriculture land (O) in the Forest Base Map

It was revealed that The Forest Base Map, which was used to create the past Forest Cover Maps, has some misclassifications due to the limitations of data and technique at that time. In particular, there were many places where Cropland/Agriculture land (O) could not be extracted. Therefore, revising the Forest Base Map was required before creating the past Forest Cover Maps to compare areas between the maps.

In the Project activities, the revised forest cover maps in 2011 were created from the Forest Base Map by reviewing multiple-year satellite imagery, LANDSAT AGP and Google Earth data for WNB and WSP Provinces. After that, the Forest Cover Maps in 2005 and 2000 were created based on the revised forest cover maps in 2011.

(b) Distinguishing Forest plantation (Qf) and Plantation other than forest plantation (Qa)

When developing the Forest Base Map, Forest plantation (Qf) was distinguished from Plantation other than forest plantation (Qa)' with reference to plantation boundaries data owned by PNGFA. It was turned out that Forest plantation (Qf) indicated on the maps are not necessarily corresponding to the actual distribution of forest plantations since PNGFA does not have every boundary data of forest plantations up to this time. Therefore, it is necessary to keep in mind that area of forest plantations in the Forest Base Map and the past Forest Cover Maps do not necessarily become the same as the statistical data treated in Plantations branch.

PNGFA is moving forward with updating GIS data of forest plantation. Once the forest plantation data is in place, the data could be used to update the forest cover maps. It is important for Inventory & Mapping branch and Plantations branch to cooperate and to build a system to work on continuously updating forest plantation data, and then to utilize the accumulated forest plantation data when creating a forest cover map in the future.

(c) Limitations of satellite imagery and other related data of the past

The Project team found that it is more difficult to create a map in past because conditions and resolutions of satellite imagery are worse, data and information to be used are limited, and we can not verify land use type on site.

Reference

Annex B. Forest Cover Map (Past): Forest Cover Map 2000, 2005, and 2011 (WNB)

Annex B. Forest Cover Map (Past): Area of Forest Cover Map 2000, 2005, and 2011 (WNB)

Annex B. Forest Cover Map (Past): Map of forest cover change between 2000 - 2011 (WNB)

Annex B. Forest Cover Map (Past): Area of forest cover change between 2000 - 2011 (WNB)

Annex B. Forest Cover Map (Past): Forest Cover Map 2000, 2005, and 2011 (WSP)

Annex B. Forest Cover Map (Past): Area of Forest Cover Map 2000, 2005, and 2011 (WSP)

Annex B. Forest Cover Map (Past): Map of forest cover change between 2000 - 2011 (WSP)

Annex B. Forest Cover Map (Past): Area of forest cover change between 2000 - 2011 (WSP)

5. Forest Cover Map 2015

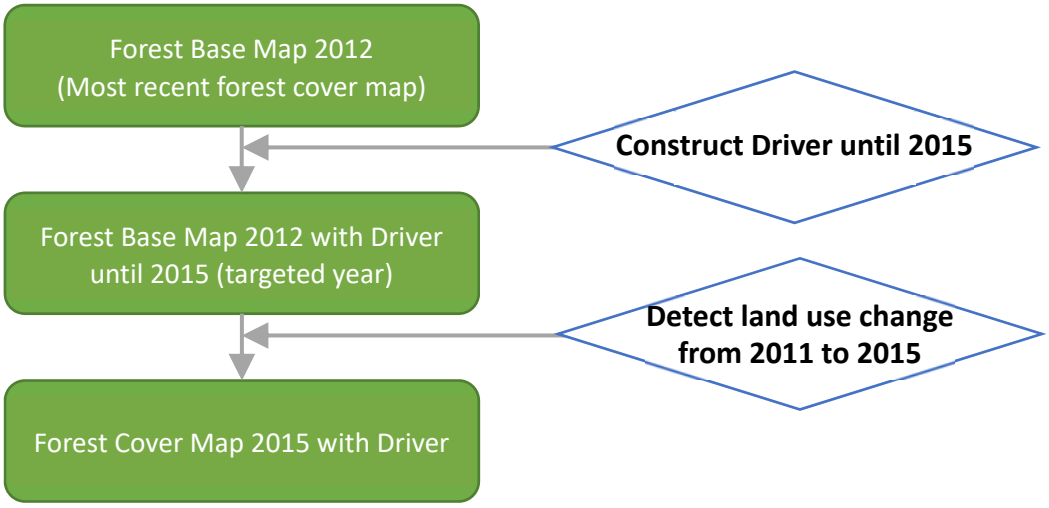
5-1. Process and Methods of developing the Forest Cover Map 2015

Regularly updating the forest cover maps of the whole country is effective for monitoring secular change of forest resource in PNG. Although national report of PNG is submitted to the United Nations Framework Convention on Climate Change (UNFCCC) based on the analysis of the Collect Earth system, the forest cover maps in 2015 and subsequent years are still useful for verification of Reference Emission Level (REL)/Forest Reference Emission Level (FREL) and development of national forest strategy, climate change control targeting and road map for REDD+. On the assumption that the forest cover maps will be updated at five-year interval, a method for updating forest cover maps was developed with consideration of giving consistency to a series of maps. It is based on a method of creating past forest cover maps and of constructing deforestation and forest degradation information into forest cover maps.

In this activities, Forest Cover Map 2015 was created from the Forest Base Map 2012, based on the forest degradation and forest cover gain. Forest Monitoring Unit (FMU) was revised for the area of Large-scale forest loss (Hansen loss 20 ha or larger) after 2011, which was applied to Land Use, Land Use Change and Forestry (LULUCF). For the area of smaller scale forest loss (Hansen loss smaller than 20 ha) after 2011, FMU was revised only when the extension of the area of degraded strata was confirmed on the imagery. Other minor forest loss information was added to the map as disturbance. Area with obvious forest recovery was also revised referring to Hansen gain data larger than 1 ha.

Method

The method of developing the Forest Cover Map 2015 consists of two parts: **(1) Driver construction** and **(2) land use change detection**. The method of Driver construction is basically the same as the method of developing forest degradation drivers of forest cover map in **chapter 3-4**, while the method of land use change detection is basically the same as the method of developing the Forest Cover Map 2000/2005 in **chapter 4-1**.



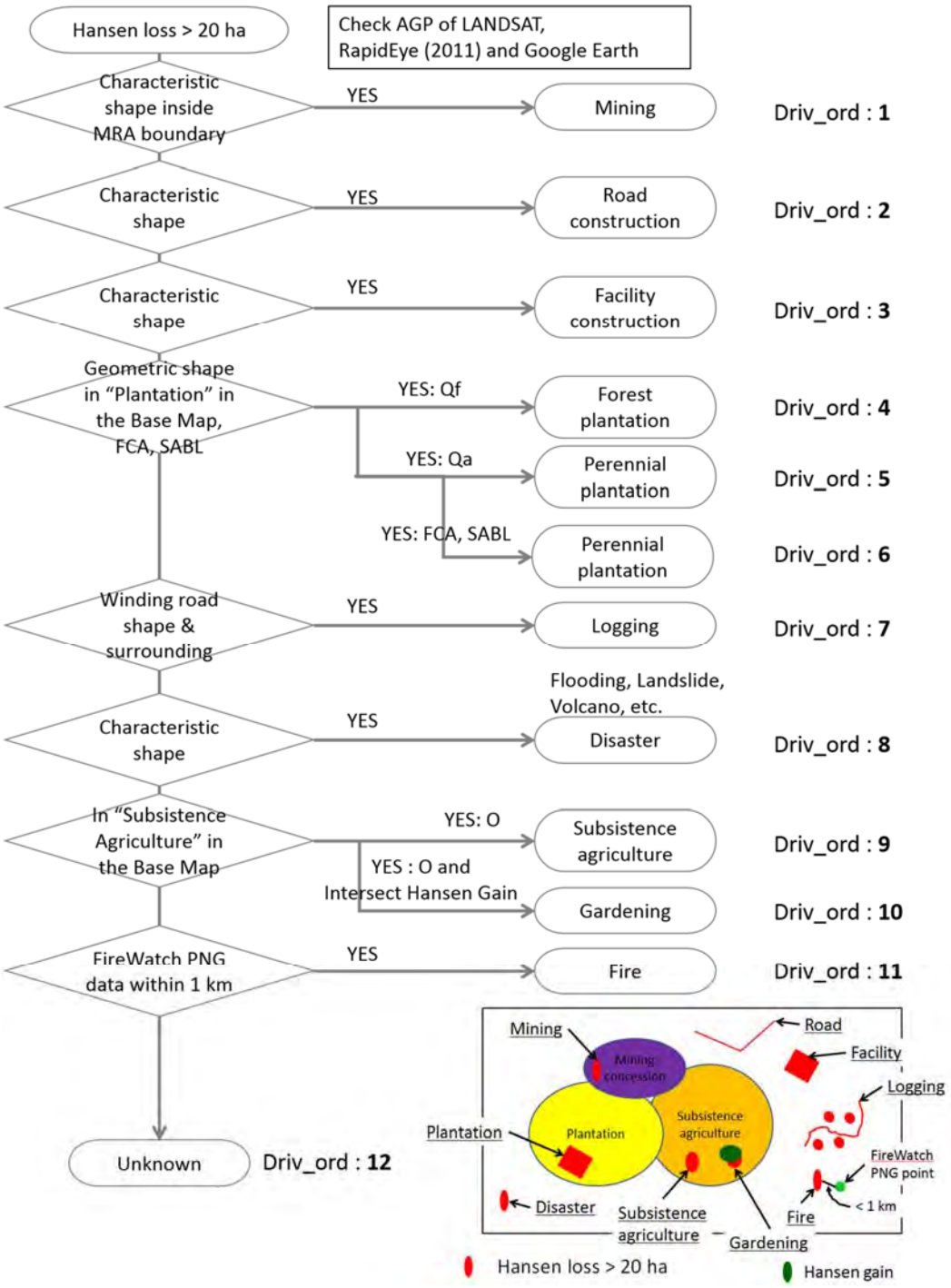
The definitions of DD drivers were used in combination with available satellite imagery and other data to analyze forest area changes and their drivers, based on presence or absence of Hansen Loss polygon and its size.

DD drivers for Hansen Loss polygons larger than 20 ha in targeted years **2001-2014** were identified by visual observation utilizing LANDSAT imagery, RapidEye Imagery (2015), and Google Earth.

The drivers were identified using the key-out method according to the rules shown in the **flowchart (a)**. Using this method, drivers are exclusive to each other, and multiple operators will identify the same driver for the same deforestation area.

The description of the DD driver (e.g. “Mining”) was added to each FMU of **the Forest Base Map**.

(a) Flowchart of driver analysis for Hansen Loss polygons larger than 20 ha

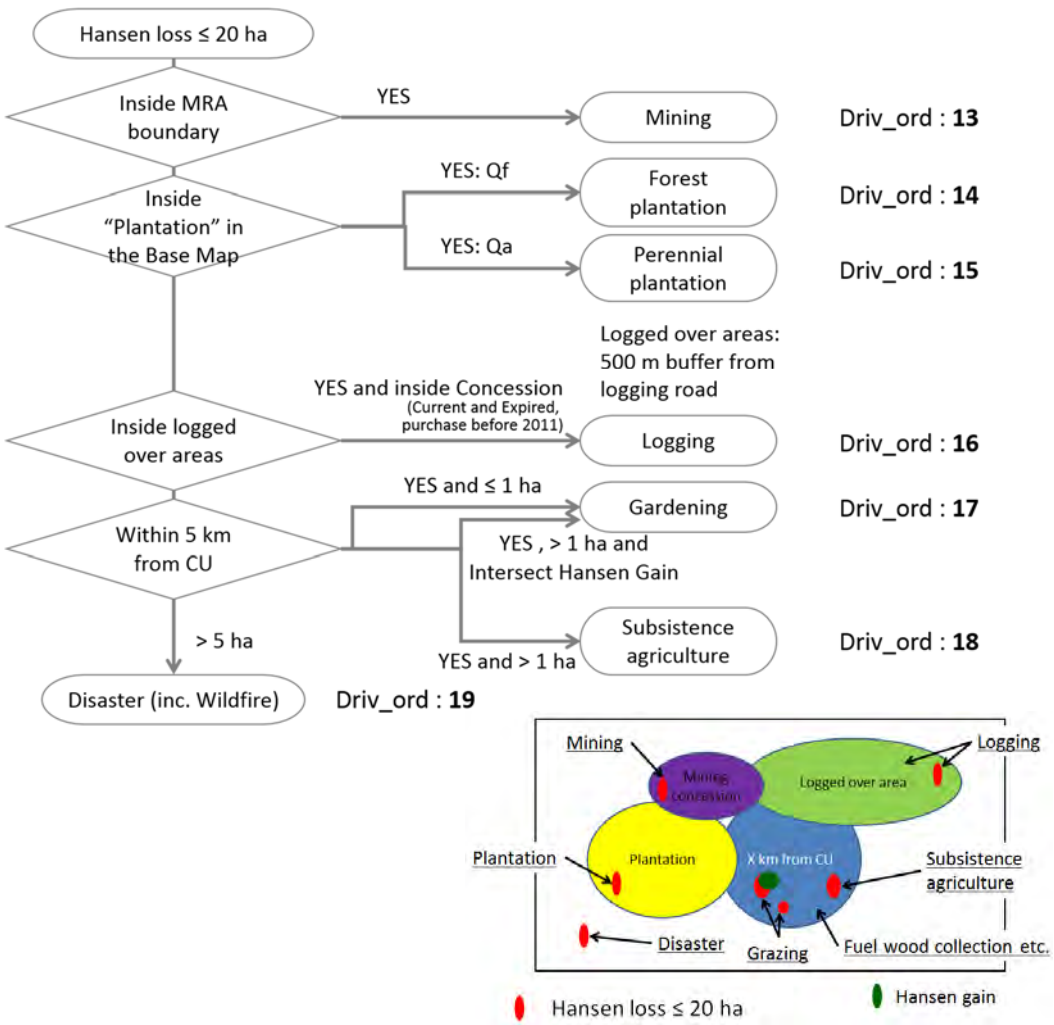


The Hansen Loss polygons 20 ha or smaller in targeted years **2001-2014** were automatically classified to DD driver using GIS data.

The drivers were identified according to the rules shown in the **flowchart (b)**.

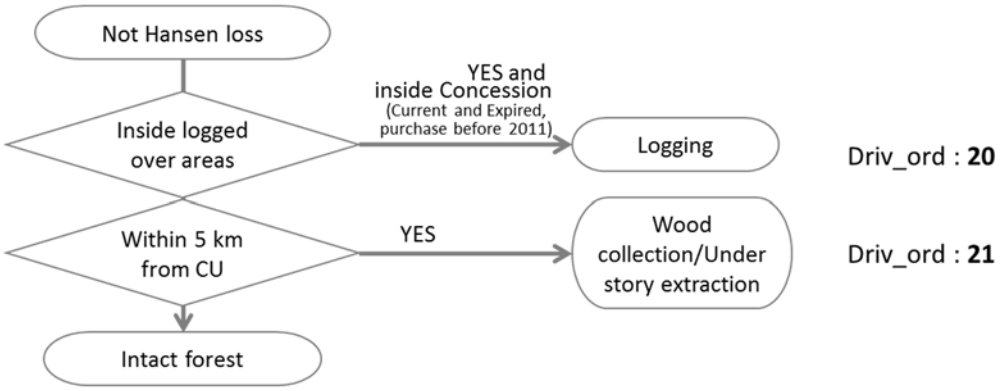
The description of the DD driver (e.g. "Mining") was then added to each FMU of the Forest Base Map. The identification of drivers of Hansen Loss polygons larger than 20 ha (see **flowchart (a)** above) was conducted earlier, chronologically. When a FMU overlapped with two or more Hansen Loss polygons, the driver identified and entered earlier was prioritized.

(b) Flowchart of driver analysis for Hansen Loss polygons 20 ha and smaller



Following the above steps, each remaining FMU polygon that indicated change in Land use class/ strata pointing to DD, but without driver information from Hansen Loss, was analyzed according to the **flowchart (c)**, and its driver information was added to FMU directly.

(c) Flowchart of driver analysis for map polygons which do not intersect Hansen Loss



Procedure

(1) Driver construction

Drivers are developed in a forest cover map in accordance with the following steps.

Step 1: Data preparation

- To collect and arrange all needed data to be used for DD analysis

Step 2: Identify drivers of large Hansen Lossyear polygons (> 20 ha)

- To identify drivers of Hansen Lossyear polygons larger than 20 ha for whole nation by image interpretation in accordance with flowchart (a) above

Step 3: Identify drivers of small Hansen Lossyear polygons (<= 20 ha)

- To identify drivers of Hansen Lossyear polygons 20 ha and smaller than 20 ha by each province by GIS analysis in accordance with flowchart (b) above

Step 4: Merge Hansen Lossyear polygons for each province

- To merge two of Hansen Lossyear polygons identified drivers in step 2 and step 3 by each province

Step 5: Input driver for each FMU

- To input driver in an attribute table of the forest cover map for each FMU using Hansen Lossyear polygons in step 4

Step 6: Input driver for each FMU without Hansen Loss

- To identify driver using some data without Hansen Lossyear polygons for each FMU

Step 7: Input driver by join table

- To complete developing driver in the attribute table to input driver name, since only driver number (Driv_ord) is used in the steps above

1. Data preparation

1-1. Prepare the following data.

Data	Work folder	File name
Forest Cover Map 2015	¥02_ana¥21_WNB.gdb (copy the Forest Base Map, "XXX_ForestBaseMap". For WNB, copy the revised version, "WNB_ForestCover_00_11"	WNB_**ForestCover_15**
Hansen lossyear	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_clp_z55.shp
Province boundary	42_Boundary¥Province_updated2014	Province_2014_z55.shp

* Work folder of the operation: 31_ForestMap¥tmp_works_dd

1-2. Prepare the following reference data necessary for identifying drivers.

Reference data	Work folder	File name	For use in	
			Step 2	Step 3
Mining	¥01_data_arg¥Mining	ML_06May_merge_utm55.shp	Yes	Yes
Forest plantation (Qf) polygon in the Forest Base Map	¥01_data_arg¥FBM_Qf_Qa¥21_WNB	WNB_FBMrev_Qf_Qa.shp * For WNB, use the revised version	(Yes)	Yes
Plantation other than forest plantation (Qa) polygon in the Forest Base Map			(Yes)	Yes
FCA and SABL polygon	¥01_data_arg¥FCA ¥01_data_arg¥SABL	FCA_mer_utm55.shp SABL_utm55.shp	Yes	
Subsistence agriculture (O) in the Forest Base Map	¥01_data_arg¥FBM_O¥21_WNB	WNB_FBMrev_O.shp * For WNB, use the revised version	(Yes)	

500 m buffer from logging road (2000, 2000-2005, 2005-2011, **2011-2015**)	¥01_data_arg¥LoggingRoad¥21_WNB	Road**2015**_WNB_500mbuf_sng * Need roads adjacent to the target province		Yes
Concession (Current and Expired, purchase before **2014**)	¥01_data_arg¥Concession	ConcessionArea_Cur_Exp_**2015**_z55.shp		Yes
5 km buffer from CU	¥01_data_arg¥CU¥04_fin	CU_5kmbuf_mer_sng_z55.shp		Yes
Hansen Gain	¥01_data_arg¥Hansen_gain	hansen_gfc2015_gain_z55.shp	Yes	Yes
FireWatch PNG	¥00_data_org¥FireLocation¥cartodb-query	cartodb-query.shp	Yes	

*Data of 500 m buffer from logging road is created by adding 500 m buffer to the original road line data.

*For 2015, concession area of 2011 can be used since no new concession area has been developed after 2011. If new area is developed in the future, use the shapefile including the area.

1-3. Prepare the following image data necessary for interpreting drivers.

Reference data	Work folder	File name	For use in	
			Step 2	Step 3
Forest Base Map (Tiff)	31_ForestMap¥ver.1¥7_Bmapv11_tiff		Yes	
RapidEye imagery	01_Satellite¥RapidEye_2010¥06_mosaic¥Mosaic.gdb		Yes	
Landsat imagery	01_Satellite¥LANDSAT_XXXX		Yes	
Annual Greenest Pixel Landsat imagery	01_Satellite¥Annual_Greenest_Pixel¥GeoTIFF¥TOA		Yes	

2. Identify Drivers of large Hansen Lossyear polygons (> 20 ha)

Driver analysis of large polygons will be done **for whole nation** at once.

2-1. Open ArcMap, and add the following data.

- Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp")
- MRA boundary ("ML_06May_merge_utm55.shp")
- FCA boundary ("FCA_mer_utm55.shp")
- SABL boundary ("SABL_utm55.shp")
- Hansen gain ("hansen_gfc2015_gain_z55.shp")
- Fire Watch PNG data ("cartodb-query.shp")
- Forest Base Map
- RapidEye imagery in 2011
- LANDSAT imagery in 2000, 2005, 2011, and 2015

2-2. From Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp"), select polygons that are larger than area of 20 ha using *Select by Attribute*, and export selected features as "hansen_gfc2015_lossyear_20ha_z55.shp".

Data	Work folder	File name
Hansen lossyear	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_clp_z55.shp
Hansen lossyear (>20 ha)	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_20ha_z55.shp

2-3. Add field named "**Driv_ord**" (data type: long) to "hansen_gfc2015_lossyear_20ha_z55.shp".

2-4. For each polygon of "hansen_gfc2015_lossyear_20ha_z55.shp", input the driver order number to the "Driv_ord" field according to the following steps by reference to **flowchart (a)**.

Refer to LAMDSAT AGP, RapidEye (2011), Google Earth data for the analysis.

Also refer to "Driver interpretation card" (**Annex L**).

Driv_ord	Driver
1	Mining
2	Road construction

3	Facility construction
4	Forest plantation
5	Perennial plantation
6	Perennial plantation (2)
7	Logging
8	Disaster
9	Subsistence Agriculture
10	Gardening
11	Fire
12	Unknown

1) When the Hansen lossyear polygon ("hansen_gfc2015_lossyear_20ha_z55.shp") is inside **MRA boundary** ("ML_06May_merge_utm56.shp") and a huge deforested area connected with road is visible on the imagery around the polygon area, enter **1** in the "Driv_ord" field.

2) If not 1), and the polygon has a characteristic long and narrow shape representing **roads**, enter **2** in the "Driv_ord" field.

3) If not 2), and the **town or airport** is visible on the imagery around the polygon area, enter **3** in the "Driv_ord" field.

4) If not 3), and the polygon is inside **"Forest plantation" (Qf)** of the Forest Base Map, and has a geometric shape, enter **4** in the "Driv_ord" field.

5) If not 4), and the polygon is inside **"Perennial plantation" (Qa)** of the Forest Base Map and has a geometric shape, enter **5** in the "Driv_ord" field.

6) If not 5), and the polygon is inside **FCA** ("FCA_mer_utm55.shp") or **SABL** ("SABL_utm55.shp"), and has a geometric shape, enter **6** in the "Driv_ord" field.

   * It should be classified as Perennial plantation for now, because the actual substance of FCA and SABL cannot be known. However distinguish from the Perennial Plantation (2) classified by the Forest Base Map Qa, because in the future it might became possible to classify them.

7) If not 6), and the polygon has a **winding road** shape or surrounding, enter **7** in the "Driv_ord" field.

8) If not 7), and the polygon has a characteristic shape that is caused by **flooding, landslide and volcano**, enter **8** in the "Driv_ord" field.

9) If not 8), and the polygon is inside the **"Substance agriculture" (O)** of the Forest Base Map, enter **9** in the "Driv_ord" field.

10) Select **"Substance agriculture"** polygons ("Driv_ord" = 9), and for those polygon intersects **Hansen gain** ("hansen_gfc2015_gain_z55.shp") using *Select Layer by Location*, enter **10** in the "Driv_ord" field.

    *Make sure to change the selection type to "Subset selection" when using *Select Layer by Location*.

11) If not 10), and the polygon is **inside 1 km buffer** from the **Fire Watch PNG** data ("cartodb-query.shp"), enter **11** in the "Driv_ord" field.

    *For 11) make sure the year of fire match with the year of Hansen loss.

12) If not 11) enter 12 in the "Driv_ord" field.

2-5. From "hansen_gfc2015_lossyear_20ha_z55.shp", select changes for each province. Use *Select Layer by Location* to select polygons intersect each selected province ("Province_2014_z55.shp"), and export selected features as "WNB_2015_lossyear_20ha_s56.shp".

Data	Work folder	File name
Hansen lossyear (>20 ha) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_2015_lossyear_20ha_s56.shp

2-6. Change the projected coordinate system accordingly to the following table.

No.	Province	Coordinate	No.	Province	Coordinate
01	WES	S54	12	SIM	S55
02	GUL	S54	13	EHP	S55
03	CEN	S55	14	MOR	S55
04	NCD	S55	15	MAD	S55
05	MIL	S55	16	ESP	S55
06	ORO	S55	17	WSP	S54
07	SHP	S54	18	MAN	S55
08	HLA	S54	19	NIP	S56
09	ENG	S54	20	ENB	S56
10	WHP	S54	21	WNB	S56
11	JIW	S54	22	ARB	S57

3. Identify Drivers of small Hansen Lossyear polygons (<= 20 ha)

Driver analysis of small polygons will be done **by each province**.

3-1. Open ArcMap, and add the following data.

- Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp")
- Province boundary ("Province_2014_z55.shp")
- 5 km buffer from Census Unit ("CU_5kmbuf_mer_sng_z56.shp")
- Hansen gain ("hansen_gfc2015_gain_z56.shp")
- Logged over areas ("Road2015_WNB_500mbuf_sng")
- Concession area ("ConcessionArea_Cur_Exp_2015_z56.shp")
- "Forest plantation" area of the Forest Base Map ("WNB_FBMrev_Qf_Qa.shp")
- MRA boundary ("ML_06May_merge_utm56.shp")

3-2. From Hansen lossyear shapefile ("hansen_gfc2015_lossyear_clp_z55.shp"), select polygons that are 20 ha or smaller using *Select Layer by Attribute*, and export selected features as "hansen_gfc2015_lossyear_0_20ha_z55.shp".

3-3. From "hansen_gfc2015_lossyear_0_20ha_z55.shp", select changes for each province. Use *Select Layer by Location* to select polygons intersect each selected province ("Province_2014_z55.shp"), and export selected features as "WNB_2015_lossyear_0_20ha_s56.shp".

*Make sure to change the projected coordinate system accordingly to each province.

3-4. Add field named "**Driv_ord**" (data type: long) to "WNB_2015_lossyear_0_20ha_s56.shp".

Data	Work folder	File name
Hansen lossyear (0-20 ha)	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_0_20ha_z55.shp
Hansen lossyear (0-20 ha) in Province	¥01_data_arg¥Hansen_Lossyear¥21_WNB	WNB_2015_lossyear_0_20ha_s56.shp

3-5. For each polygon of "WNB_2011_lossyear_0_20ha_s56.shp", input the driver order number to the "Driv_ord" field according to the following steps. The entire flow is visualized in **flowchart (b)**.

*The actual process will start from the bottom of the flow to the top, in order to overwrite the drivers in lower order.

Driv_ord	Driver
13	Mining
14	Forest plantation
15	Perennial plantation
16	Logging
17	Gardening
18	Subsistence agriculture
19	Disaster

1) Input **99** in the "Driv_ord" field of Hansen lossyear polygon ("WNB_2015_lossyear_0_20ha_s56.shp").

2) For the polygon of area **larger than 5 ha** ("area_ha" > 5), enter **19** in the "Driv_ord" field.

3) When the polygon intersects **5 km buffer** from **Census Unit** ("CU_5kmbuf_mer_sng_z56.shp"), enter **18** in the "Driv_ord" field.

4) When 3), and the polygon intersects **Hansen gain** ("hansen_gfc2015_gain_z56.shp"), enter **17** in the "Driv_ord" field (*Select layer by Location*).

   *Make sure to change the selection type to "Subset selection" when selecting the polygon using *Select layer by Location*.

5) When 3), and the polygon is **smaller than 1 ha** ("Driv_ord" = 18 AND "area_ha" <= 1), enter **17** in the "Driv_ord" field.

6) When the polygon intersects **logged over areas** ("Road2015_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2015_z56.shp"), enter **16** in the "Driv_ord" field.

   *Make sure to include the road information of the adjacent province.

   *Make sure to change the selection type to "New selection" before selecting the polygons intersect logged over areas, and change again to "Subset selection" when selecting the polygons intersect concession area using *Select layer by Location*.

7) When the polygon intersects "**Perennial plantation" (Qa)** in the Forest Base Map ("WNB_FBMrev_Qf_Qa.shp"), enter **15** in the "Driv_ord" field.

   *Make sure to change the selection type to "New selection" before selecting the polygons intersect Perennial plantation using *Select layer by Location*.

8) When the polygon intersects **"Forest plantation" (Qf)** in the Forest Base Map ("WNB_FBMrev_Qf_Qa.shp"), enter **14** in the "Driv_ord" field.

9) When the polygon intersects **MRA boundary** ("ML_06May_merge_utm56.shp"), enter **13** in the "Driv_ord" field (*Select layer by Location*).

4. Merge Hansen Lossyear polygons for each province

4-1. Add the following data on ArcMap.

- Hansen lossyear (>20 ha) data for 2001-2014 ("WNB_2015_lossyear_20ha_s56.shp")
- Hansen lossyear (<=20 ha) data for 2001-2014 ("WNB_2015_lossyear_0_20ha_s56.shp")

4-2. Merge two Hansen lossyear data for small and large area ("WNB_2015_lossyear_20ha_s56.shp" and "WNB_2015_lossyear_0_20ha_s56.shp") and export data to analysis folder as "WNB_2015_lossyear_20ha_s56.shp"

Data	Work folder	File name
Hansen lossyear with driver info (2000-2015) in Province	¥02_ana¥21_WNB¥FBM_2015	WNB_**2015**_lossyear_s56.shp

5. Input driver for each FMU

In this step, the driver will be added to each FMU by overlaying Hansen lossyear polygon. For those FMUs including more than two Hansen lossyear polygons, the lower (high priority) value of "Driv_ord" will be applied. For the same value of "Driv_ord", a lossyear polygon with the lowest (former) year takes the priority.

5-1. Add the following data on ArcMap.

- Forest Cover Map 2015 ("WNB_ForestCover_15")
- Hansen lossyear data ("WNB_2015_lossyear_s56.shp")

5-2. Add field named "**kari**" (data type: long) to Hansen lossyear data ("WNB_2015_lossyear_s56.shp").

5-3. Using *Calculate Field*, input number which contains both driver order information and the year of Hansen loss to "**kari**" field.

Equation: **[Driv_ord] * 100 + [GRIDCODE]**

5-4. Select polygons with "kari" field **larger than 9000** ("kari" > 9000), and input **9999** to the selected features.

**Close the Map document and open ArcMap (new Map document) again to avoid ArcGIS bug.*

5-5. Using *Identity*, overlay Hansen lossyear polygon ("WNB_2015_lossyear_s56.shp") and the Forest Cover Map 2015 ("WNB_ForestCover_15") and save outputs to FCM_2015 folder as "WNB_FCM2015_Driv_iden.shp".

*Arc Info license is required for using *Identity*.

Data	Work folder	File name
Forest Base Map overlayed Hansen lossyear	¥02_ana¥21_WNB¥FBM_2015	WNB_**FCM2015**_Driv_iden.shp

5-6. Open the attribute table of "WNB_FCM2015_Driv_iden.shp", and select polygons without driver information (**"kari" = 0**) and input **9999** to the "**kari**" field.

5-7. Right click on the "**FMU_id**" field to choose "**Summary**". Summarize the minimum value of "kari" field for each FMU. Save the summary table as "FMU_DrivOrd.dbf".

*This operation is done for identifying the driver with the lowest order for each FMU.

Data	Work folder	File name
Summary table	¥02_ana¥21_WNB¥FCM_2015	FMU_DrivOrd.dbf

5-8. Add the following three fields to the Forest Base Map ("WNB_ForestCover_15").

Field	Name	Data type	Length
Driver	Driv_15	Text	50
Driver order	Drv_Ord_15	Long integer	
Year	Y15	Long integer	

5-9. Using *Join table*, join summary table ("FMU_DrivOrd.dbf") to the Forest Cover Map 2015 ("WNB_ForestCover_15") using "**FMU_id**" field as join field.

5-10. Input driver order information to "**Drv_Ord_15**" field by calculating the following equation using *Calculate Field*.

Equation: **([FMU_DrivOrd_1.Min_kari] - Right ([FMU_DrivOrd_1.Min_kari], 2)) / 100**

5-11. Input year information to "**Y15**" field by calculating the following equation using *Calculate Field*.

Equation: **2000 + Right ([FMU_DrivOrd_1.Min_kari], 2)**

5-12. Select polygons without year information (**Y15 = 2099**) and input **9999** to the "**Y15**" field.

5-13. Remove joined table.

6. Input driver for each FMU without Hansen loss

6-1. Open ArcMap, and add the following data.

- Forest Cover Map 2015 ("WNB_ForestCover_15")
- Logged over areas for 2000 ("Road2000_WNB_500mbuf_sng")
- Logged over areas for 2005 ("Road2000_2005_WNB_500mbuf_sng")
- Logged over areas for 2011 ("Road2005_2011_WNB_500mbuf_sng")
- Logged over areas for 2015 ("Road2005_2015_WNB_500mbuf_sng")

*Year information will be added to the drivers identified by logged over areas.

- Concession area ("ConcessionArea_Cur_Exp_2015_z56.shp")
- 5 km buffer from Census Unit ("CU_5kmbuf_mer_sng_z56.shp")

6-2. For each polygon of the Forest Cover Map 2015 ("WNB_ForestCover_15"), input the driver order number to the "Drv_Ord_15" field according to the following steps by reference to **flowchart (c)**.

*Make sure not to overwrite the polygon which already has a driver information from Hansen loss.

Order	Driver
20	Logging
21	Wood collection/Understory extraction

*Grazing is excluded from this analysis, because it usually happens in grassland.

1) When the polygon of the Forest Cover Map 2015 ("WNB_ForestCover_15") does not have driver information (**Driv_Ord_15= 99**) and intersects the **logged over areas** ("**Road2000**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2000_z56.shp"), enter **20** in the "**Drv_Ord_15**" field, enter **2000** in the "**Y15**" field.

   *Make sure the change the selection type to "Subset selection" when selecting the polygon using *Select Layer by Location*.

2) When the polygon does not have driver information (**Drv_Ord_15= 99**) and intersects

the **logged over areas** ("**Road2000_2005**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2005_z56.shp"), enter **20** in the "**Drv_Ord_15**" field, enter **2005** in the "**Y15**" field.

3) When the polygon does not have driver information (**Drv_Ord_15= 99**) and intersects the **logged over areas** ("**Road2005_2011**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2011_z56.shp"), enter **20** in the "**Drv_Ord_15**" field, enter **2011** in the "**Y15**" field.

4) When the polygon does not have driver information (**Drv_Ord_15= 99**) and intersects the **logged over areas** ("**Road2011_2015**_WNB_500mbuf_sng") and **concession area** ("ConcessionArea_Cur_Exp_2015_z56.shp"), enter **20** in the "**Drv_Ord_15**" field, enter **2015** in the "**Y15**" field.

5) If not 1) - 4) (**Drv_Ord_15= 99**), and the polygon intersects **5 km buffer** from **Census Unit** ("CU_5kmbuf_mer_sng_z56.shp"), enter **21** in the "**Driv_ord_15**" field.

7. Input driver by join table

7-1. Join DriverTab table (DriverTab$) using "Driv_ord_15" as join field, and input the driver to "**Driv_15** field. ([DriverTab$.Driver])

7-2. Those polygons with "-" in "Driver" field are considered as intact forest.

7-3. Remove joined table.

(2) Land use change detection

Land use changed area is detected in accordance with the following steps. FMU is revised for the area of Hansen loss polygons larger than 20 ha which is applied to LULUCF.

Step 1: Prepare Hansen Loss data larger than 20 ha extended after 2011

- To collect and arrange Hansen Loss and Lossyear data to be used for detecting changed area larger than 20 ha which extended during 2011-2014

Step 2: Prepare changed area layer

- To create changed area layer utilizing Hansen loss polygons created in step 1

Step 3: Input temporally driver of change area polygons

- To add temporally driver of the change area as a reference for interpretation

Step 4: Update Forest Cover Map 2015

- To identify land use in 2015 of the change area

Step 5: Add forest recovery information

- To identify forest recovery area

Step 6: Add new ID

- To add new IDs of the polygons of the Forest Cover Map 2015

1. Prepare Hanse Loss data larger than 20 ha extended after 2011

This process will be done **for whole nation** at once.

1-1. Prepare the Hansen Loss and Lossyear **polygon** data.

Data	Work folder	File name
Hansen loss	¥01_data_arg¥Hansen_Loss	Hansen_gfc2015_loss_02_clp.shp
Hansen lossyear	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_clp_z55.shp

* Hansen data above must be processed in a day-to-day role. For reference, the preparation process is shown below.

1) Convert original raster data to polygon using *Raster to Polygon* (“hansen_gfc2015_loss_00_ras2vec.shp”).
2) Change the coordinate system of the feature to WGS 1984 UTM Zone 55S using *Project* (“hansen_gfc2015_loss_z55.shp”).
3) Clip the feature with PNG boundary (“Country_2014_z55.shp”) using *Clip* (“hansen_gfc2015_loss_02_clp.shp”).

The target polygons of this procedure is Hansen loss of area larger than 20 ha which extended during 2011-2014.

1-2. Open ArcMap, and add the following data.

- Hansen loss data (“hansen_gfc2015_loss_loss_02_clp.shp”)
- Hansen lossyear data (“Hansen_gfc2015_lossyear_clp_z55.shp)

1-3. From “hansen_gfc2015_loss_02_clp.shp”, select polygons larger than 20 ha using *Select Layer by Attribute*, and export the selected feature as

"hansen_gfc2015_loss_03_20ha.shp".

1-4. From "Hansen_gfc2015_lossyear_clp_z55.shp, select changes for targeted year of 2011-2014 ("GRIDCODE" >= **11**), and export selected features as "hansen_gfc2015_lossyear_Y11_14.shp".

Data	Work folder	File name
Hansen loss (0-20 ha)	¥01_data_arg¥Hansen_Loss	hansen_gfc2015_loss_03_20ha.shp
Hansen lossyear (2011-2014)	¥01_data_arg¥Hansen_Lossyear	hansen_gfc2015_lossyear_Y11_14.shp

1-5. AUsing Select layer by Location, select the Hansen loss polygons larger than 20 ha ("hansen_gfc2015_loss_03_20ha.shp"), which intersect with "hansen_gfc2015_lossyear_Y11_14.shp", and export selected features as "hansen_gfc2015_loss_04_20ha_y11_14.shp".

Data	Work folder	File name
Hansen loss (0-20 ha, extended during 2011-2014)	¥01_data_arg¥Hansen_Loss	hansen_gfc2015_loss_04_20ha_y11_14.shp

1-6. Add the following field to the target Hansen loss shapefile ("hansen_gfc2015_loss_04_20ha_y11_14.shp").

Field	Name	Data type	Length
Driver order	Driv_ord	Long integer	
Land use 2015	lu15	Text	10

2. Prepare changed area layer

Changed area layer will be created utilizing Hansen loss polygons created in step 1.

2-1. Add the following data on ArcMap.

- Hansen loss data created in step 1 ("hansen_gfc2015_loss_04_20ha_y11_14.shp")
- Province boundary ("Province_2014_z55.shp")

2-2. Fill holes of Hansen loss polygons. This process is not indispensable.

1) Using *Editor*, create a polygon larger than the whole area and save the shapefile as

"tmp_cover_z55.shp". The coordinate should be set as WGS 1984 UTM Zone 55S.

2) *Union* whole area polygon ("tmp_cover_z55.shp") and Hansen loss ("hansen_gfc2015_loss_04_20ha_y11_14.shp"), and save the output feature class as "hancen_gfc2015_loss_05_unicov.shp".

3) Using *Multipart to Singlepart*, convert union feature ("hancen_gfc2015_loss_05_unicov.shp") to singlepart and save the output feature class as "hancen_gfc2015_loss_06_sng.shp"

4) Select the largest polygon of singlepart feature ("hancen_gfc2015_loss_06_sng.shp"), and delete the polygon using *Editor*.

5) Using *Select Layer by Attribute*, select all small polygons (GRIDCODE = 1) of hancen_gfc2015_loss_06_sng.shp, *Eliminate* those polygons and save output feature class as "hancen_gfc2015_loss_07_elim_z55.shp".

Data	Work folder	File name
Hansen loss temporary processing data	¥01_data_arg¥Hansen _Loss	tmp_cover_z55.shp
		hancen_gfc2015_loss_05_unicov.shp
		hancen_gfc2015_loss_06_sng.shp
		hancen_gfc2015_loss_07_elim_z55.shp

2-3. From "hancen_gfc2015_loss_07_elim_z55.shp" (or "hansen_gfc2015_loss_04_20ha_y11_14.shp"), select changes for each province. Use *Select Layer by Location* to select polygons which intersect each selected province ("Province_2014_z55.shp"), and export selected feature as "WNB_2015_changed.shp" in FCM_2015 folder. Make sure to change the projected coordinate system accordingly to the table in chapter 5-1 (1) step2-6.

Data	Work folder	File name
Change area (0-20 ha, extended during 2011-2014)	¥02_ana¥21_WNB¥FCM_ 2015	WNB_2015_changed.shp

3. Input temporally driver of change area polygons

This process will be done **by each province**.

In this step, temporally driver of the change area ("WNB_2015_changed.shp") will be identified by lossyear polygon with driver information created in previous procedure ("WNB_2015_lossyear_s56.shp"), as a reference for interpretation.

3-1. Open ArcMap, and add the following data.

- Change area layer ("WNB_2015_changed.shp")
- Hansen lossyear data ("WNB_2015_lossyear_s56.shp")

3-2. Using *Feature To Point*, convert change area polygon data to point data, and save the output as "WNB_2015_changed_01_pnt.shp".

Make sure to check "Inside polygon".

3-3. Using *Spatial Join*, join point data ("WNB_2015_changed_01_pnt.shp") with Hansen lossyear data with driver information ("WNB_2015_lossyear_s56.shp"), and save output feature class as "WNB_2015_changed_02_spjoin.shp".

Make sure to change the match option to "Closest".

Data	Work folder	File name
Driver detect processing data	¥02_ana¥21_WNB¥FCM_2015	WNB_2015_changed_01_pnt.shp
		WNB_2015_changed_02_spjoin.shp

3-4. Join spatial joined data ("WNB_2015_changed_02_spjoin.shp") table to change area layer ("WNB_2015_changed.shp"), using "ID" field for both input join field and output join field.

3-5. Using Calculate Field, copy "Driv_ord" of "WNB_2015_changed_02_spjoin.shp" to "Driv_ord" field of "WNB_2015_changed.shp".

4. Update Forest Cover Map 2015

4-1. Open ArcMap, and add the following data.

- Hansen Cover Map 2015 ("WNB_ForestCover15")
- Change area layer ("WNB_2015_changed.shp")
- Satellite imagery

4-2. Add the following field to Forest Cover Map 2015 ("WNB_ForestCover15").

Field	Name	Data type	Length
Land use 2015	lu15	Text	12

4-3. Using *Calculate Field*, copy "Landuse" field for "lu15" field.

*For WNB, copy "lu11" field.

4-4. Check the satellite imagery for all polygons of change area layer

("WNB_2015_changed.shp"). Using *Editor*, cut the changed area of the Forest Cover Map 2015 ("WNB_ForestCover15") referring to the change area polygon and interpreting satellite imagery.

Consider following matters for this procedure.

- ✓ Changes that are obvious in 1:50,000 scale is targeted.
- ✓ Zoom in when cutting or editing the polygons, because shape of some polygons is sometimes unexpected (Make sure not to create tiny polygons when editing).
- ✓ If the shape of changed area is similar to FMU boundary, editing is unnecessary since many tiny polygons are not preferable. Do not mind the slight difference in shapes
- ✓ NEVER merge polygons. Each polygon has their own ID and consistency will be lost by merging them.

4-5. Also, identify land use in 2015 and input land use code in "lu15" field.

Refer to the following table for inputting code for each land use.

	Code	Description	Note
	P	Low altitude forest on plains and fans – below 1000 m	Slope ≦ 6
	H	Low altitude forest on uplands – below 1000 m	Slope ＞ 6
	L	Lower montane forest – above 1000 m	
	Mo	Montane forest – above 3000 m	
	B	Littoral forest	
	D	Dry seasonal forest	
	Fri	Seral forest	
	Fsw	Swamp forest	
	M	Mangrove forest	
	W	Woodland	
	Sa	Savanna	
	Sc	Scrub	
	G	Grassland and herbland	
	Ga	Alpine grassland – above 3200 m	
	Gi	Subalpine grassland – above 2500 m	
	O	Cropland/Agriculture land	
	Qa	Plantation other than forest plantation	
	Qf	Forest plantation	
	Z	Bare areas	
	U	Larger urban centres	
	E	Lake & larger rivers	
	Es	Sea (outside land)	

To identify land use in 2015, use the value of “Driv_ord” of “WNB_2015_changed.shp” as a reference. Refer to the following table for identifying land use in 2015 derived from the driver.

Driver order	Driver	Land use 2015
1, 13	Mining	U
2	Road construction	U / Z / G
3	Facility construction	U / Z / G
4, 14	Forest plantation	Qf
5, 6, 15	Perennial plantation	Qa
7, 16	Logging	-
8, 19	Disaster (flooding, landslide, volcano, etc.)	- / G / Z / E
9, 18	Subsistence agriculture	O
10, 17	Gardening	-
11	Fire	- / G / Z
12	Unknown	Identify from imagery

*Remember that the “Driv_ord” in change area layer is only temporal and possibly wrong.

*Use the change area polygons only as a reference. Land use change editing should be done mainly by imagery interpretation. Do not automatically fill the “lu15” field from the table above. (E.g. It is possible for the forest to be converted into perennial plantation even if a change area polygon does not overlap with plantation.)

*For the change area polygon almost completely included in O, Qa, Qf, or with little changes after 2011, there is no need to confirm the land use change.

*Some area is changed for wider range than the shape of change area polygons. Referring to Hansen loss smaller than 20 ha may be helpful for cutting FMU polygon.

*Mainly check for forest and grassland, although there are some cases of Subsistence agriculture (O) becoming Plantation.

*If the driver is Logging or Gardening, there is no need to revise the 2015 map since they are treated as forest degradation.

*For Disaster and Fire, interpretation should be made depending on each change polygon. (E.g. Interpret as land use change for the large-scale intense disturbance area, where the recovery seems to take long time.)

5. Add forest recovery information

5-1. Open ArcMap, and add the following data.

- Hansen gain data ("Hansen_gfc2015_gain_z55.shp")
- Province boundary ("Province_2014_z55.shp)
- Forest Cover Map 2015 ("WNB_ForestCover_15")
- Satellite imagery

5-2. To arrange gain data, add a field with geometric information of area (ha) to Hansen gain data ("hansen_gfc2015_gain_z55.shp").

From "hansen_gfc2015_gain_z55.shp", select gain polygons **larger than 1 ha** for each province.

5-3. Using *Select Layer by Location*, select polygons which intersect each selected province ("Province_2014_z55.shp"). And then, using *Subset Selection of Select Layer by Attribute*, select the polygon larger than 1 ha (**"POLY_AREA" >=1**), and export selected features as "WNB_2015_gain_s56.shp".

Make sure to change the projected coordinate system accordingly to the table in chapter 5-1 (1) step2-6.

Data	Work folder	File name
Hansen gain (>1 ha) in Province	¥01_arg¥Hansen_gain¥21_WNB	WNB_2015_gain_s56.shp

Within the Hansen gain polygon, those that are not forest, plantation or subsistence agriculture in 2015 will be the target polygon.

5-4. Using *Select Layer by Attribute*, to select Forest Cover Map 2015 ("WNB_ForestCover_15") polygons that are Grassland or Bareland (**lu15 = 'G' OR lu15 = 'Ga' OR lu15 = 'Gi' OR lu15 = 'Z'**). And then, using *Select Layer by Location*, select gain polygon ("WNB_2015_gain_s56.shp") which intersects with the selected Forest Cover Map 2015, and export selected features as "WNB_2015_gain_1hasel_s56.shp".

Data	Work folder	File name
Hansen gain (>1 ha, intersect with Grassland or Bareland) in Province	¥02_ana¥21_WNB ¥FCM_2015	WNB_2015_gain_1hasel_s56 .shp

5-5. Check the Forest Cover Map 2015 ("WNB_ForestCover15") for all polygons of Hansen gain

area layer ("WNB_2015_gain_1hasel_s56.shp"). If the area larger than about 1 ha had obvious forest recovery, cut the changed area of the Forest Cover Map using *Editor*, and input new land use type in "lu15" field.

*Most of the polygons also overlap with Forest and Plantation. If the area is difficult to classify between forest and grassland, revision of the Forest Cover Map is not necessary.

6. Add new ID

6-1. Add field named "lu15_id" (data type: long) to Forest Cover Map 2015 ("WNB_ForestCover15").

6-2. Using *Field Calculator*, enter new ID to "lu15_id" field.

Outputs of the Forest Cover Map 2015 are shown in **Annex C**.

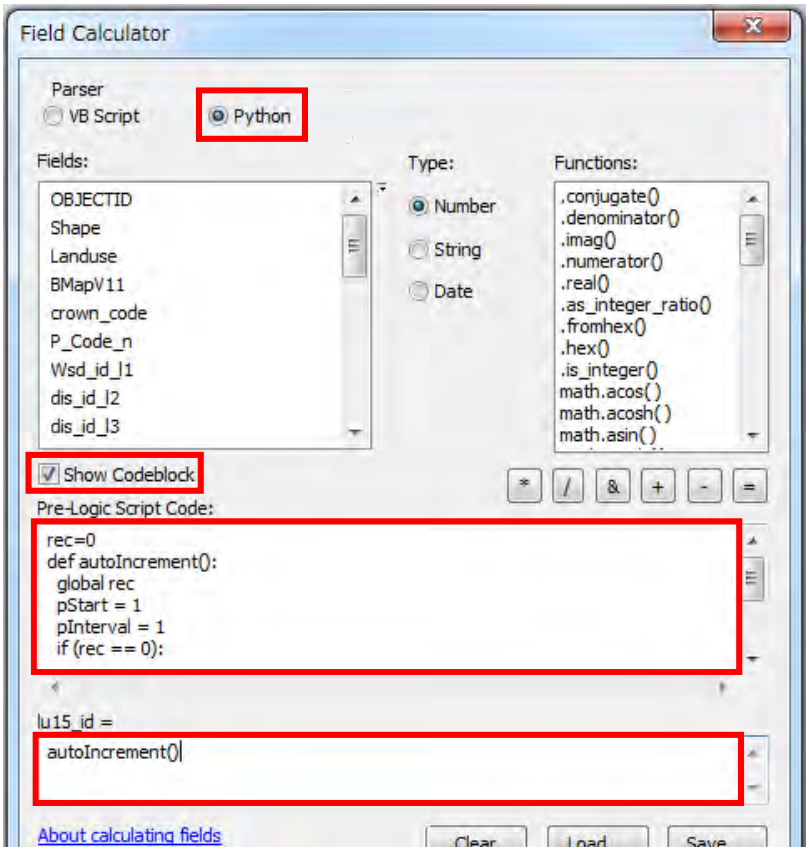
<Tip 3: How to input new ID>

New ID will be given to each FMU after the update of Forest Cover Map.

1. Open attribute table of the Forest Cover Map ("WNB_ForestCover_15.shp").
2. Right click on the "lu15_id" field and select *Field Calculator*.
3. Select **Python** as Parser, and check on **Show Codeblock**. For *Pre-Logic Script Code*: enter following code.

```
rec=0
def autoIncrement():
  global rec
  pStart = 1
  pInterval = 1
  if (rec == 0):
    rec = pStart
  else:
    rec = rec + pInterval
return rec
```

4. For *lu15_id =*, enter "autoIncrement()". Enter "OK".



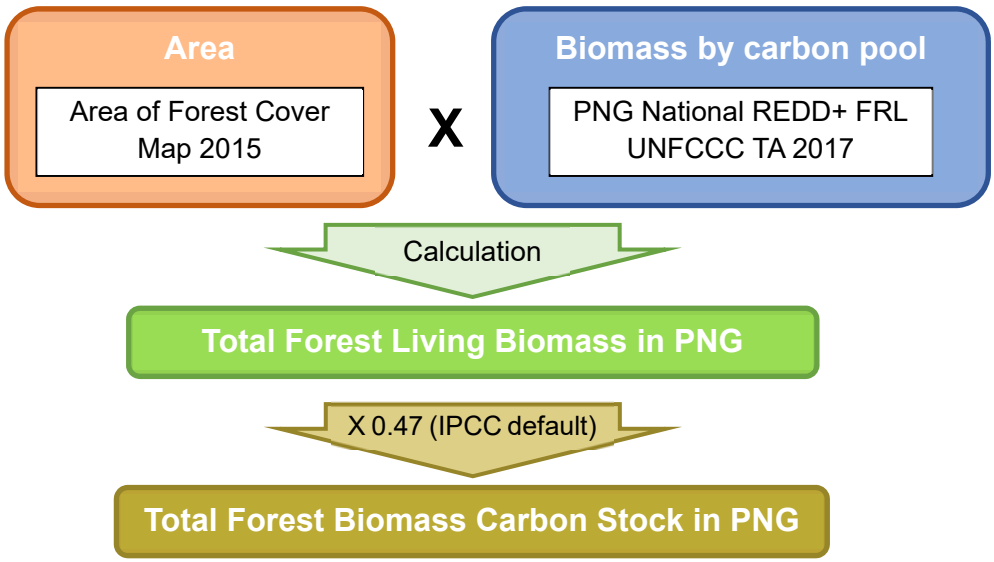
5-2. Forest biomass and carbon stock of Forest Cover Map 2015

PNG's Forest Reference Level (FRL) was submitted to UNFCCC in January 2017, with technical support from FAO. The FRL was reported in "Papua New Guinea's National REDD+ Forest Reference Level – Submission for UNFCCC Technical Assessment in 2017". In this report, point sampling that applies Collect Earth was assigned to areas of each forest type to calculate forest carbon stocks. In the Project, forest carbon stocks for entire PNG were calculated on a trial basis using the Forest Cover Map 2015.

Method and process of calculating forest living biomass and forest biomass carbon stocks

Basic design of calculation method

Forest living biomass was calculated assigning the Forest Cover Maps to areas, and values assigned in the "PNG National REDD+ FRL 2017" were used for above-ground living biomass (AGLB) value and below-ground living biomass (BGLB) ration, which was also the IPCC default value. Forest biomass carbon stocks were calculated by multiplying the forest living biomass by the default value in the IPCC guideline for carbon content.



Basic design of forest living biomass / forest carbon stocks calculation method

Calculation of AGLB

AGLB was calculated by multiplying the area for each land cover class (forest type) on the Forest Cover Map 2015 by the AGLB value assigned in the "PNG National REDD+ FRL 2017".

Area of each forest type (Forest Cover Map 2015) X AGLB per ha (PNG National REDD+ FRL = AGLB of each forest type

Forest Cover Map 2015						
Forest type		Human impact	Area (ha)		AGLB value (t/ha)		AGLB of each forest type (Mt)
P	Low Altitude Forest on Plains & Fans	Primary	3,119,231		223		695.59
		Disturbance	5,014,087		146		732.06
H	Low Altitude Forest on Uplands	Primary	4,475,346		223		998.00
		Disturbance	7,128,517		146		1,040.76
L	Lower Montane Forest	Primary	3,345,477		140		468.37
		Disturbance	4,119,871		92		379.03
Mo	Montane Forest	Primary	257,917		140		36.11
		Disturbance	96,578		92		8.89
D	Dry Seasonal Forest	Primary	758,768		130		98.64
		Disturbance	176,439		85		15.00
B	Littoral Forest	Primary	22,518	X	223	=	5.02
		Disturbance	44,098		146		6.44
Fri	Seral Forest	Primary	67,900		223		15.14
		Disturbance	79,731		146		11.64
Fsw	Swamp Forest	Primary	945,622		223		210.87
		Disturbance	1,044,263		146		152.46
M	Mangrove Forest	Primary	163,685		192		31.43
		Disturbance	355,279		126		44.77
W	Woodland	Primary	1,493,062		130		194.10
		Disturbance	1,495,948		85		127.16
Sa	Savanna	Primary	348,076		130		45.25
		Disturbance	287,048		85		24.40
Sc	Scrub	Primary	298,100		70		20.87
		Disturbance	93,609		46		4.31
Qf	Forest Plantation	Primary	55		150		0.01
		Disturbance	67,896		98		6.65

Calculation of AGLB based on Forest Cover Map 2015

Calculation of BGLB

BGLB was calculated by multiplying the area for each land cover class on the Forest Cover Map 2015 by the BGLB value. The BGLB value was calculated by multiplying the AGBL value by the BGLB ratio. For the BGLB ratio.

Area of each forest type (Forest Cover Map 2015) X BGLB per unit area AGLB per ha x R (ratio of BGB to AGB) R: IPCC default value = BGLB of each forest type

Forest Cover Map 2015							
Forest type	Human impact	Area (ha)		AGLB value (t/ha)	R	BGLB value (t/ha)		BGLB of each forest type (Mt)
P	Primary	3,119,231		223	0.37	82.51		257.37
	Disturbance	5,014,087		146	0.37	54.02		270.86
H	Primary	4,475,346		223	0.37	82.51		369.26
	Disturbance	7,128,517		146	0.37	54.02		385.08
L	Primary	3,345,477		140	0.27	37.8		126.46
	Disturbance	4,119,871		92	0.27	24.84		102.34
Mo	Primary	257,917		140	0.27	37.8		9.75
	Disturbance	96,578		92	0.27	24.84		2.40
D	Primary	758,768		130	0.28	36.4		27.62
	Disturbance	176,439		85	0.28	23.8		4.20
B	Primary	22,518	X	223	0.37	82.51	=	1.86
	Disturbance	44,098		146	0.37	54.02		2.38
Fri	Primary	67,900		223	0.37	82.51		5.60
	Disturbance	79,731		146	0.37	54.02		4.31
Fsw	Primary	945,622		223	0.37	82.51		78.02
	Disturbance	1,044,263		146	0.37	54.02		56.41
M	Primary	163,685		192	0.49	94.08		15.40
	Disturbance	355,279		126	0.49	61.74		21.93
W	Primary	1,493,062		130	0.28	36.4		54.35
	Disturbance	1,495,948		85	0.28	23.8		35.60
Sa	Primary	348,076		130	0.28	36.4		12.67
	Disturbance	287,048		85	0.28	23.8		6.83
Sc	Primary	298,100		70	0.4	28		8.35
	Disturbance	93,609		46	0.4	18.4		1.72
Qf	Primary	55		150	0.37	55.5		0.00
	Disturbance	67,896		98	0.37	36.26		2.46

Calculation of BGLB based on Forest Cover Map 2015

Calculation of total forest living biomass

Total forest living biomass was calculated by adding the AGLB and the BGLB calculated above.

AGLB + BGLB = Total Living Biomass

Forest Cover Map 2015		AGLB (Mt)		BGLB (Mt)		Total Living Biomass (Mt)
Forest type	Human impact					
P	Primary	695.59		257.37		952.96
	Disturbance	732.06		270.86		1,002.92
H	Primary	998.00		369.26		1,367.26
	Disturbance	1,040.76		385.08		1,425.85
L	Primary	468.37		126.46		594.83
	Disturbance	379.03		102.34		481.37
Mo	Primary	36.11		9.75		45.86
	Disturbance	8.89		2.40		11.28
D	Primary	98.64		27.62		126.26
	Disturbance	15.00		4.20		19.20
B	Primary	5.02	+	1.86	=	6.88
	Disturbance	6.44		2.38		8.82
Fri	Primary	15.14		5.60		20.74
	Disturbance	11.64		4.31		15.95
Fsw	Primary	210.87		78.02		288.90
	Disturbance	152.46		56.41		208.87
M	Primary	31.43		15.40		46.83
	Disturbance	44.77		21.93		66.70
W	Primary	194.10		54.35		248.45
	Disturbance	127.16		35.60		162.76
Sa	Primary	45.25		12.67		57.92
	Disturbance	24.40		6.83		31.23
Sc	Primary	20.87		8.35		29.21
	Disturbance	4.31		1.72		6.03
Qf	Primary	0.01		0.00		0.01
	Disturbance	6.65		6.65		13.31
Total		5,372.95		1,867.43		7,240.38

Calculation of forest living biomass based on Forest Cover Map 2015

Calculation of forest carbon stocks

Forest carbon stocks were calculated by multiplying the forest living biomass by the default value in the IPCC guideline for carbon content.

Total Living Biomass X Carbon Fraction (CF) = Total forest biomass carbon

Forest Cover Map 2015		Total Living Biomass (Mt)		GF		Total forest biomass carbon (Mt)
Forest type	Human impact					
P	Primary	952.9563181	X	0.47	=	447.89
	Disturbance	1002.917631				471.37
H	Primary	1367.263028				642.61
	Disturbance	1425.846003				670.15
L	Primary	594.8258046				279.57
	Disturbance	481.3657157				226.24
Mo	Primary	45.85772205				21.55
	Disturbance	11.28411544				5.30
D	Primary	126.2590235				59.34
	Disturbance	19.19651072				9.02
B	Primary	6.879507139				3.23
	Disturbance	8.820479314				4.15
Fri	Primary	20.74426026				9.75
	Disturbance	15.94771577				7.50
Fsw	Primary	288.8971038				135.78
	Disturbance	208.873543				98.17
M	Primary	46.82690096				22.01
	Disturbance	66.70010282				31.35
W	Primary	248.4454598				116.77
	Disturbance	162.7591329				76.50
Sa	Primary	57.91992785				27.22
	Disturbance	31.23084014				14.68
Sc	Primary	29.21375285				13.73
	Disturbance	6.028449016				2.83
Qf	Primary	0.011341011				0.01
	Disturbance	13.30766291				6.25
Total		7240.378051				3,402.98

Calculation of forest carbon stocks on Forest Cover Map 2015

Outputs of the forest biomass and carbon stocks on Forest Cover Map 2015 are shown in **Annex C**.

5-3. Issues found in the Forest Cover Map 2015 and way to address them

In this section, we describe (i) issues and points to keep in mind found in the Forest Cover Map

2015, (ii) how the Project tackled them during the course of the Project activities, and (iii) future possible works toward improvements.

The Project team found the following issues through the process of developing the Forest Cover Map 2015 for entire PNG based on the Forest Base Map 2012.

(a) Inability to compare difference in periodical changes between the Forest Base Map and the Forest Cover Map 2015

It was revealed that The Forest Base Map has some misclassifications, especially in Cropland/Agriculture land (O) class, due to the limitations of data and technique at that time. The misclassifications which could be identified when developing the maps were modified in the Forest Cover Map 2015. This means you can not simply compare difference in periodical changes between the Forest Base Map and the Forest Cover Map 2015. It is necessary to keep in mind that the Forest Base Map could have misclassifications.

(b) The amount of time to update a forest cover map for entire PNG

It took longer than expected to develop the Forest Cover Map 2015 since the Forest Base Map has some misclassifications. The Project team needed to interpret satellite imagery and digitize new boundaries when detecting misclassifications in the Forest Base Map. It took much time, but it was worthwhile, the Forest Cover Map 2015 became a more accurate map. It must take a shorter time to update the Forest Cover Map in the same method in the future. It is expected it will take about three days per one province.

(c) Detecting forest recovery

In Project activities, we used Hansen Gain data to detect forest recovery areas, but there were not so many areas of such a size as to be taken as forest recovery from 2011 to 2015. We found that it was hard to distinguish forest and grassland.

Future forest cover maps should be updated on the basis of the method which was used when creating the Forest Cover Map 2015, but it also should be considered about possibility to innovate new technologies with stepwise confirmation in field study.

Reference

CCDA, 2017, 'Papua New Guinea's National REDD+ Forest Reference Level – Submission for UNFCCC Technical Assessment in 2017'. Climate Change and Development Authority, Port

Moresby, Papua New Guinea

Annex C. Forest Cover Map 2015: Forest Cover Map 2015 (PNG)

Annex C. Forest Cover Map 2015: Area of Forest Cover Map 2015 (PNG)

Annex C. Forest Cover Map 2015: Forest biomass and carbon stocks on Forest Cover Map 2015 (PNG)

Annex L. Driver Interpretation card

Annex

A. Forest Base Map 2012 (ver.1.1)

- Forest Base Map 2012 (PNG)
- Area of Forest Base Map 2012 (PNG)
- Forest degradation driver map of Forest Base Map 2012 (PNG)
- Area of forest degradation driver map of Forest Base Map 2012 (PNG)
- Forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WNB)
- Area of forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WNB)
- Forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WSP)
- Area of forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WSP)

B. Forest Cover Map (Past)

- Forest Cover Map 2000, 2005, and 2011 (WNB)
- Area of Forest Cover Map 2000, 2005, and 2011 (WNB)
- Map of forest cover change between 2000 - 2011 (WNB)
- Area of forest cover change between 2000 - 2011 (WNB)
- Forest Cover Map 2000, 2005, and 2011 (WSP)
- Area of Forest Cover Map 2000, 2005, and 2011 (WSP)
- Map of forest cover change between 2000 - 2011 (WSP)
- Area of forest cover change between 2000 - 2011 (WSP)

C. Forest Cover Map 2015

- Forest Cover Map 2015 (PNG)
- Area of Forest Cover Map 2015 (PNG)
- Forest biomass on Forest Cover Map 2015 (PNG)
- Forest carbon stocks on Forest Cover Map 2015 (PNG)

D. Manual for downloading and Processing Landsat Images

E. Manual for downloading and Processing SAR

F. Manual to use Google Earth Engine (related to Greenest Pixel)

G. Arrangement of Global Forest Change data published by Hansen et al.

H. Digitizing road network utilizing LANDSAT imagery

I. Manual of topology check

J. Accuracy assessment of the Forest Base Map

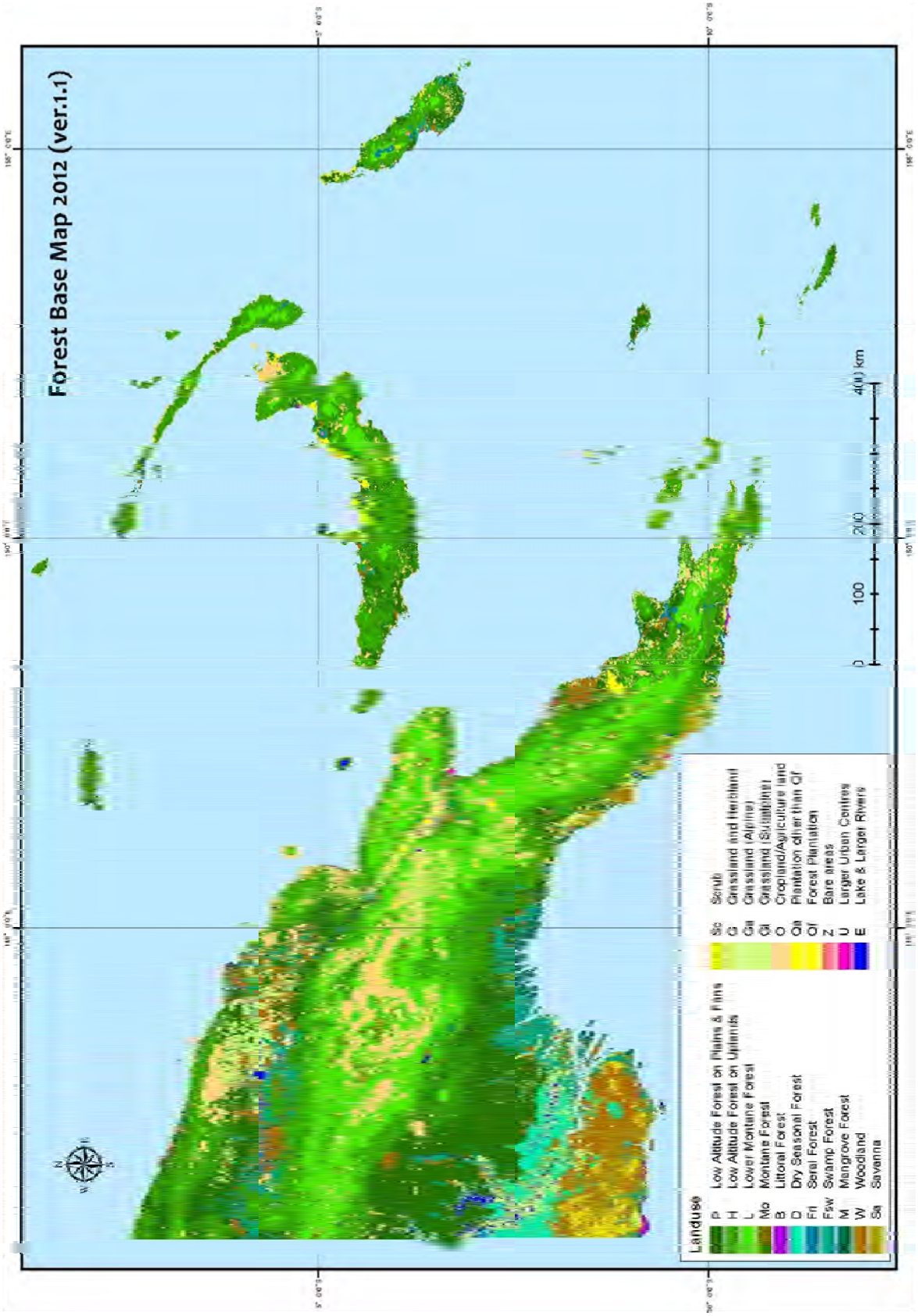
K. Excel tips

L. Driver interpretation card

M. Procedure to create raster data (Geo-TIFF) with colormap file

A. Forest Base Map 2012 (ver.1.1)

Forest Base Map 2012 (PNG)



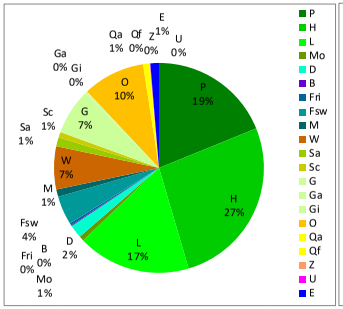
Area of Forest Base Map 2012 (PNG)

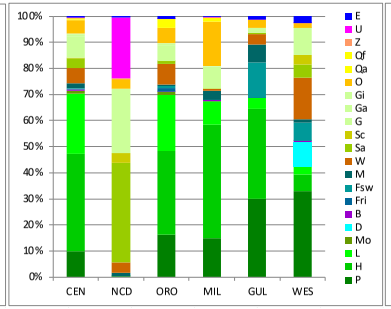
Forest Base Map (ver.1.1: Landcover + Draft Cropland/Agriculture landuse): Vegetation Type Area (ha) x Province　　＊Islands outside PNG, which are located to the south of WES and ARB, are removed.

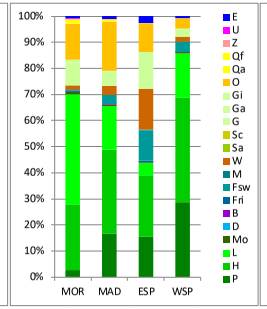
	VEG	VEGNAME	SUM	CEN	NCD	ORO	MIL	GUL	WES	MOR	MAD	ESP	WSP	SIM	ENG	EHP	SHP	HLA	WHP	JIW	WNB	ENB	MAN	NIL	ARB
	P	Low Altitude Forest on Plains & Fans	8,707,393	292,663	86	365,484	209,994	1,037,694	3,219,756	92,047	487,379	678,469	1,031,108	8,251	2,720	2,073	153,026	22,282	9,485	9,220	508,762	135,360	67,533	138,886	235,116
	H	Low Altitude Forest on Uplands	12,264,035	1,101,655	32	728,478	616,187	1,200,039	629,928	845,576	921,766	1,011,379	1,436,375	117,027	63,505	56,316	436,709	117,054	21,954	70,752	1,050,299	831,846	107,118	531,003	369,036
	L	Lower Montane Forest	8,042,001	680,095		485,745	129,735	149,739	290,126	1,421,949	482,384	229,009	611,335	283,511	606,659	597,381	565,842	657,590	132,980	201,434	66,313	269,688		103,008	77,478
	Mo	Montane Forest	355,513	39,006		30,097	647		2,661	39,179	21,849	4,055	18,002	15,852	108,371	13,368	9,163	19,510	15,086	18,668					
	D	Dry Seasonal Forest	935,368						935,368																
	B	Littoral Forest	70,358	12,076		894	4,379	1,023	37,194	1,103	1,059	2,077	2,265								1,111	2,458	20	1	4,700
	Fri	Seral Forest	158,719	6,762		26,476	1,166	356	9,833	3,705	5,801	24,439	2,976								20,373	18,427		6,910	31,493
	Fsw	Swamp Forest	2,035,431	9,065		18,202	1,118	465,646	684,614	20,519	95,286	508,138	137,879		377		15,516	244	80	46	24,365	58		644	53,636
	M	Mangrove Forest	521,933	52,658	305	15,267	46,700	241,240	111,843	3,150	277	17,783	669								8,299	2,636	3,755	14,622	2,730
	W	Woodland	3,062,749	172,725	1,071	177,622	12,001	136,701	1,574,990	52,079	98,179	680,002	66,858				14,375	380			33,882	2,311		20,193	19,382
	Sa	Savanna	639,969	113,592	9,970	23,732	35	14,486	478,122						32										
	Sc	Scrub	392,078	6,673	978	1,631	1,332		374,163	11			282					111			112	27			6,759
	G	Grassland and Herbland	3,238,324	241,325	6,395	139,929	120,098	72,942	1,009,672	295,741	163,740	615,054	106,321	30,188	21,432	193,577	49,985	28,771	12,784	8,748	32,069	17,537	5,790	24,994	41,230
	Ga	Grassland (Alpine)	110,602	19,612		8,379	2,148		941	10,955	2,246	446	1,802	752	40,796	763	2,265	17,778	1,601	100					16
	Gi	Grassland (Subalpine)	86,979	11,580		6,562	426		344	18,207	6,827	183	2,550	6,167	7,600	643	12,666	751	8,379	4,095					
	O	Cropland/Agriculture land	4,413,543	151,455	1,012	133,601	240,870	107,317	186,534	470,069	540,450	477,416	141,174	147,357	319,520	236,001	231,061	187,341	218,349	159,904	125,999	201,665	6,160	78,911	51,377
	Qa	Plantation other than Qf	411,614	6,440		78,527	22,874	1,069		35,048	23,639	1,338	1,479	169	126	4,592	23		9,639	5,978	146,980	21,552	750	16,412	34,981
	Qf	Forest Plantation	66,670	18,179			1,214			17,719	4,893				25	4,911	319		1,474			17,931			7
	Z	Bare areas	23,880	152	6	412	50		27	9,001	2,890		1,984		19	171	1,498	205	338	256	1,137	1,286	1,018	656	2,774
	U	Larger Urban Centres	23,896	692	6,095	1,025	772	202	727	7,361	1,497	752	318	600		837	182				185	619	514	359	1,158
	E	Lake & Larger Rivers	600,105	19,378	165	21,308	4,921	43,404	250,937	25,206	30,164	118,060	29,389	3,467	2,257	4,043	12,121	3,575	849	1,320	14,114	6,025	418	3,095	5,886
		SUM	46,161,159	2,955,783	26,114	2,263,371	1,416,666	3,471,860	9,797,778	3,368,621	2,890,325	4,368,599	3,592,766	613,341	1,173,438	1,114,676	1,504,751	1,055,593	432,998	480,522	2,034,000	1,529,425	193,077	939,696	937,760

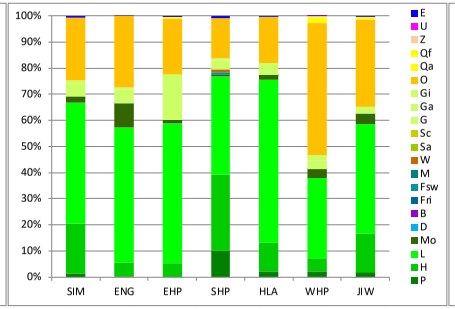
	Forest Cover Area	(ha)																						
	Forest	33,157,421	2,212,157	423	1,670,643	1,011,138	3,095,737	5,921,322	2,444,946	2,020,694	2,475,349	3,240,610	424,640	781,657	674,049	1,180,575	816,680	181,059	300,120	1,679,523	1,278,404	178,426	795,076	774,196
	Forest&Woodland	36,220,170	2,384,882	1,494	1,848,265	1,023,139	3,232,438	7,496,312	2,497,024	2,118,872	3,155,350	3,307,467	424,640	781,657	674,049	1,194,950	817,060	181,059	300,120	1,713,405	1,280,715	178,426	815,269	793,578
＊	Forest&Woodland&Scrub&Savanna	37,252,217	2,505,147	12,442	1,873,627	1,024,507	3,246,924	8,348,597	2,497,035	2,118,872	3,155,350	3,307,749	424,640	781,688	674,049	1,194,950	817,171	181,059	300,120	1,713,517	1,280,741	178,426	815,269	800,337

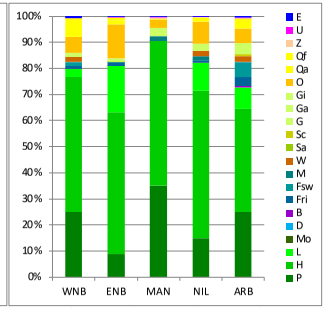
	Forest Cover Rate	(%)																						
	Forest	71.8%	74.8%	1.6%	73.8%	71.4%	89.2%	60.4%	72.6%	69.9%	56.7%	90.2%	69.2%	66.6%	60.5%	78.5%	77.4%	41.8%	62.5%	82.6%	83.6%	92.4%	84.6%	82.6%
	Forest&Woodland	78.5%	80.7%	5.7%	81.7%	72.2%	93.1%	76.5%	74.1%	73.3%	72.2%	92.1%	69.2%	66.6%	60.5%	79.4%	77.4%	41.8%	62.5%	84.2%	83.7%	92.4%	86.8%	84.6%
＊	Forest&Woodland&Scrub&Savanna	80.7%	84.8%	47.6%	82.8%	72.3%	93.5%	85.2%	74.1%	73.3%	72.2%	92.1%	69.2%	66.6%	60.5%	79.4%	77.4%	41.8%	62.5%	84.2%	83.7%	92.4%	86.8%	85.3%



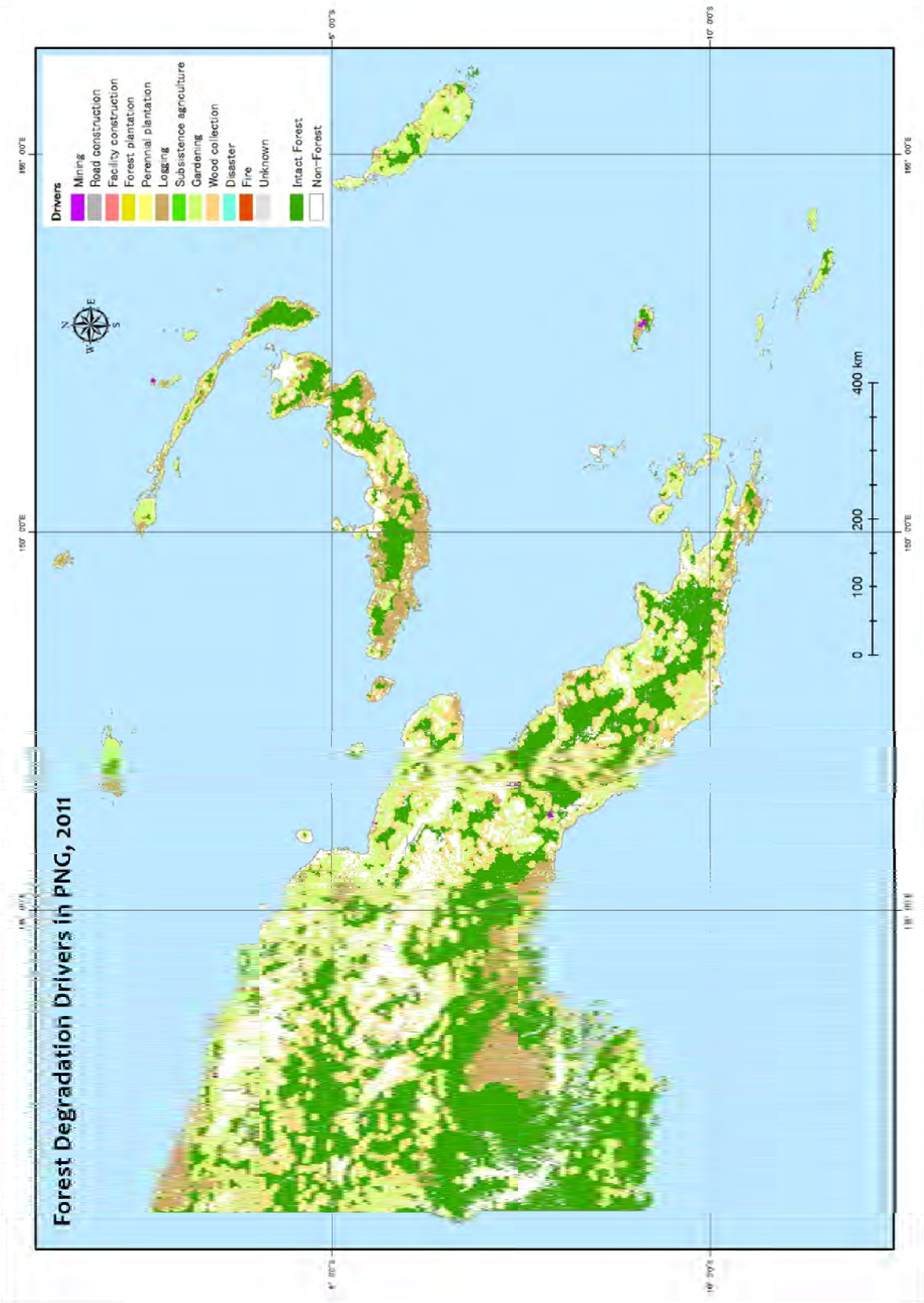








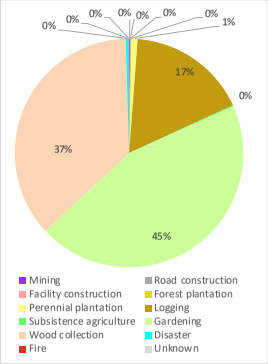
Forest degradation driver map of Forest Base Map 2012 (PNG)

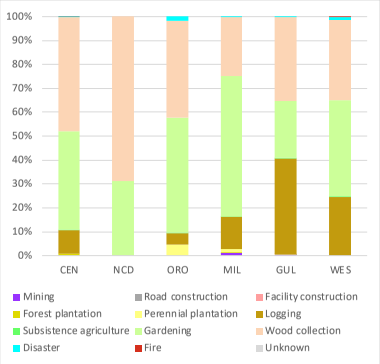


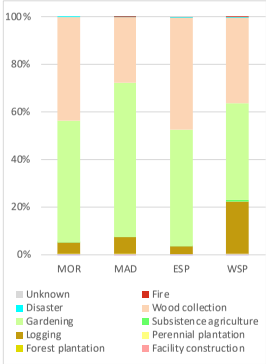
Area of forest degradation driver map of Forest Base Map 2012 (PNG)

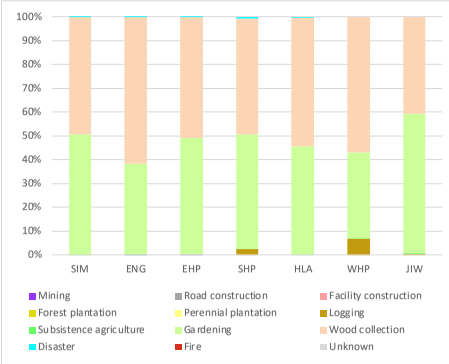
Forest Degradation Drivers of Forest Cover Map 2011: Drivers Area (ha) x Province

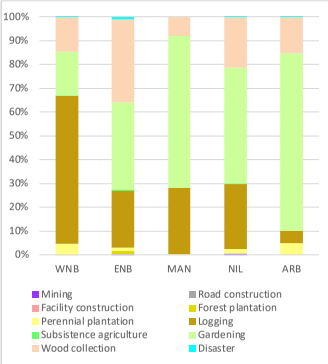
Drivers	SUM	CEN	NCD	ORO	MIL	GUL	WES	MOR	MAD	ESP	WSP	SIM	ENG	EHP	SHP	HLA	WHP	JIW	WNB	ENB	MAN	NIL	ARB
Mining	37,262	1,162	0	0	8,517	5,218	273	6,417	1,646	4,305	4,455	0	226	798	0	0	0	0	0	1,338	0	2,907	0
Road construction	2,722	0	0	0	0	1,442	0	0	0	0	513	0	0	0	0	0	0	0	0	579	0	187	0
Facility construction	1,630	0	0	0	0	581	589	0	145	0	135	0	0	0	0	0	0	0	180	0	0	0	0
Forest plantation	34,225	12,658	0	0	2,687	0	0	1,266	5,836	0	0	0	0	576	0	0	41	0	137	11,024	0	0	0
Perennial plantation	175,703	2,158	0	43,599	11,410	229	0	765	1,239	910	3,362	25	0	147	0	0	30	103	54,294	11,790	474	10,725	34,441
Logging	3,512,466	148,504	0	47,753	106,917	626,746	720,713	85,983	115,480	63,834	432,329	0	0	0	12,621	0	8,047	1,231	724,572	182,551	42,279	159,544	33,361
Subsistence agriculture	35,869	1,818	0	2,167	1,248	3,512	2,395	3,542	2,261	1,344	6,302	71	844	713	73	795	21	317	2,003	4,781	58	863	743
Gardening	9,293,873	633,626	3,868	460,737	467,578	369,876	1,177,497	911,065	1,084,992	891,873	796,861	121,177	183,384	253,156	235,690	159,874	43,246	124,412	214,989	279,746	96,982	282,066	501,176
Wood collection	7,578,478	732,405	8,573	388,916	199,108	544,289	977,640	775,314	463,411	860,090	695,540	117,326	295,095	262,168	237,441	191,132	67,796	86,050	169,140	268,620	12,251	122,555	103,614
Disaster	90,487	783	0	18,178	394	3,018	36,535	1,906	2,188	4,868	7,920	25	324	670	3,571	981	0	0	1,306	6,940	0	358	523
Fire	6,542	234	0	0	0	0	4,370	0	969	647	321	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	2,457	0	0	0	0	0	954	0	0	1,413	0	0	0	0	0	0	0	0	0	90	0	0	0
(Intact Forest)	16,109,308	953,620	0	912,278	225,433	1,692,013	5,427,632	693,057	435,812	1,326,067	1,051,445	186,016	301,792	150,911	705,234	464,389	60,403	88,007	550,934	495,351	26,382	236,062	126,473
SUM	36,881,022	2,486,968	12,442	1,873,627	1,023,293	3,246,924	8,348,598	2,479,316	2,113,980	3,155,350	2,999,183	424,640	781,664	669,138	1,194,631	817,171	179,585	300,120	1,717,558	1,262,811	178,426	815,269	800,330





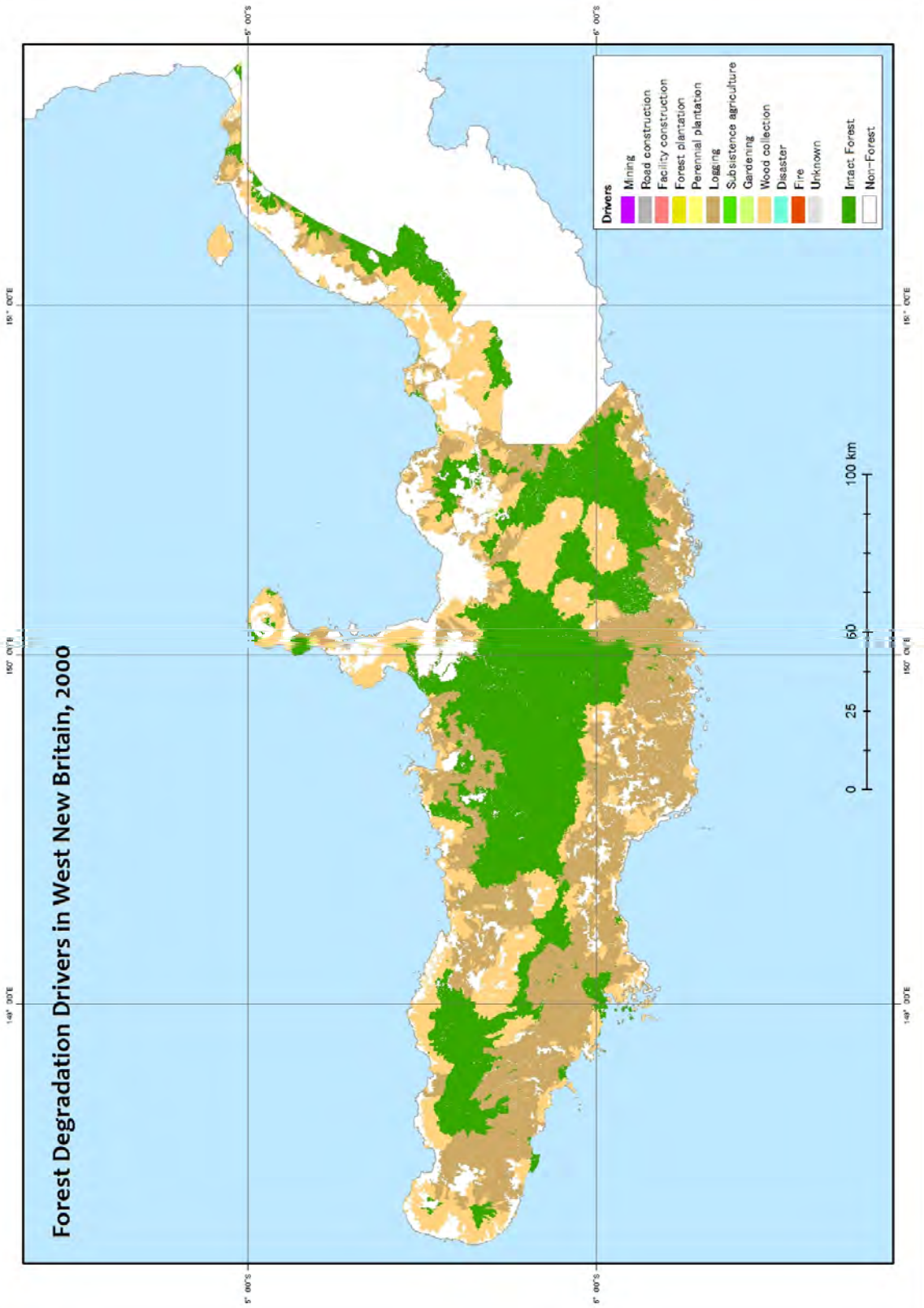


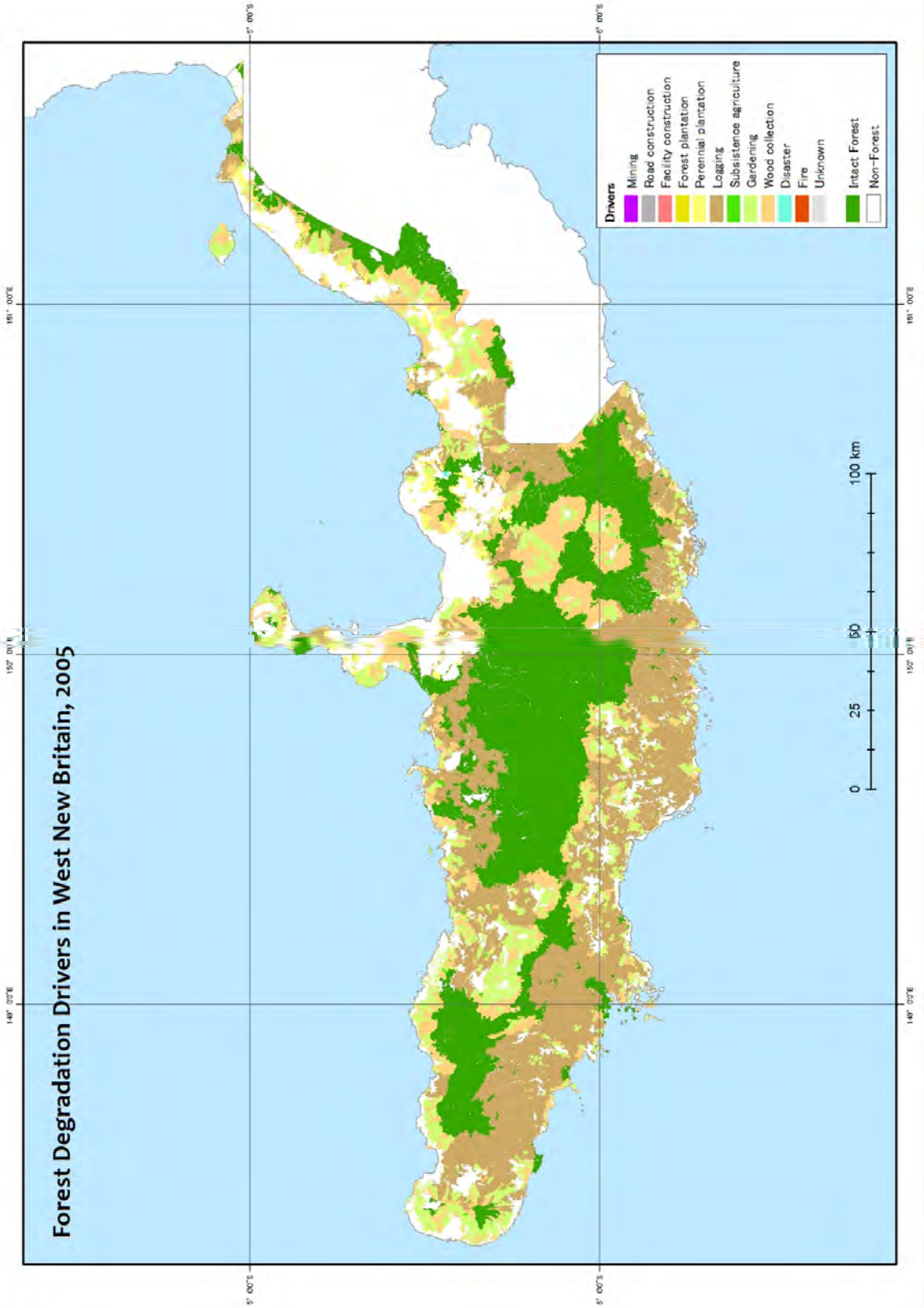


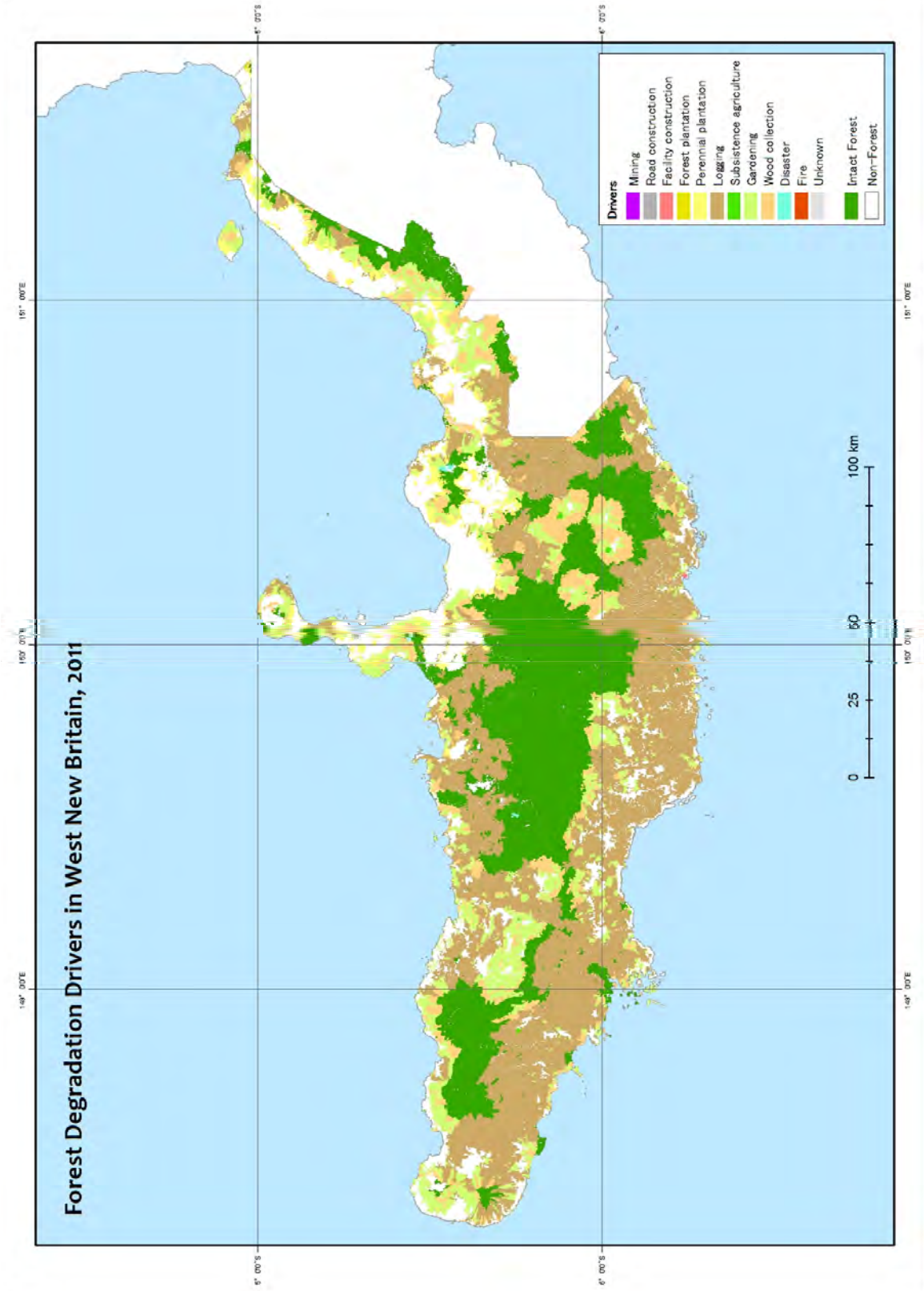


＊The Forest Base Maps are used. But, as for WNB and WSP, the revised Forest Cover Maps 2011 are used.
＊Islands outside PNG, which are located to the south of WES and ARB, are removed.

Forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WNB)



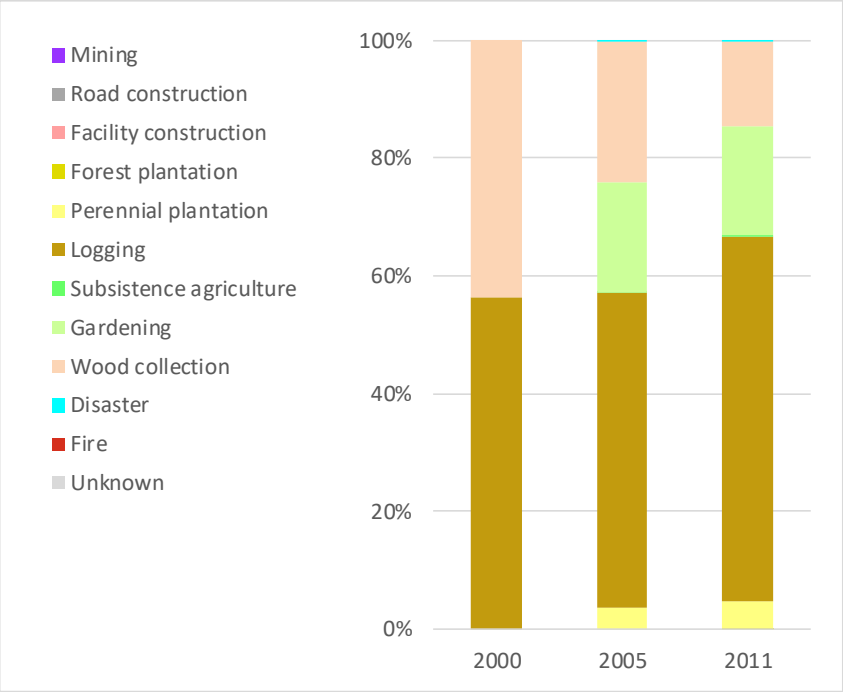




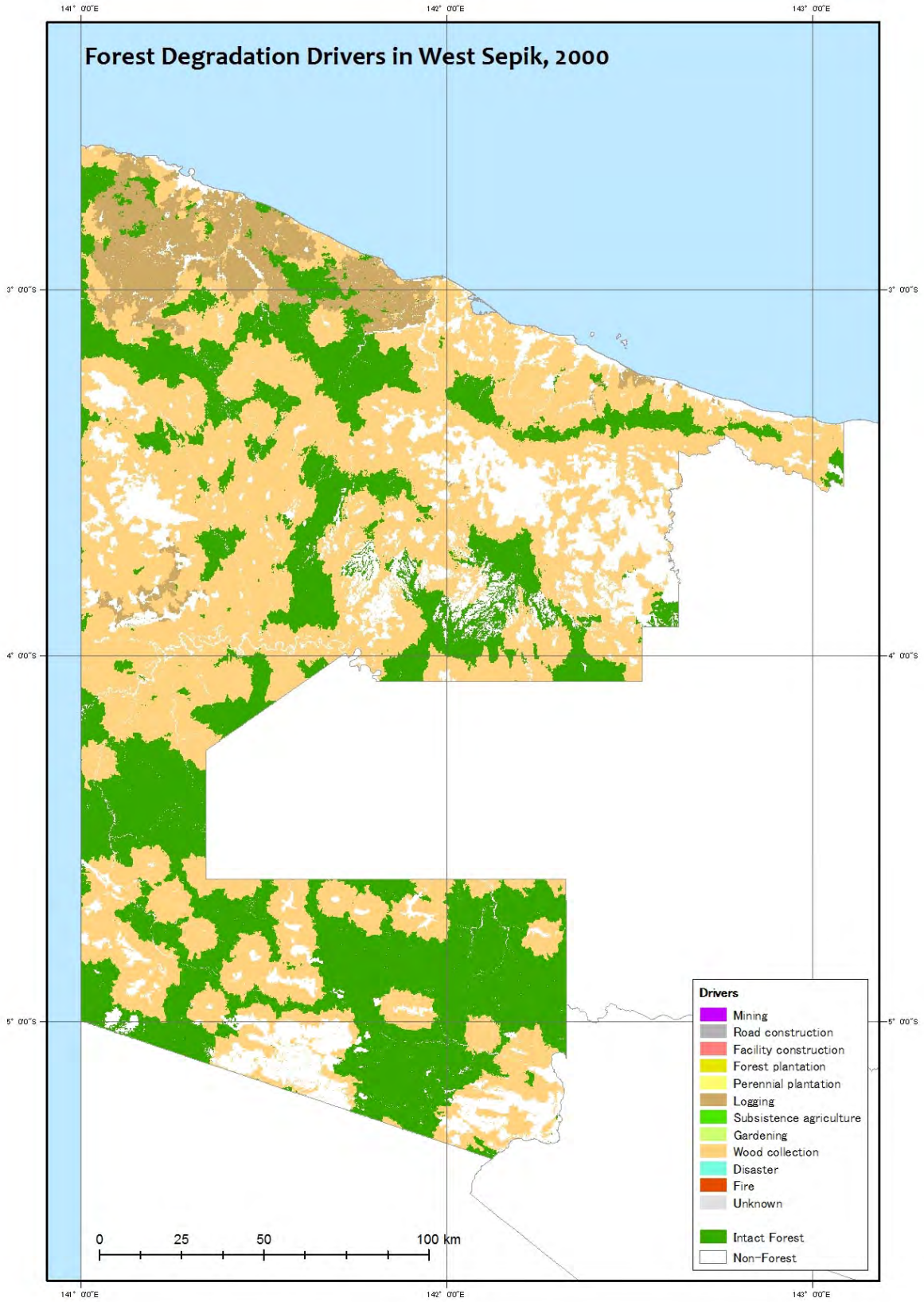
Area of forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WNB)

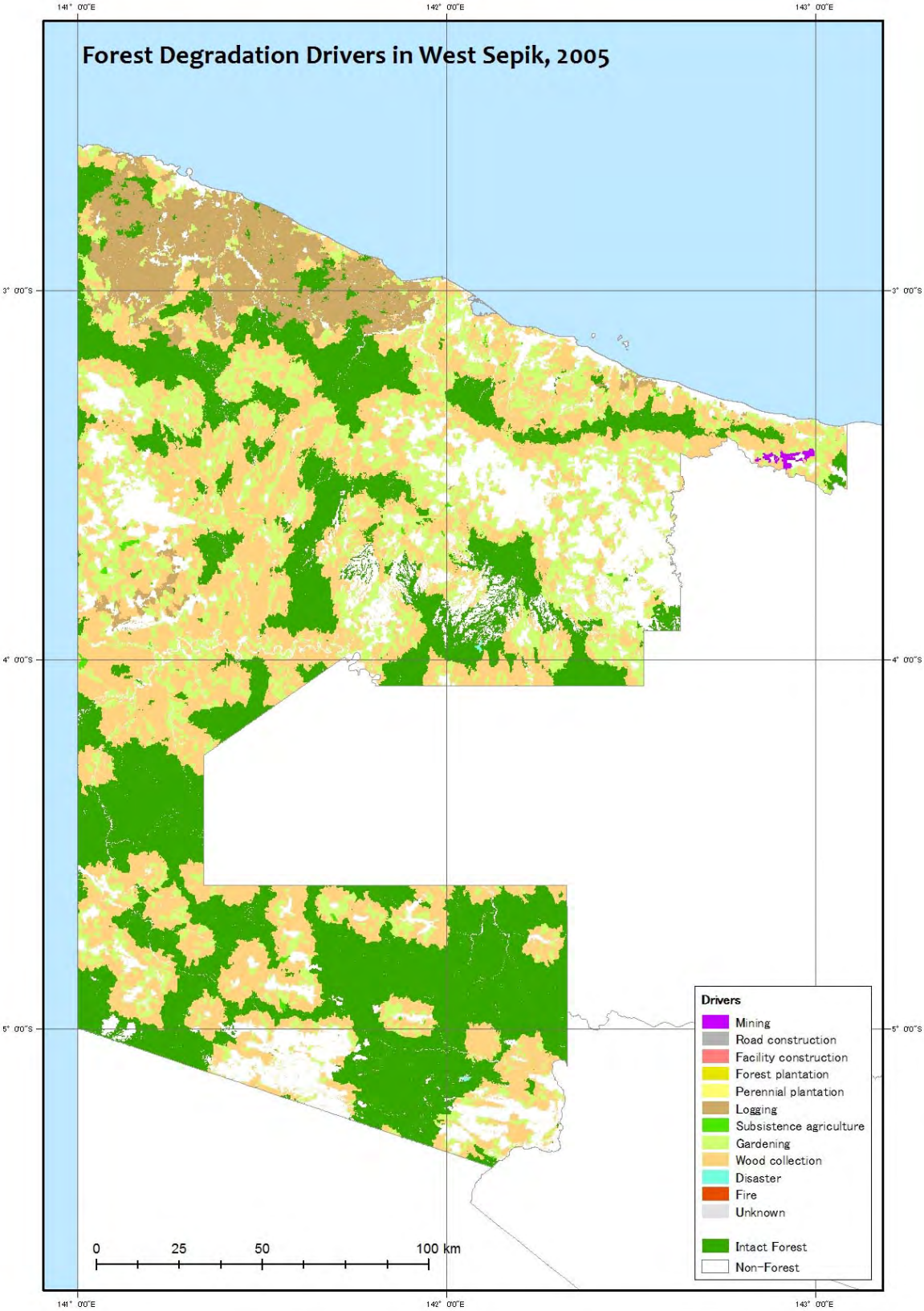
Forest Degradation Drivers of WNB: Drivers Area (ha) x Year

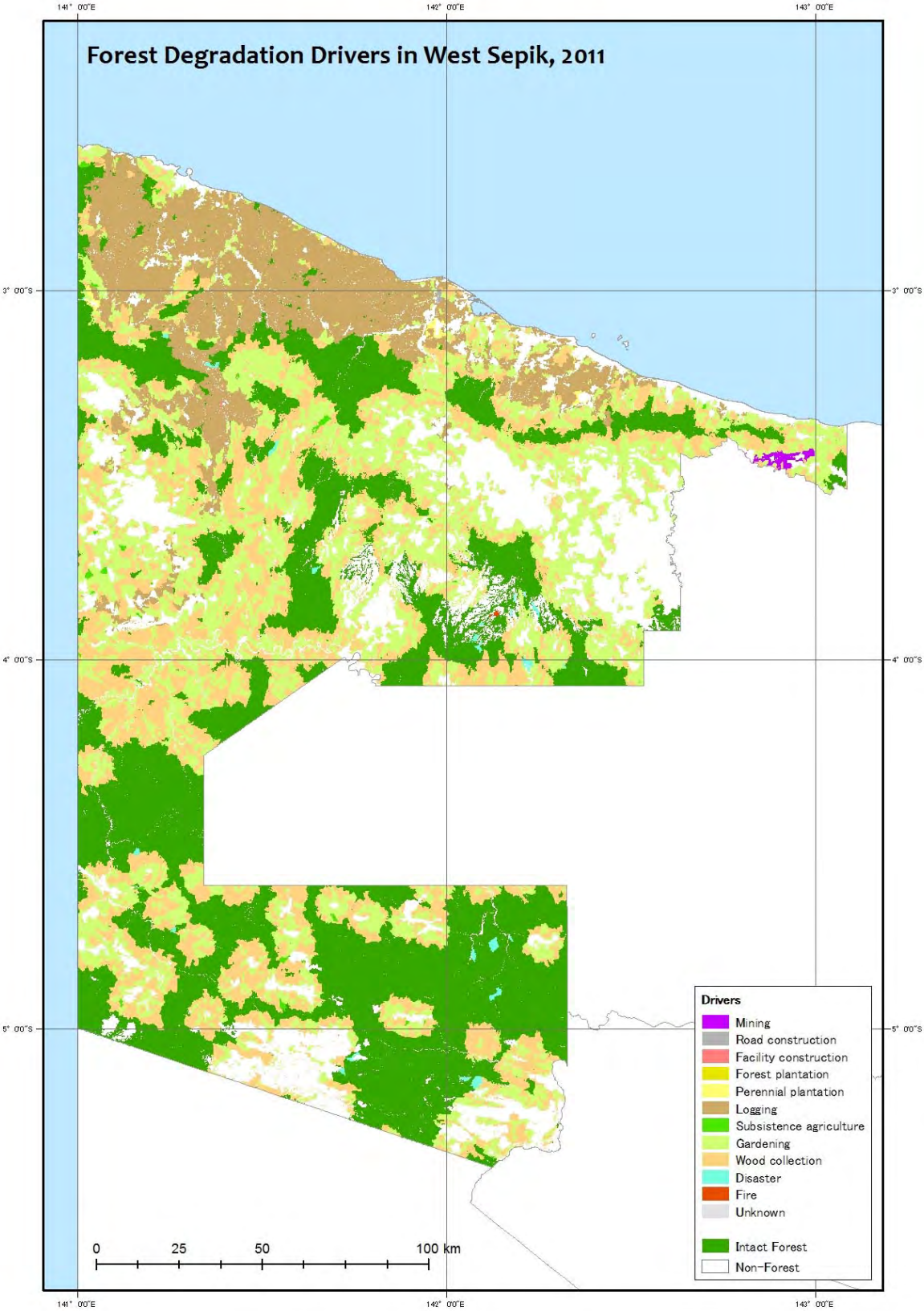
	Drivers	2000	2005	2011
	Mining	–	0	0
	Road construction	–	0	0
	Facility construction	–	0	180
	Forest plantation	–	0	137
	Perennial plantation	–	39,818	54,294
	Logging	614,318	592,924	724,572
	Subsistence agriculture	–	1,862	2,003
	Gardening	–	207,225	214,989
	Wood collection	474,105	265,713	169,140
	Disaster	–	1,209	1,306
	Fire	–	0	0
	Unknown	–	0	0
	(Intact Forest)	669,525	629,811	550,934
	SUM	1,757,949	1,738,561	1,717,558



Forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WSP)



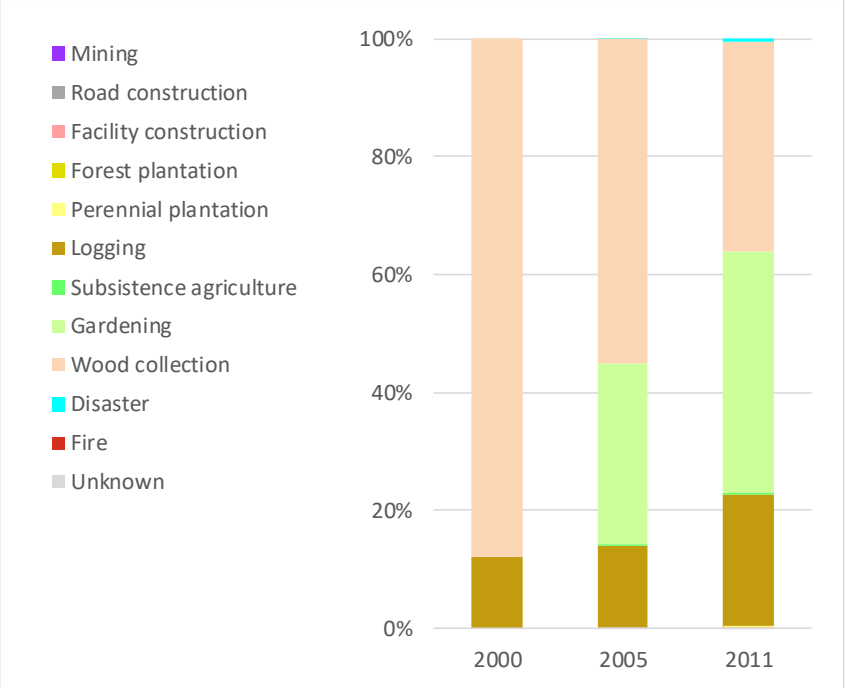




Area of forest degradation driver map of Forest Cover Map 2000, 2005, and 2011 (WSP)

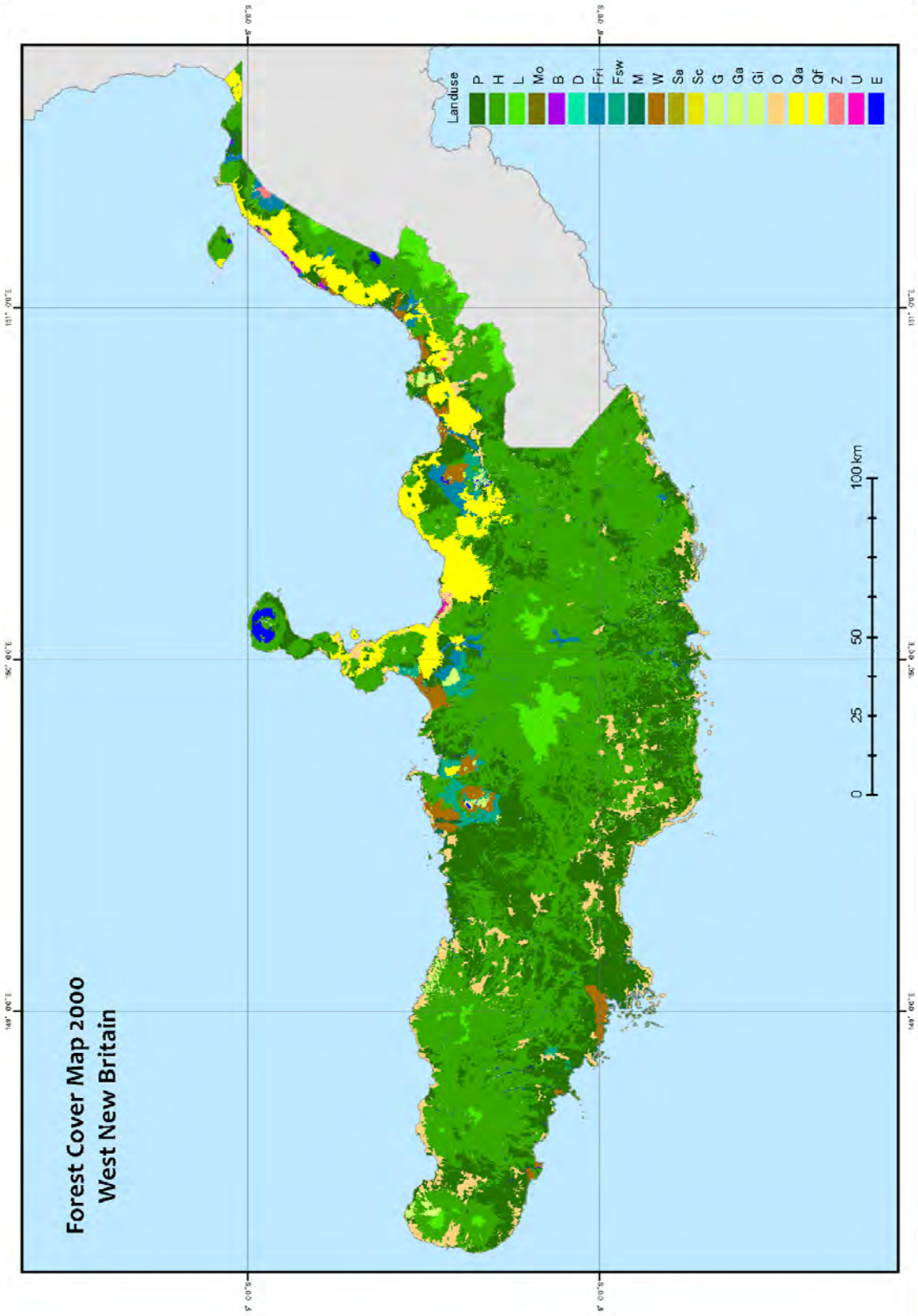
Forest Degradation Drivers of WSP: Drivers Area (ha) x Year

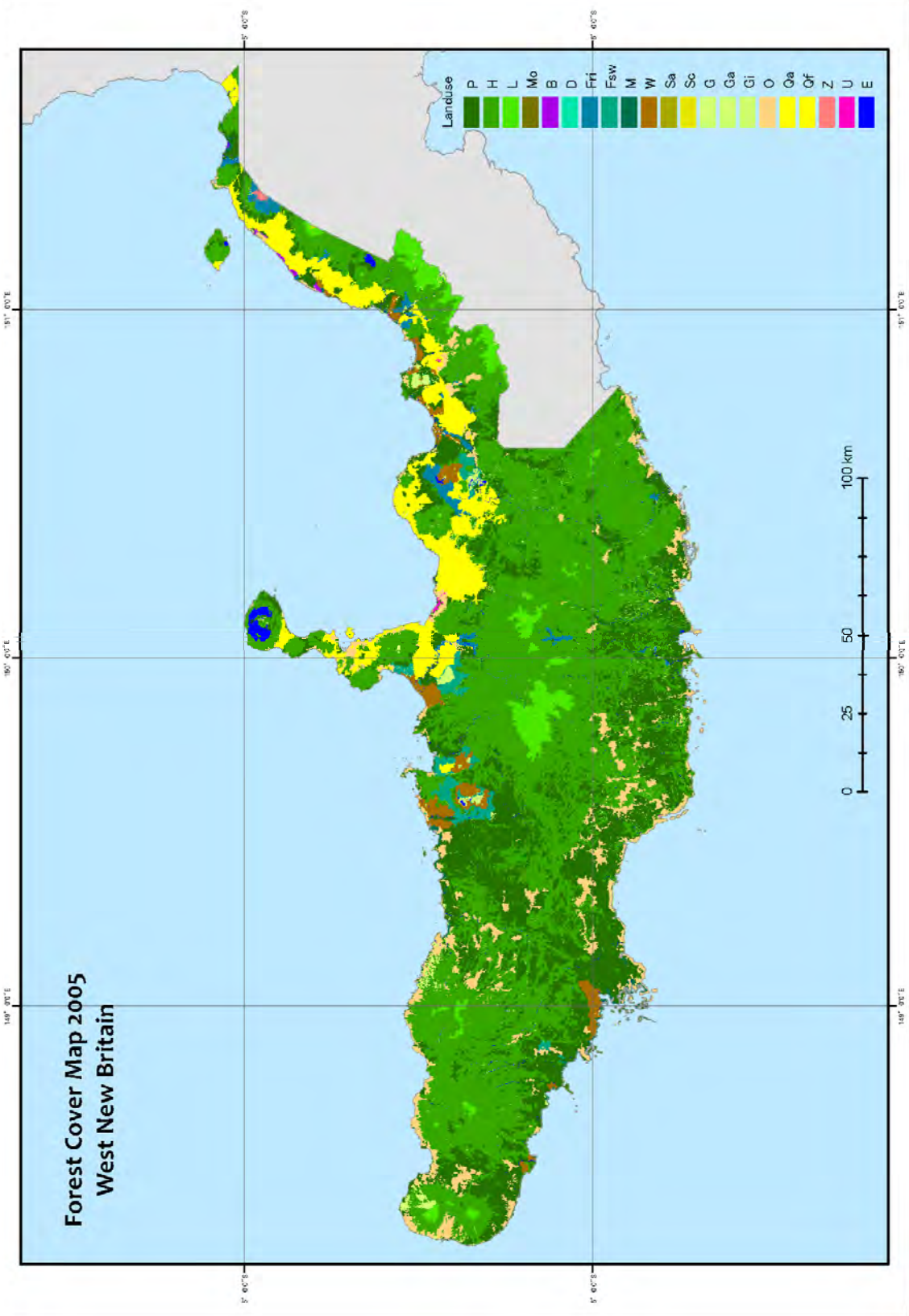
	Drivers	2000	2005	2011
	Mining	–	3,350	4,455
	Road construction	–	0	513
	Facility construction	–	0	135
	Forest plantation	–	0	0
	Perennial plantation	–	444	3,362
	Logging	232,422	263,344	432,329
	Subsistence agriculture	–	5,720	6,302
	Gardening	–	594,167	796,861
	Wood collection	1,690,079	1,057,868	695,540
	Disaster	–	549	7,920
	Fire	–	0	321
	Unknown	–	0	0
	(Intact Forest)	1,132,492	1,111,709	1,051,445
	SUM	3,054,993	3,037,150	2,999,183

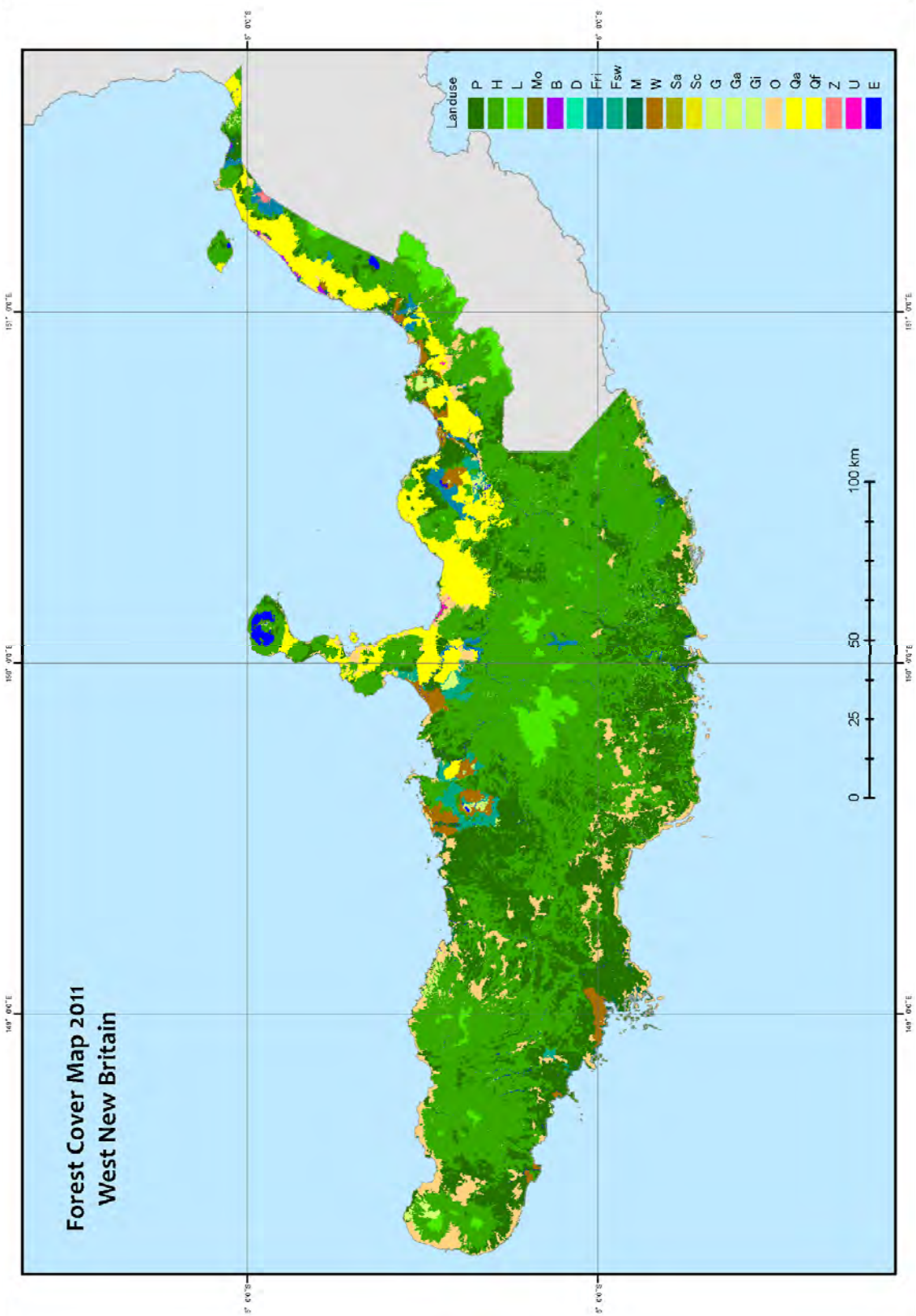


B. Forest Cover Map (Past)

Forest Cover Map 2000, 2005, and 2011 (WNB)







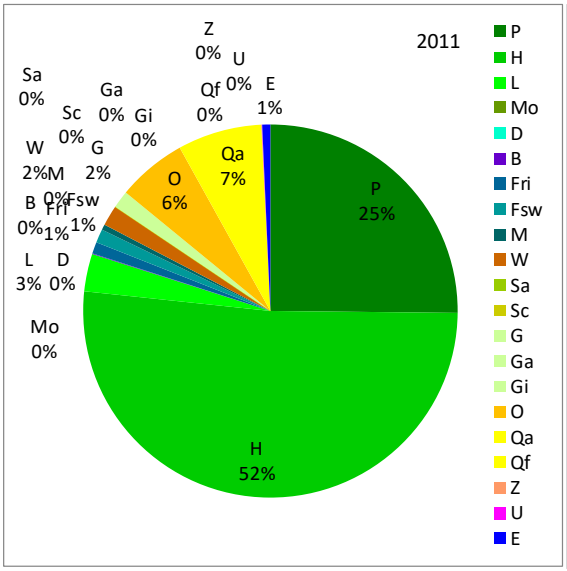
Area of Forest Cover Map 2000, 2005, and 2011 (WNB)

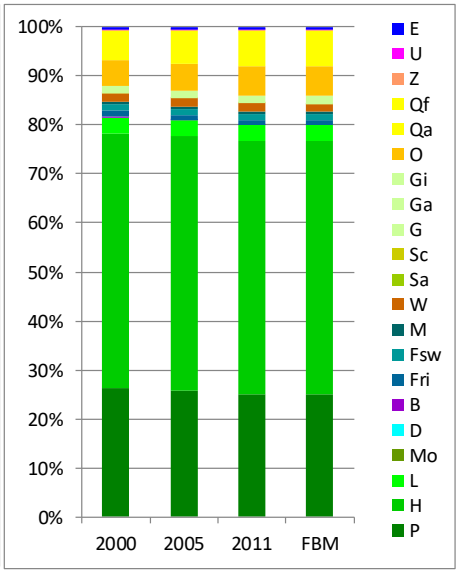
Forest Cover Map of WNB: Vegetation Type Area (ha) x Year

	VEG	VEGNAME	2000	2005	2011	FBM
	P	Low Altitude Forest on Plains & Fans	535,769	524,515	511,652	508,762
	H	Low Altitude Forest on Uplands	1,056,131	1,053,508	1,048,040	1,050,299
	L	Lower Montane Forest	66,383	66,383	66,313	66,313
	Mo	Montane Forest				
	D	Dry Seasonal Forest				
	B	Littoral Forest	1,392	1,222	1,111	1,111
	Fri	Seral Forest	25,263	20,605	20,366	20,373
	Fsw	Swamp Forest	26,076	26,029	24,208	24,365
	M	Mangrove Forest	9,667	9,667	9,553	8,299
	W	Woodland	37,156	36,803	36,203	33,882
	Sa	Savanna				
	Sc	Scrub	112	112	112	112
	G	Grassland and Herbland	29,015	29,121	30,721	32,069
	Ga	Grassland (Alpine)				
	Gi	Grassland (Subalpine)				
	O	Cropland/Agriculture land	106,022	112,050	122,038	125,999
	Qa	Plantation other than Qf	125,378	138,350	147,766	146,980
	Qf	Forest Plantation				
	Z	Bare areas	1,137	1,137	1,137	1,137
	U	Larger Urban Centres	651	651	651	185
	E	Lake & Larger Rivers	14,130	14,130	14,130	14,114
		SUM	2,034,281	2,034,281	2,034,000	2,034,000

	Forest Cover Area				
	Forest	1,720,681	1,701,927	1,681,243	1,679,523
	Forest & Woodland	1,757,837	1,738,730	1,717,446	1,713,405
*	Forest & Woodland & Scrub & Savanna	1,757,949	1,738,842	1,717,558	1,713,517

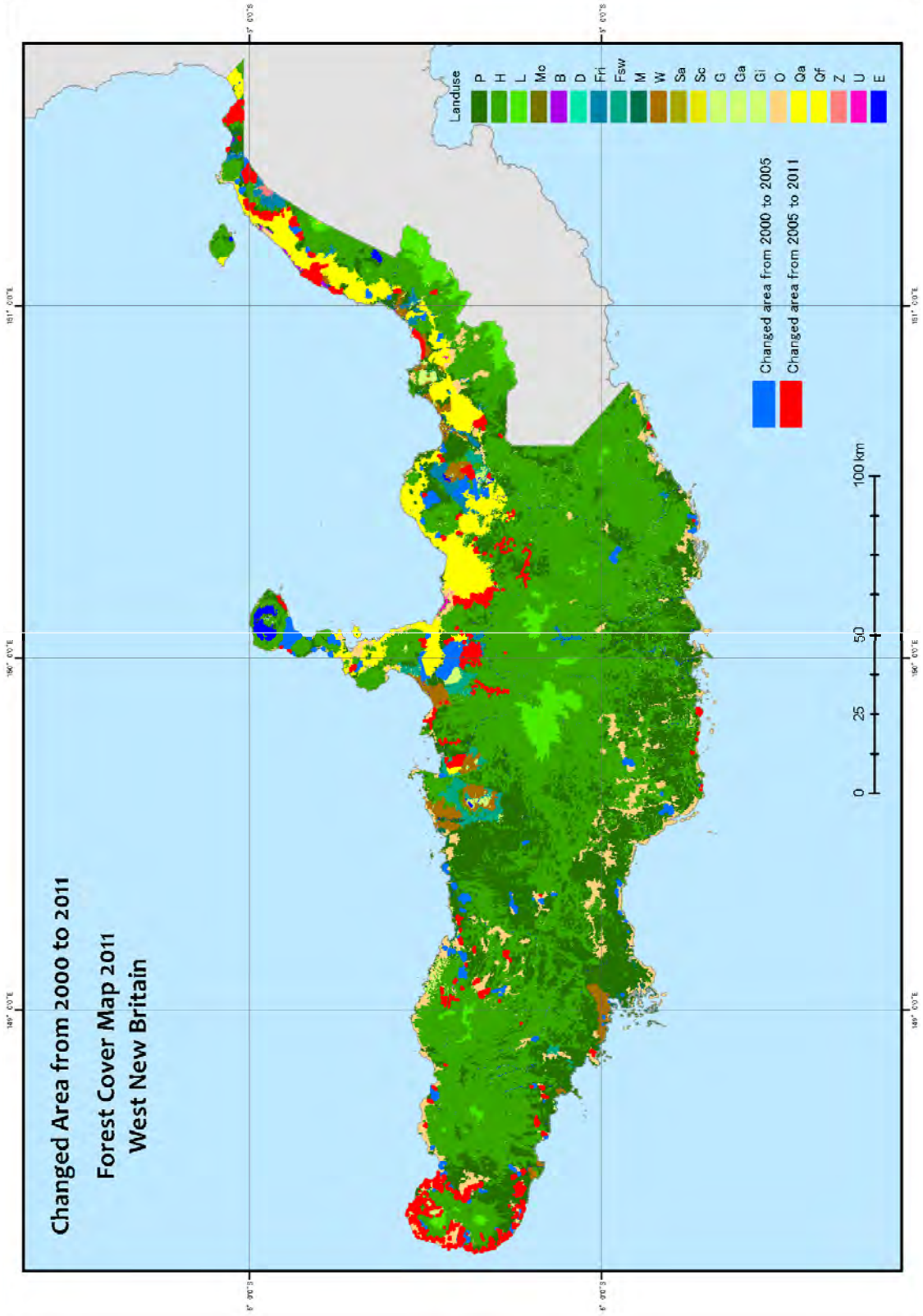
	Forest Cover Rate				
	Forest	84.6%	83.7%	82.7%	82.6%
	Forest & Woodland	86.4%	85.5%	84.4%	84.2%
*	Forest & Woodland & Scrub & Savanna	86.4%	85.5%	84.4%	84.2%





*FBM: Forest Base Map 2012 (ver.1.1)

Map of forest cover change between 2000 - 2011 (WNB)

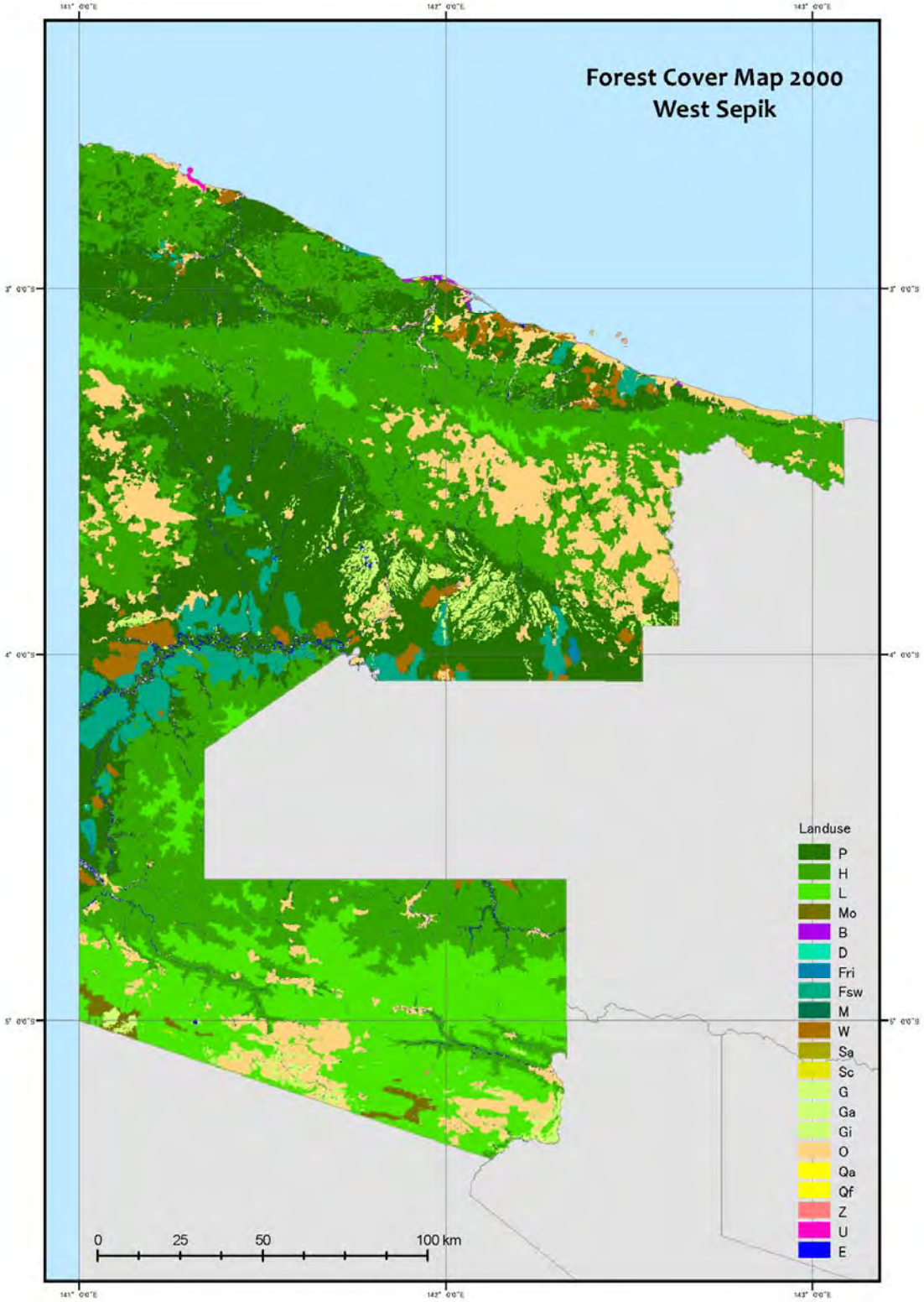


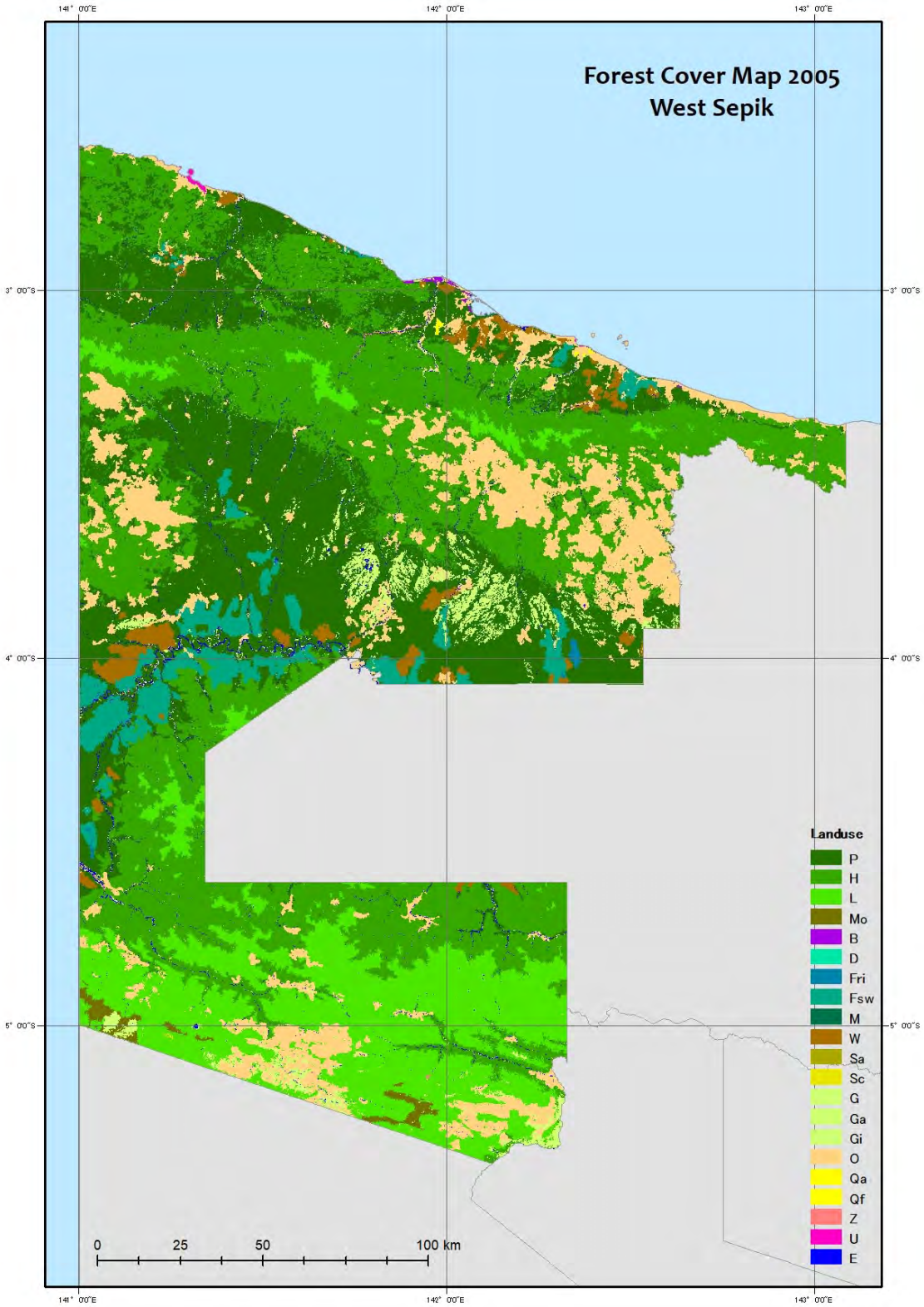
Area of forest cover change between 2000 - 2011 (WNB)

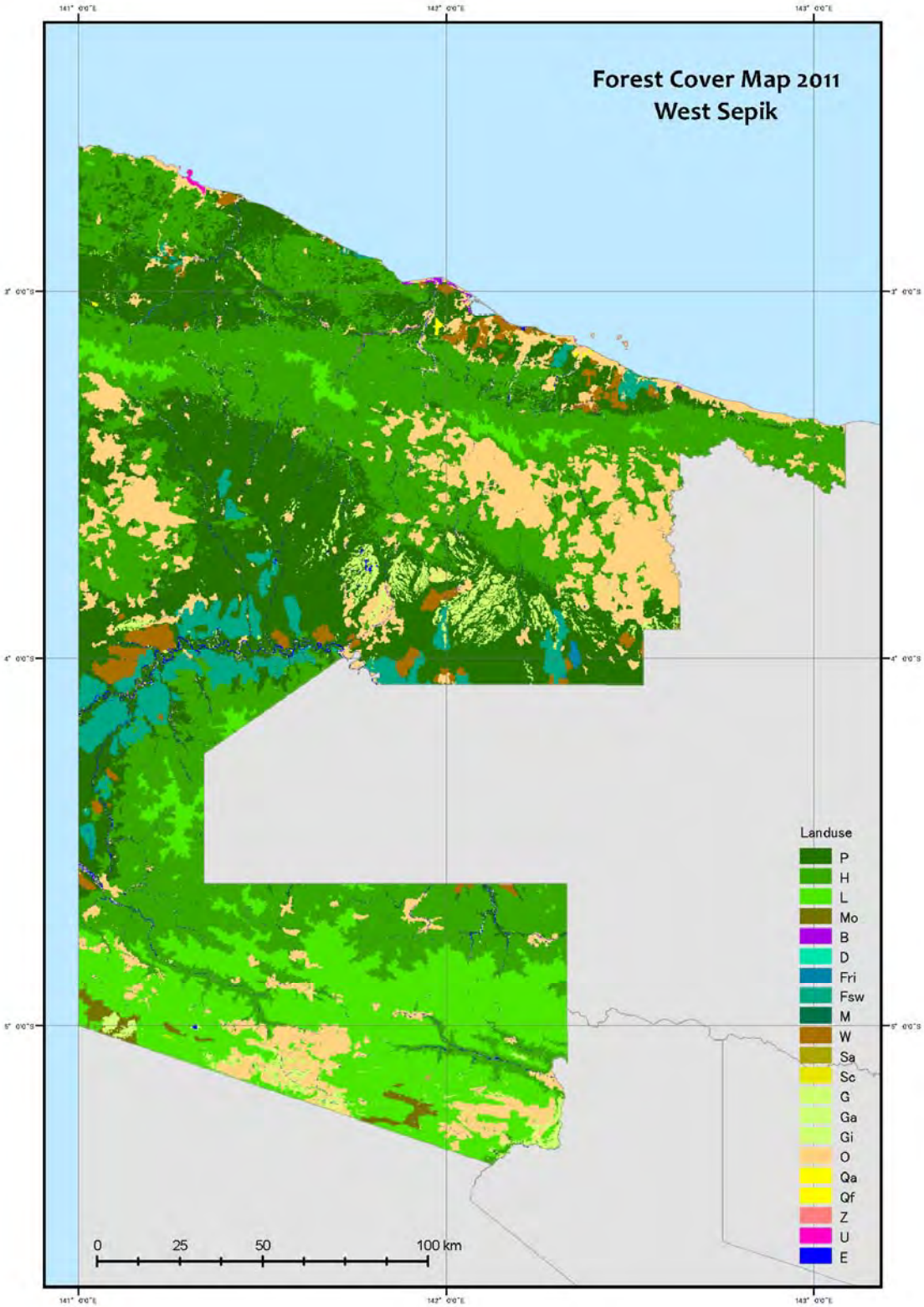
Forest Cover Map of WNB: Changed Area (ha) x Year

	VEG	2000->2005	2005->2011	Sum
	P	-11,254	-12,863	-24,117
	H	-2,623	-5,468	-8,092
	L	0	-70	-70
	Mo	0	0	0
	D	0	0	0
	B	-171	-111	-281
	Fri	-4,658	-238	-4,896
	Fsw	-47	-1,820	-1,868
	M	0	-114	-114
	W	-354	-600	-954
	Sa	0	0	0
	Sc	0	0	0
	G	106	1,600	1,706
	Ga	0	0	0
	Gi	0	0	0
	O	6,028	9,988	16,016
	Qa	12,972	9,416	22,388
	Qf	0	0	0
	Z	0	0	0
	U	0	0	0
	E	0	0	0

Forest Cover Map 2000, 2005, and 2011 (WSP)







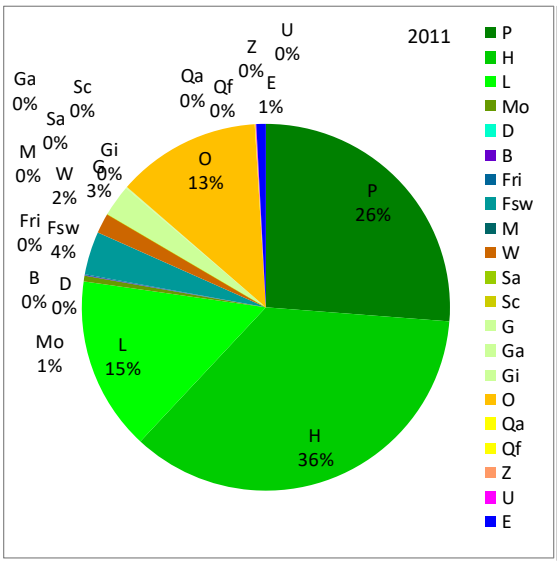
Area of Forest Cover Map 2000, 2005, and 2011 (WSP)

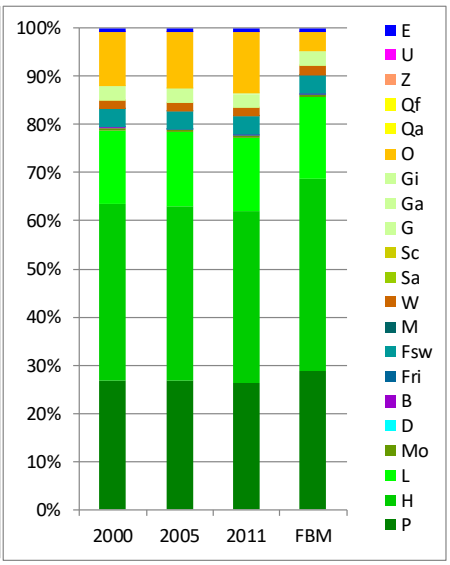
Forest Cover Map of WSP: Vegetation Type Area (ha) x Year

	VEG	VEGNAME	2000	2005	2011	FBM
	P	Low Altitude Forest on Plains & Fans	966,122	960,534	942,453	1,031,108
	H	Low Altitude Forest on Uplands	1,313,392	1,302,847	1,282,868	1,436,375
	L	Lower Montane Forest	550,787	550,608	550,405	611,335
	Mo	Montane Forest	18,002	18,002	18,002	18,002
	D	Dry Seasonal Forest				
	B	Littoral Forest	1,972	1,799	1,611	2,265
	Fri	Seral Forest	2,976	2,976	2,976	2,976
	Fsw	Swamp Forest	136,275	136,053	135,997	137,879
	M	Mangrove Forest	667	667	667	669
	W	Woodland	64,520	64,173	63,962	66,858
	Sa	Savanna				
	Sc	Scrub	280	280	280	282
	G	Grassland and Herbland	99,671	99,266	99,940	106,321
	Ga	Grassland (Alpine)	1,792	1,802	1,802	1,802
	Gi	Grassland (Subalpine)	2,550	2,550	2,550	2,550
	O	Cropland/Agriculture land	399,017	417,481	454,517	141,174
	Qa	Plantation other than Qf	1,272	1,299	1,501	1,479
	Qf	Forest Plantation				
	Z	Bare areas	1,999	1,992	2,022	1,984
	U	Larger Urban Centres	1,489	1,495	1,495	318
	E	Lake & Larger Rivers	29,984	29,716	29,719	29,389
		SUM	3,592,766	3,593,541	3,592,766	3,592,766

	Forest Cover Area				
	Forest	2,990,193	2,973,486	2,934,978	3,240,610
	Forest & Woodland	3,054,713	3,037,660	2,998,940	3,307,467
*	Forest & Woodland & Scrub & Savanna	3,054,992	3,037,939	2,999,220	3,307,749

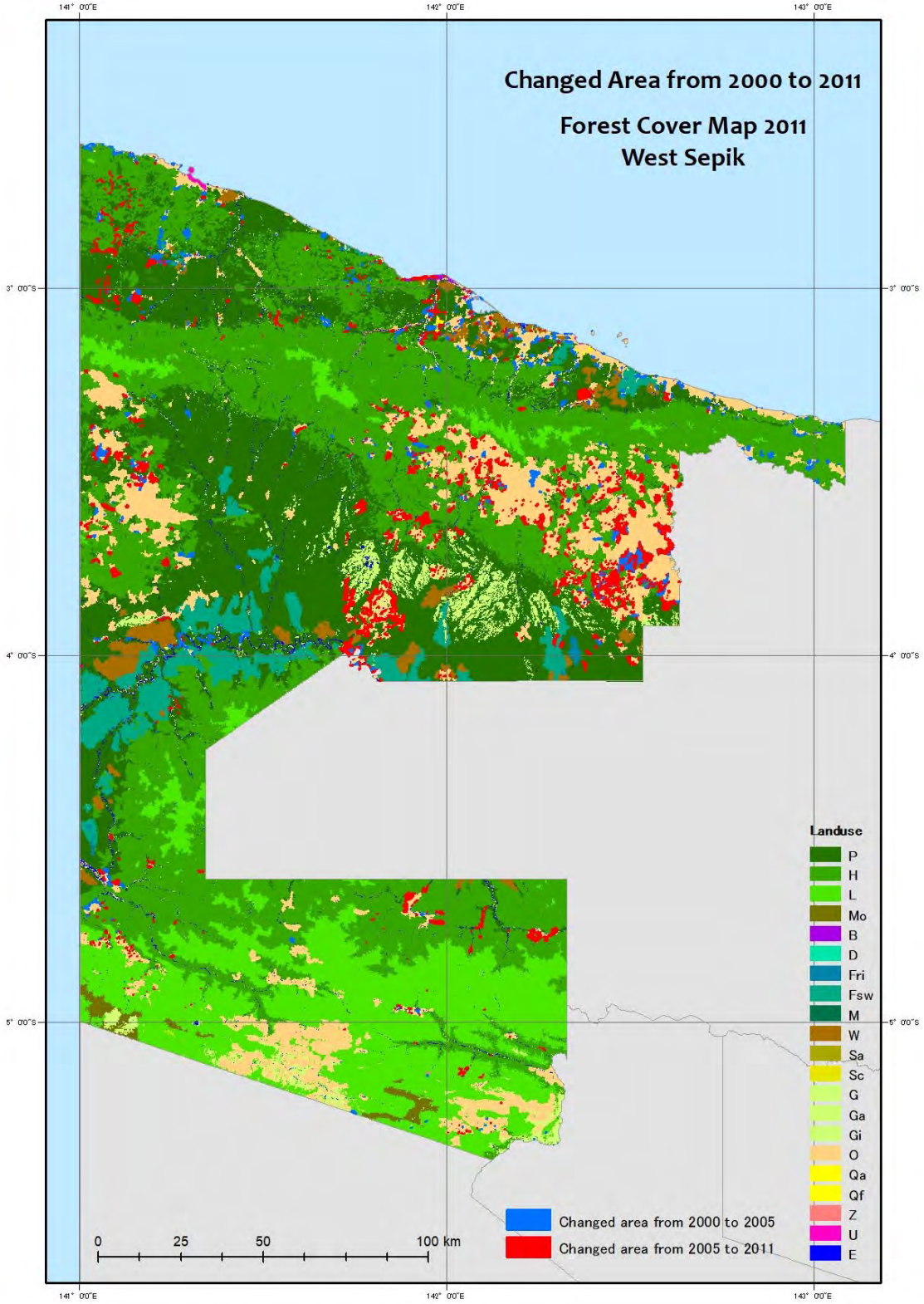
	Forest Cover Rate				
	Forest	83.2%	82.7%	81.7%	90.2%
	Forest & Woodland	85.0%	84.5%	83.5%	92.1%
*	Forest & Woodland & Scrub & Savanna	85.0%	84.5%	83.5%	92.1%





*FBM: Forest Base Map 2012 (ver.1.1)

Map of forest cover change between 2000 - 2011 (WSP)



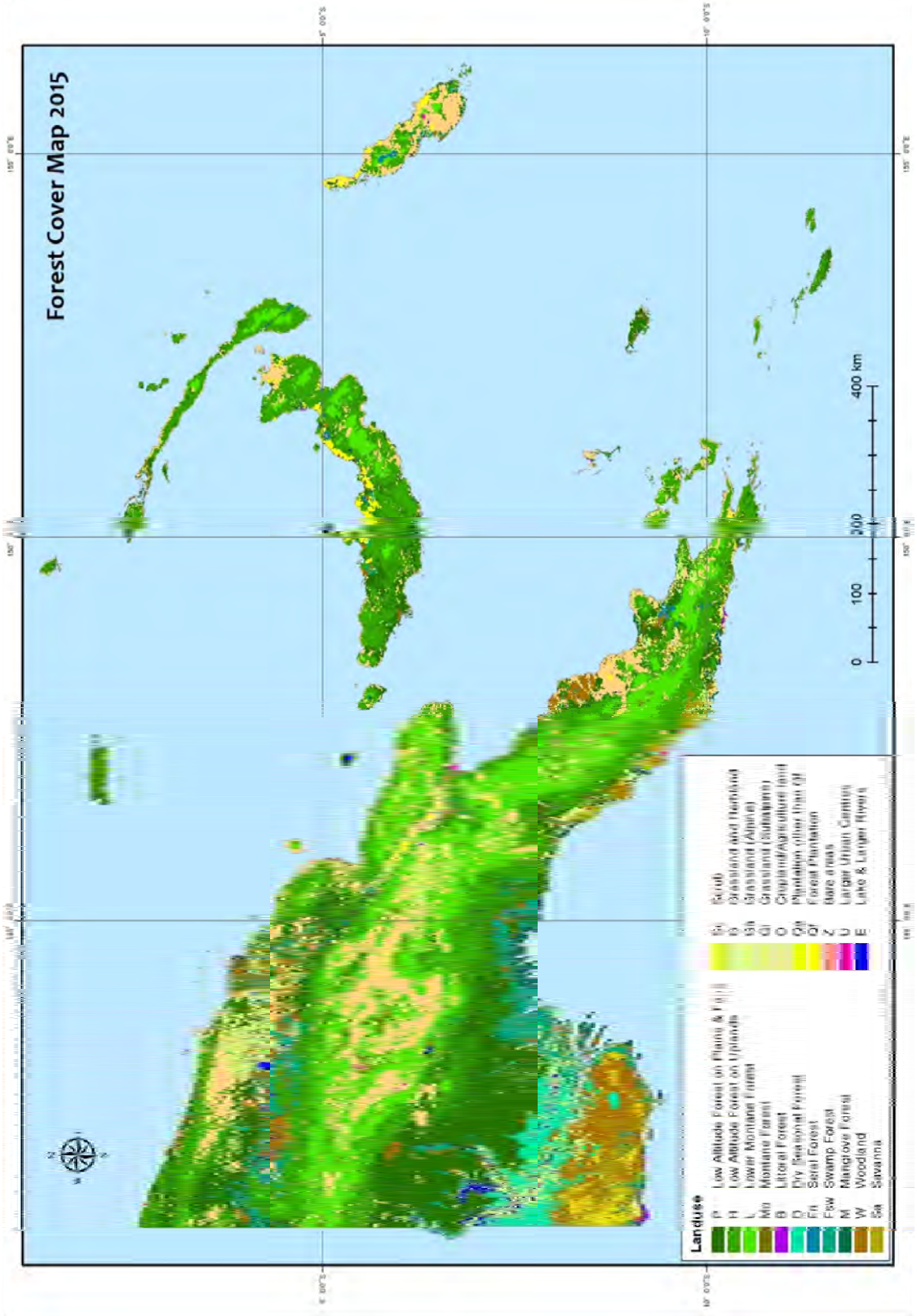
Area of forest cover change between 2000 - 2011 (WSP)

Forest Cover Map of WSP: Changed Area (ha) x Year

	VEG	2000->2005	2005->2011	Sum
	P	-5,588	-18,081	-23,669
	H	-10,545	-19,979	-30,525
	L	-178	-203	-382
	Mo	0	0	0
	D	0	0	0
	B	-173	-188	-362
	Fri	0	0	0
	Fsw	-222	-56	-278
	M	0	0	0
	W	-347	-211	-558
	Sa	0	0	0
	Sc	0	0	0
	G	-404	673	269
	Ga	11	0	11
	Gi	0	0	0
	O	18,464	37,036	55,499
	Qa	27	202	229
	Qf	0	0	0
	Z	-7	30	23
	U	6	0	6
	E	-268	3	-265

C. Forest Cover Map 2015

Forest Cover Map 2015 (PNG)



Area of Forest Cover Map 2015 (PNG)

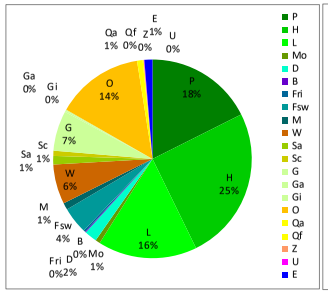
Forest Cover Map 2015: Vegetation Type Area (ha) x Province

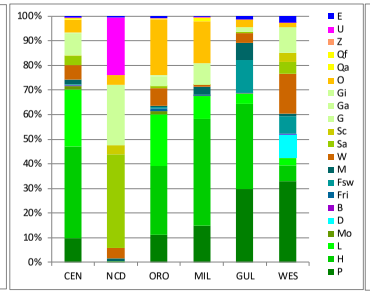
＊Islands outside PNG, which are located to the south of WES and ARB, are removed.

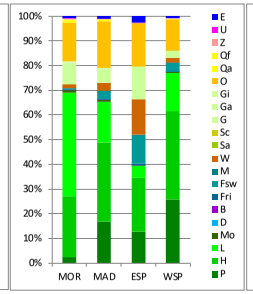
	VEG	VEGNAME	SUM	CEN	NCD	ORO	MIL	GUL	WES	MOR	MAD	ESP	WSP	SIM	ENG	EHP	SHP	HLA	WHP	JIW	WNB	ENB	MAN	NIL	ARB
	P	Low Altitude Forest on Plains & Fans	8,133,318	291,297	86	250,148	209,617	1,037,288	3,219,315	83,273	487,257	561,207	929,227	6,636	2,616	2,073	136,408	12,307	5,937	8,890	509,372	128,978	62,107	137,337	51,942
	H	Low Altitude Forest on Uplands	11,603,863	1,100,915	32	632,574	616,187	1,199,609	628,310	829,418	921,453	943,443	1,282,150	109,872	49,428	56,311	411,192	56,573	18,167	64,456	1,045,668	821,476	105,341	530,199	181,087
	L	Lower Montane Forest	7,465,348	680,095		474,980	129,735	149,739	289,140	1,409,655	482,290	224,211	550,342	251,897	480,057	579,057	443,042	544,065	101,833	164,273	66,313	269,688		103,008	71,928
	Mo	Montane Forest	354,495	39,006		30,097	647		2,661	39,179	21,849	4,055	18,002	15,852	107,762	13,368	9,163	19,510	14,676	18,668					
	D	Dry Seasonal Forest	935,207						935,207																
	B	Littoral Forest	66,616	12,076		70	4,379	1,023	37,194	1,103	1,059	1,262	1,611								1,111	2,345	20	1	3,364
	Fri	Seral Forest	147,631	6,762		25,796	1,166	356	9,833	3,504	5,801	24,393	2,976								20,140	17,638		6,910	22,355
	Fsw	Swamp Forest	1,989,886	9,065		12,803	1,118	465,631	684,599	20,519	95,286	492,947	135,886		183		14,417	212	80	14	23,525	58		644	32,900
	M	Mangrove Forest	518,964	52,658	305	11,533	46,700	241,236	111,843	3,150	277	17,575	667								9,553	2,636	3,649	14,622	2,561
	W	Woodland	2,989,010	172,725	1,071	160,862	12,001	136,701	1,574,900	51,379	97,924	630,395	63,962				13,110	380			34,719	2,309		20,193	16,380
	Sa	Savanna	635,125	113,592	9,970	18,914	35	14,486	478,110						18										
	Sc	Scrub	391,709	6,673	978	1,626	1,332		374,163	11			280					111			112	27			6,397
	G	Grassland and Herbland	3,005,981	241,444	6,395	87,406	120,132	72,940	1,009,448	283,329	163,822	581,845	100,034	20,804	16,486	185,494	6,174	13,450	2,936	1,524	30,357	18,935	4,860	25,203	12,964
	Ga	Grassland (Alpine)	107,065	19,612		8,379	2,148		941	10,798	2,246	446	1,802	736	37,858	763	2,249	17,741	1,228	100					16
	Gi	Grassland (Subalpine)	86,977	11,580		6,562	426		344	18,207	6,827	183	2,550	6,167	7,597	643	12,666	751	8,379	4,095					
	O	Cropland/Agriculture land	6,577,558	152,320	1,012	509,751	241,016	108,176	188,809	524,018	541,151	763,427	457,098	197,050	464,474	262,392	442,258	384,704	267,182	210,680	122,620	202,662	14,130	79,621	443,006
	Qa	Plantation other than Qf	422,484	7,534		10,628	23,051	1,069		30,798	23,639	2,482	12,936	169	126	4,592	1		9,847	6,158	154,594	35,412	877	17,621	80,951
	Qf	Forest Plantation	67,951	18,207			1,214			17,654	4,893				25	4,911	290		1,569			19,189			
	Z	Bare areas	24,151	152	6	360	50		1,298	9,341	2,890		2,022		16	171	363		315	257	1,137	1,427	967	656	2,724
	U	Larger Urban Centres	38,332	692	6,095	352	792	202	727	8,081	1,497	2,699	1,495	691	4,429	857	1,300	2,438	0	88	651	619	708	585	3,332
	E	Lake & Larger Rivers	599,488	19,378	165	20,530	4,921	43,404	250,937	25,206	30,164	118,028	29,725	3,467	2,362	4,043	12,119	3,352	849	1,319	14,129	6,025	418	3,095	5,853
		SUM	46,161,159	2,955,783	26,114	2,263,371	1,416,666	3,471,860	9,797,778	3,368,621	2,890,325	4,368,599	3,592,766	613,341	1,173,438	1,114,676	1,504,751	1,055,593	432,998	480,522	2,034,000	1,529,425	193,077	939,696	937,760

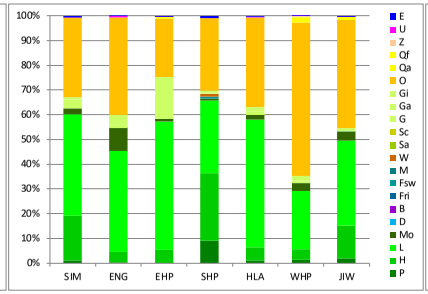
	Forest Cover Area	(ha)																							
	Forest	31,283,279	2,210,079	423	1,438,002	1,010,762	3,094,881	5,918,102	2,407,454	2,020,165	2,269,094	2,920,861	384,257	640,072	655,720	1,014,513	632,666	142,262	256,300	1,675,681	1,262,009	171,117	792,722	366,137
	Forest&Woodland	34,272,288	2,382,804	1,494	1,598,863	1,022,763	3,231,582	7,493,002	2,458,833	2,118,089	2,899,490	2,984,823	384,257	640,072	655,720	1,027,622	633,045	142,262	256,300	1,710,400	1,264,318	171,117	812,915	382,517
＊	Forest&Woodland&Scrub&Savanna	35,299,122	2,503,069	12,442	1,619,404	1,024,130	3,246,068	8,345,275	2,458,844	2,118,089	2,899,490	2,985,102	384,257	640,090	655,720	1,027,622	633,156	142,262	256,300	1,710,512	1,264,344	171,117	812,915	388,913

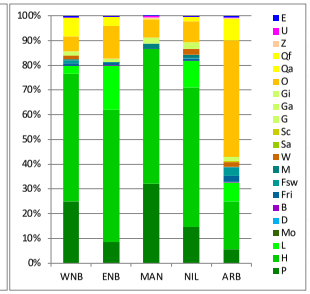
	Forest Cover Rate	(%)																							
	Forest	67.8%	74.8%	1.6%	63.5%	71.3%	89.1%	60.4%	71.5%	69.9%	51.9%	81.3%	62.6%	54.5%	58.8%	67.4%	59.9%	32.9%	53.3%	82.4%	82.5%	88.6%	84.4%	39.0%
	Forest&Woodland	74.2%	80.6%	5.7%	70.6%	72.2%	93.1%	76.5%	73.0%	73.3%	66.4%	83.1%	62.6%	54.5%	58.8%	68.3%	60.0%	32.9%	53.3%	84.1%	82.7%	88.6%	86.5%	40.8%
＊	Forest&Woodland&Scrub&Savanna	76.5%	84.7%	47.6%	71.5%	72.3%	93.5%	85.2%	73.0%	73.3%	66.4%	83.1%	62.6%	54.5%	58.8%	68.3%	60.0%	32.9%	53.3%	84.1%	82.7%	88.6%	86.5%	41.5%











Above-ground living biomass

VEG	VEGNAME	SUM	CEN	NCD	ORO	MIL	GUL	WES	MOR	MAD	ESP	WSP	SIM	ENG	EHP	SHP	HLA	WHP	JIW	WNB	ENB	MAN	NIL	ARB
P	Low Altitude Forest on Plains & Fans	1,813.73	64.96	0.02	55.78	46.74	231.32	717.91	18.57	108.66	125.15	207.22	1.48	0.58	0.46	30.42	2.74	1.32	1.98	113.59	28.76	13.85	30.63	11.58
H	Low Altitude Forest on Uplands	2,587.66	245.50	0.01	141.06	137.41	267.51	140.11	184.96	205.48	210.39	285.92	24.50	11.02	12.56	91.70	12.62	4.05	14.37	233.18	183.19	23.49	118.23	40.38
L	Lower Montane Forest	1,045.15	95.21		66.50	18.16	20.96	40.48	197.35	67.52	31.39	77.05	35.27	67.21	81.07	62.03	76.17	14.26	23.00	9.28	37.76		14.42	10.07
Mo	Montane Forest	49.63	5.46		4.21	0.09		0.37	5.49	3.06	0.57	2.52	2.22	15.09	1.87	1.28	2.73	2.05	2.61					
D	Dry Seasonal Forest	121.58						121.58																
B	Littoral Forest	14.86	2.69		0.02	0.98	0.23	8.29	0.25	0.24	0.28	0.36								0.25	0.52	0.00	0.00	0.75
Fri	Seral Forest	32.92	1.51		5.75	0.26	0.08	2.19	0.78	1.29	5.44	0.66								4.49	3.93		1.54	4.99
Fsw	Swamp Forest	443.74	2.02		2.86	0.25	103.84	152.67	4.58	21.25	109.93	30.30		0.04		3.22	0.05	0.02	0.00	5.25	0.01		0.14	7.34
M	Mangrove Forest	99.64	10.11	0.06	2.21	8.97	46.32	21.47	0.60	0.05	3.37	0.13								1.83	0.51	0.70	2.81	0.49
W	Woodland	388.57	22.45	0.14	20.91	1.56	17.77	204.74	6.68	12.73	81.95	8.32				1.70	0.05			4.51	0.30		2.63	2.13
Sa	Savanna	82.57	14.77	1.30	2.46	0.00	1.88	62.15						0.00										
Sc	Scrub	27.42	0.47	0.07	0.11	0.09		26.19	0.00			0.02					0.01			0.01	0.00			0.45
G	Grassland and Herbland																							
Ga	Grassland (Alpine)																							
Gi	Grassland (Subalpine)																							
O	Cropland/Agriculture land																							
Qa	Plantation other than Qf																							
Qf	Forest Plantation	10.19	2.73			0.18			2.65	0.73				0.00	0.74	0.04		0.24			2.88			
Z	Bare areas																							
U	Larger Urban Centres																							
E	Lake & Larger Rivers																							
	SUM	6,717.66	467.89	1.59	301.88	214.70	689.91	1498.16	421.90	421.02	568.47	612.49	63.47	93.95	96.70	190.39	94.36	21.94	41.97	372.40	257.86	38.05	170.40	78.18

Below-ground living biomass

VEG	VEGNAME	SUM	CEN	NCD	ORO	MIL	GUL	WES	MOR	MAD	ESP	WSP	SIM	ENG	EHP	SHP	HLA	WHP	JIW	WNB	ENB	MAN	NIL	ARB
P	Low Altitude Forest on Plains & Fans	671.08	24.03	0.01	20.64	17.30	85.59	265.63	6.87	40.20	46.31	76.67	0.55	0.22	0.17	11.26	1.02	0.49	0.73	42.03	10.64	5.12	11.33	4.29
H	Low Altitude Forest on Uplands	957.43	90.84	0.00	52.19	50.84	98.98	51.84	68.44	76.03	77.84	105.79	9.07	4.08	4.65	33.93	4.67	1.50	5.32	86.28	67.78	8.69	43.75	14.94
L	Lower Montane Forest	282.19	25.71		17.95	4.90	5.66	10.93	53.28	18.23	8.48	20.80	9.52	18.15	21.89	16.75	20.57	3.85	6.21	2.51	10.19		3.89	2.72
Mo	Montane Forest	13.40	1.47		1.14	0.02		0.10	1.48	0.83	0.15	0.68	0.60	4.07	0.51	0.35	0.74	0.55	0.71					
D	Dry Seasonal Forest	34.04						34.04																
B	Littoral Forest	5.50	1.00		0.01	0.36	0.08	3.07	0.09	0.09	0.10	0.13								0.09	0.19	0.00	0.00	0.28
Fri	Seral Forest	12.18	0.56		2.13	0.10	0.03	0.81	0.29	0.48	2.01	0.25								1.66	1.46		0.57	1.84
Fsw	Swamp Forest	164.19	0.75		1.06	0.09	38.42	56.49	1.69	7.86	40.67	11.21		0.02		1.19	0.02	0.01	0.00	1.94	0.00		0.05	2.71
M	Mangrove Forest	48.82	4.95	0.03	1.09	4.39	22.70	10.52	0.30	0.03	1.65	0.06								0.90	0.25	0.34	1.38	0.24
W	Woodland	108.80	6.29	0.04	5.86	0.44	4.98	57.33	1.87	3.56	22.95	2.33				0.48	0.01			1.26	0.08		0.74	0.60
Sa	Savanna	23.12	4.13	0.36	0.69	0.00	0.53	17.40						0.00										
Sc	Scrub	10.97	0.19	0.03	0.05	0.04		10.48	0.00			0.01					0.00			0.00	0.00			0.18
G	Grassland and Herbland																							
Ga	Grassland (Alpine)																							
Gi	Grassland (Subalpine)																							
O	Cropland/Agriculture land																							
Qa	Plantation other than Qf																							
Qf	Forest Plantation	3.77	1.01			0.07			0.98	0.27				0.00	0.27	0.02		0.09			1.07			
Z	Bare areas																							
U	Larger Urban Centres																							
E	Lake & Larger Rivers																							
	SUM	2,335.49	160.93	0.47	102.79	78.55	256.96	518.63	135.29	147.58	200.17	217.93	19.73	26.53	27.48	63.96	27.02	6.49	12.97	136.67	91.67	14.16	61.71	27.80

Total living biomass

VEG	VEGNAME	SUM	CEN	NCD	ORO	MIL	GUL	WES	MOR	MAD	ESP	WSP	SIM	ENG	EHP	SHP	HLA	WHP	JIW	WNB	ENB	MAN	NIL	ARB
P	Low Altitude Forest on Plains & Fans	2,484.81	88.99	0.03	76.42	64.04	316.90	983.53	25.44	148.86	171.45	283.89	2.03	0.80	0.63	41.67	3.76	1.81	2.72	155.62	39.40	18.97	41.96	15.87
H	Low Altitude Forest on Uplands	3,545.10	336.34	0.01	193.26	188.25	366.49	191.96	253.40	281.51	288.23	391.71	33.57	15.10	17.20	125.62	17.28	5.55	19.69	319.46	250.97	32.18	161.98	55.32
L	Lower Montane Forest	1,327.34	120.92		84.45	23.07	26.62	51.41	250.64	85.75	39.86	97.85	44.79	85.35	102.96	78.77	96.73	18.11	29.21	11.79	47.95		18.31	12.79
Mo	Montane Forest	63.03	6.94		5.35	0.11		0.47	6.97	3.88	0.72	3.20	2.82	19.16	2.38	1.63	3.47	2.61	3.32					
D	Dry Seasonal Forest	155.62						155.62																
B	Littoral Forest	20.35	3.69		0.02	1.34	0.31	11.36	0.34	0.32	0.39	0.49								0.34	0.72	0.01	0.00	1.03
Fri	Seral Forest	45.10	2.07		7.88	0.36	0.11	3.00	1.07	1.77	7.45	0.91								6.15	5.39		2.11	6.83
Fsw	Swamp Forest	607.93	2.77		3.91	0.34	142.25	209.15	6.27	29.11	150.60	41.51		0.06		4.40	0.06	0.02	0.00	7.19	0.02		0.20	10.05
M	Mangrove Forest	148.47	15.06	0.09	3.30	13.36	69.01	32.00	0.90	0.08	5.03	0.19								2.73	0.75	1.04	4.18	0.73
W	Woodland	497.37	28.74	0.18	26.77	2.00	22.75	262.06	8.55	16.29	104.90	10.64				2.18	0.06			5.78	0.38		3.36	2.73
Sa	Savanna	105.68	18.90	1.66	3.15	0.01	2.41	79.56						0.00										
Sc	Scrub	38.39	0.65	0.10	0.16	0.13		36.67	0.00			0.03					0.01			0.01	0.00			0.63
G	Grassland and Herbland																							
Ga	Grassland (Alpine)																							
Gi	Grassland (Subalpine)																							
O	Cropland/Agriculture land																							
Qa	Plantation other than Qf																							
Qf	Forest Plantation	13.96	3.74			0.25			3.63	1.01				0.01	1.01	0.06		0.32			3.94			
Z	Bare areas																							
U	Larger Urban Centres																							
E	Lake & Larger Rivers																							
	SUM	9,053.15	628.82	2.06	404.67	293.25	946.86	2016.79	557.19	568.60	768.64	830.43	83.20	120.48	124.18	254.35	121.39	28.43	54.94	509.07	349.53	52.21	232.11	105.98

Forest carbon stocks

VEG	VEGNAME	SUM	CEN	NCD	ORO	MIL	GUL	WES	MOR	MAD	ESP	WSP	SIM	ENG	EHP	SHP	HLA	WHP	JIW	WNB	ENB	MAN	NIL	ARB
P	Low Altitude Forest on Plains & Fans	1,167.86	41.83	0.01	35.92	30.10	148.94	462.26	11.96	69.97	80.58	133.43	0.95	0.38	0.30	19.59	1.77	0.85	1.28	73.14	18.52	8.92	19.72	7.46
H	Low Altitude Forest on Uplands	1,666.20	158.08	0.00	90.83	88.48	172.25	90.22	119.10	132.31	135.47	184.10	15.78	7.10	8.09	59.04	8.12	2.61	9.26	150.15	117.96	15.13	76.13	26.00
L	Lower Montane Forest	623.85	56.83		39.69	10.84	12.51	24.16	117.80	40.30	18.74	45.99	21.05	40.12	48.39	37.02	45.47	8.51	13.73	5.54	22.54		8.61	6.01
Mo	Montane Forest	29.62	3.26		2.52	0.05		0.22	3.27	1.83	0.34	1.50	1.32	9.01	1.12	0.77	1.63	1.23	1.56					
D	Dry Seasonal Forest	73.14						73.14																
B	Littoral Forest	9.57	1.73		0.01	0.63	0.15	5.34	0.16	0.15	0.18	0.23								0.16	0.34	0.00	0.00	0.48
Fri	Seral Forest	21.20	0.97		3.70	0.17	0.05	1.41	0.50	0.83	3.50	0.43								2.89	2.53		0.99	3.21
Fsw	Swamp Forest	285.73	1.30		1.84	0.16	66.86	98.30	2.95	13.68	70.78	19.51		0.03		2.07	0.03	0.01	0.00	3.38	0.01		0.09	4.72
M	Mangrove Forest	69.78	7.08	0.04	1.55	6.28	32.44	15.04	0.42	0.04	2.36	0.09								1.28	0.35	0.49	1.97	0.34
W	Woodland	233.76	13.51	0.08	12.58	0.94	10.69	123.17	4.02	7.66	49.30	5.00				1.03	0.03			2.72	0.18		1.58	1.28
Sa	Savanna	49.67	8.88	0.78	1.48	0.00	1.13	37.39						0.00										
Sc	Scrub	18.04	0.31	0.05	0.07	0.06		17.23	0.00			0.01					0.01			0.01	0.00			0.29
G	Grassland and Herbland																							
Ga	Grassland (Alpine)																							
Gi	Grassland (Subalpine)																							
O	Cropland/Agriculture land																							
Qa	Plantation other than Qf																							
Qf	Forest Plantation	6.56	1.76			0.12			1.71	0.47				0.00	0.47	0.03		0.15			1.85			
Z	Bare areas																							
U	Larger Urban Centres																							
E	Lake & Larger Rivers																							
	SUM	4,254.98	295.54	0.97	190.20	137.83	445.03	947.89	261.88	267.24	361.26	390.30	39.10	56.62	58.36	119.54	57.05	13.36	25.82	239.26	164.28	24.54	109.09	49.81

D. Downloading and Processing Landsat Images

Downloading and Processing Landsat Images

Downloading Landsat images from USGS website

1. **Registering with USGS**

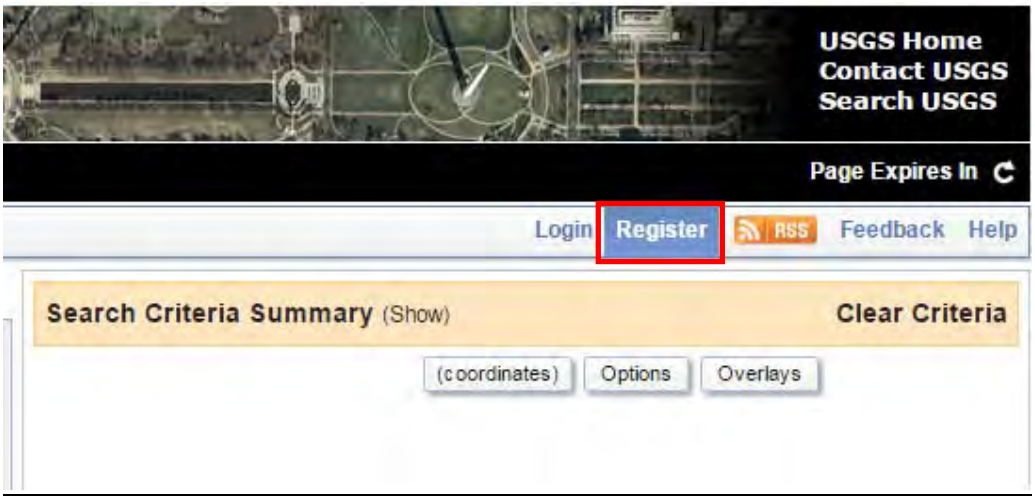
You need to have an account with USGS before you can down load any data.

Opening an account with USGS:

Open up google web browser (Google Chrome, Internet Explorer, Firefox, etc.)

- Type in the following into the address space on the web browser: http://earthexplorer.usgs.gov/
- Create an account with USGS.

  Click on the 'Register' tab.



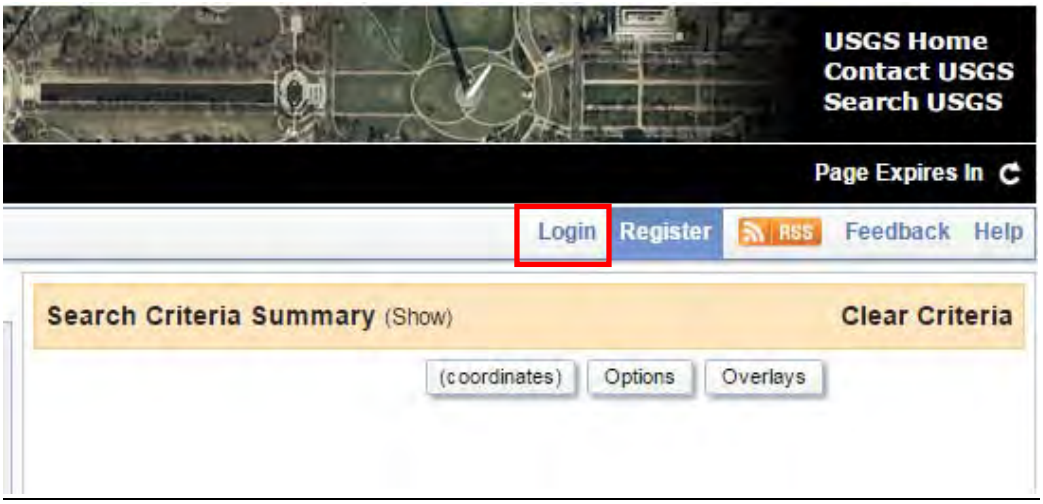
User Registration page opens. Fill out the details and submit.

When you have successfully open an account with USGS, your User name and your Pass word will be sent to your Gmail.

(Create a Gmail account if you do not have one)

Open up your Gmail and check to see if you have received your USGS User name and Password.

If you already have an account with USGS, click on the 'Login' tab and enter your User name and Password.



2. <u>ArcMap</u>

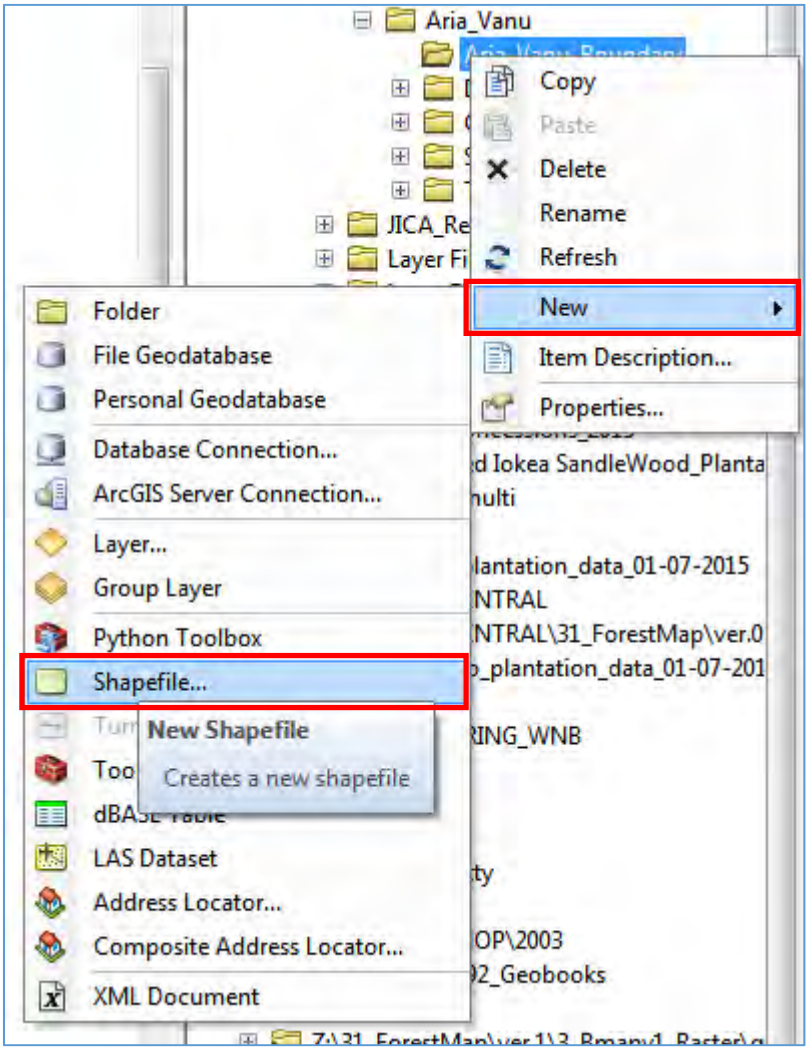
- Open up ArcMap. Go to the catalogue window. Using 'Catalogue' navigate to the folder where the concession boundary you are interested in is.

  (Note: For the purpose of this Manual, we will be using Aria Vanu Block 1 and 2 as our target concession areas.)

  Click on the concession boundary you want, drag it and drop it into ArcMap Data view.

  To make it easier to locate your interested concession area in USGS webpage and to download its Landsat satellite image, you need to create a simple shape file around the vicinity of the concession area.

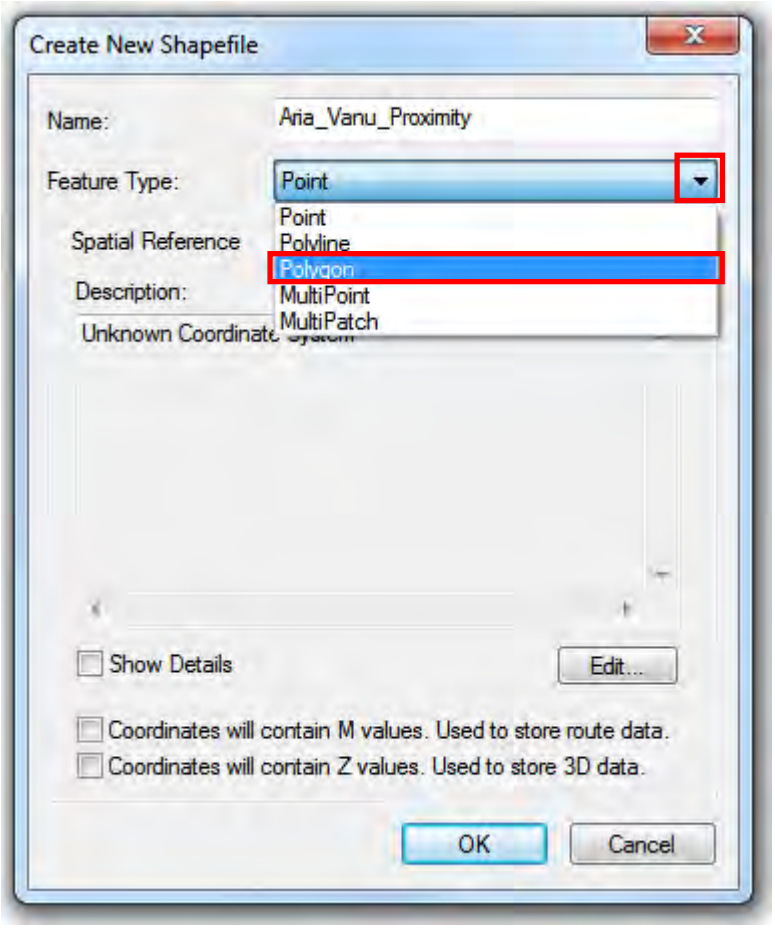
- Go to ‘Catalogue’ window on ArcMap and navigate to your desired output folder. Right-click on the folder, go down to ‘New’ and click on ‘Shapefile…’:



“Create New Shapefile” window appears.

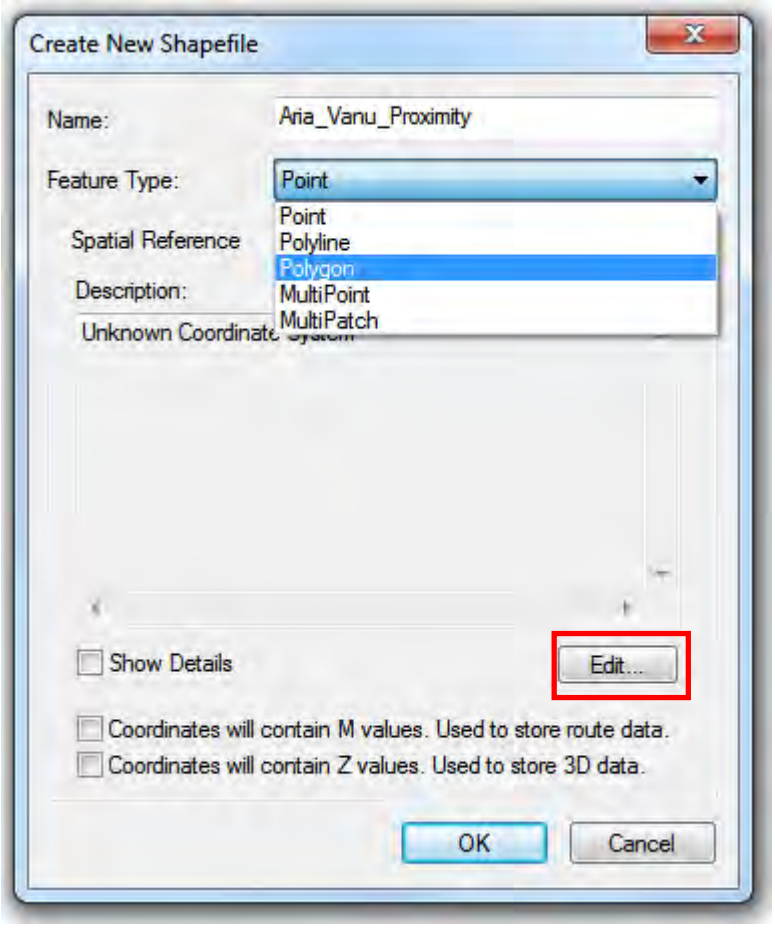
Give a name for the new shapefile.

Feature type: Click on the drop-down arrow and select “Polygon”.

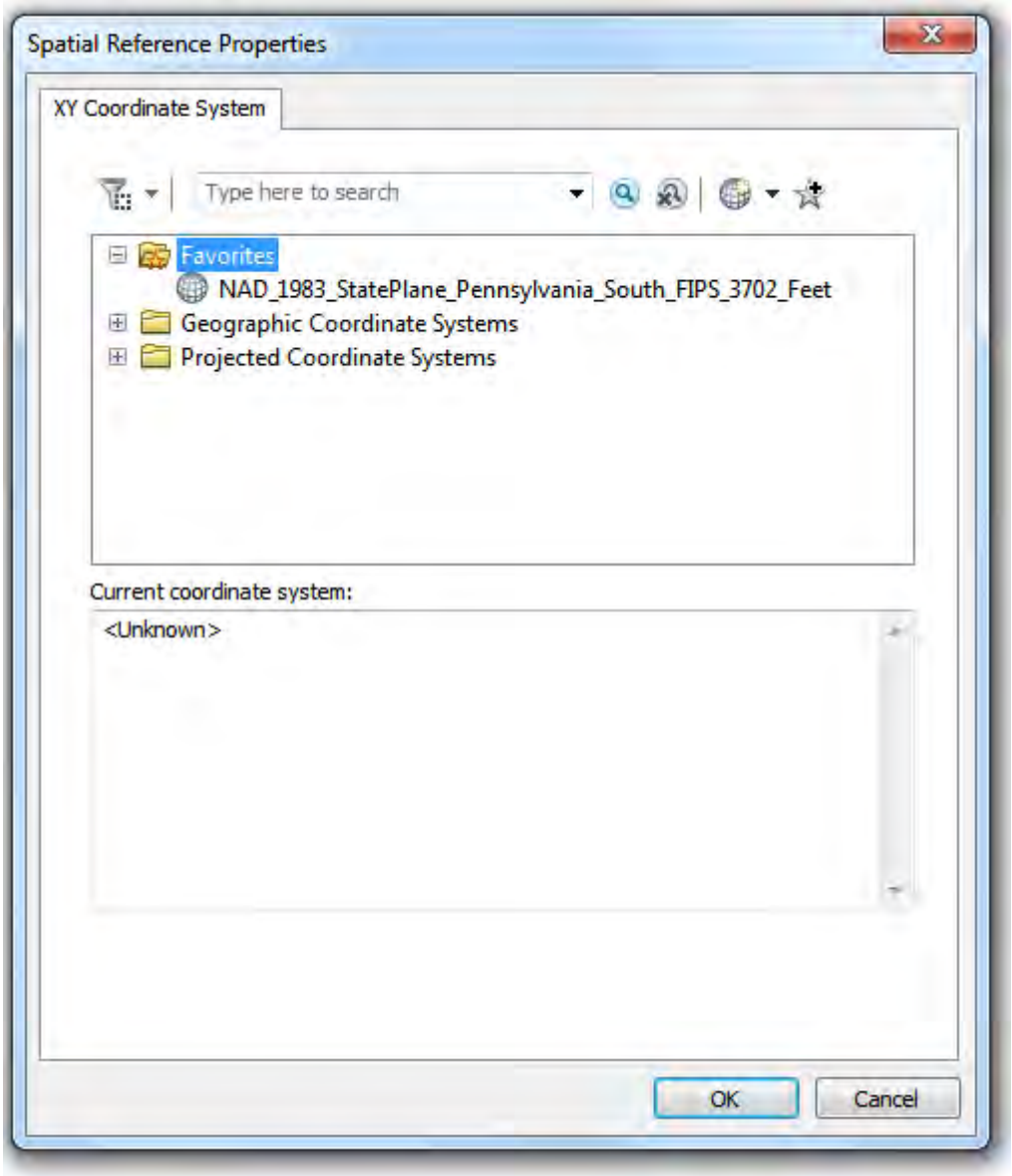


Now you must attach/Import coordinates to your newly created shapefile.

Under ‘Spatial Reference’, ‘Description’, click on the “Edit” button.

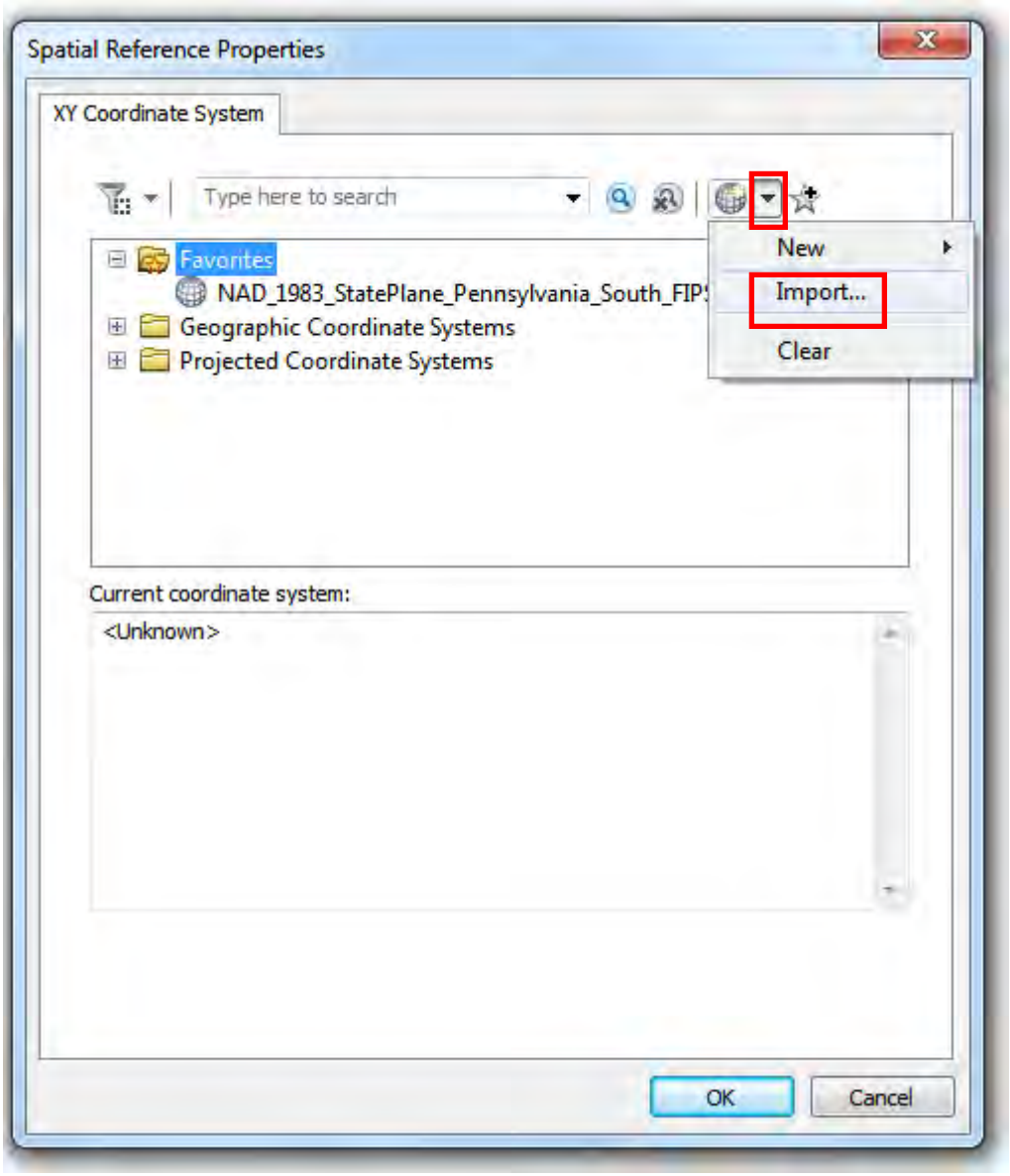


“Spatial Reference Properties” window pops up.



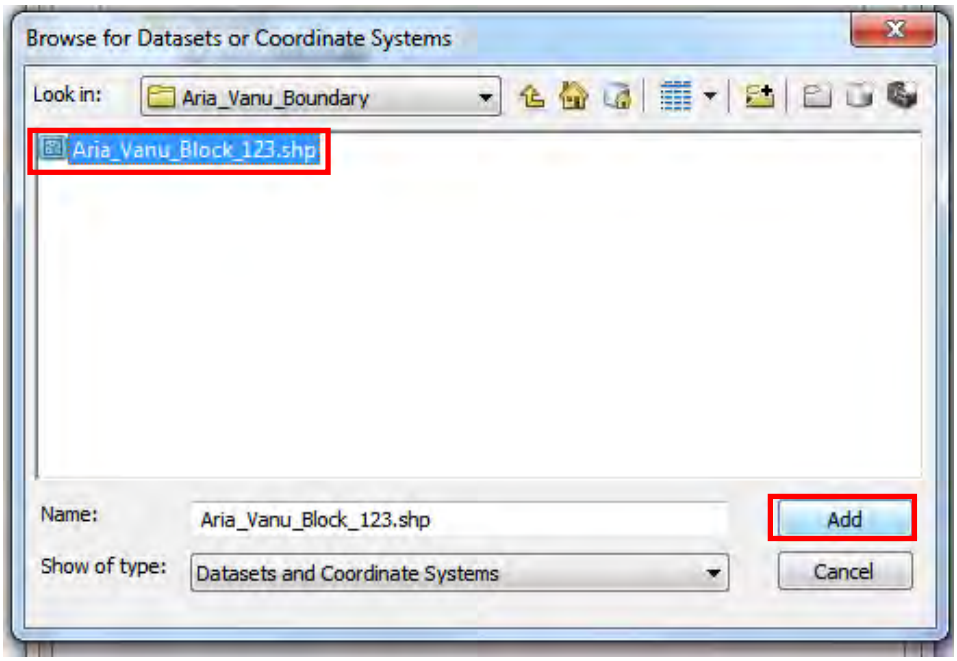
Click on the drop down arrow beside the “Add Coordinate System” button (globe icon).

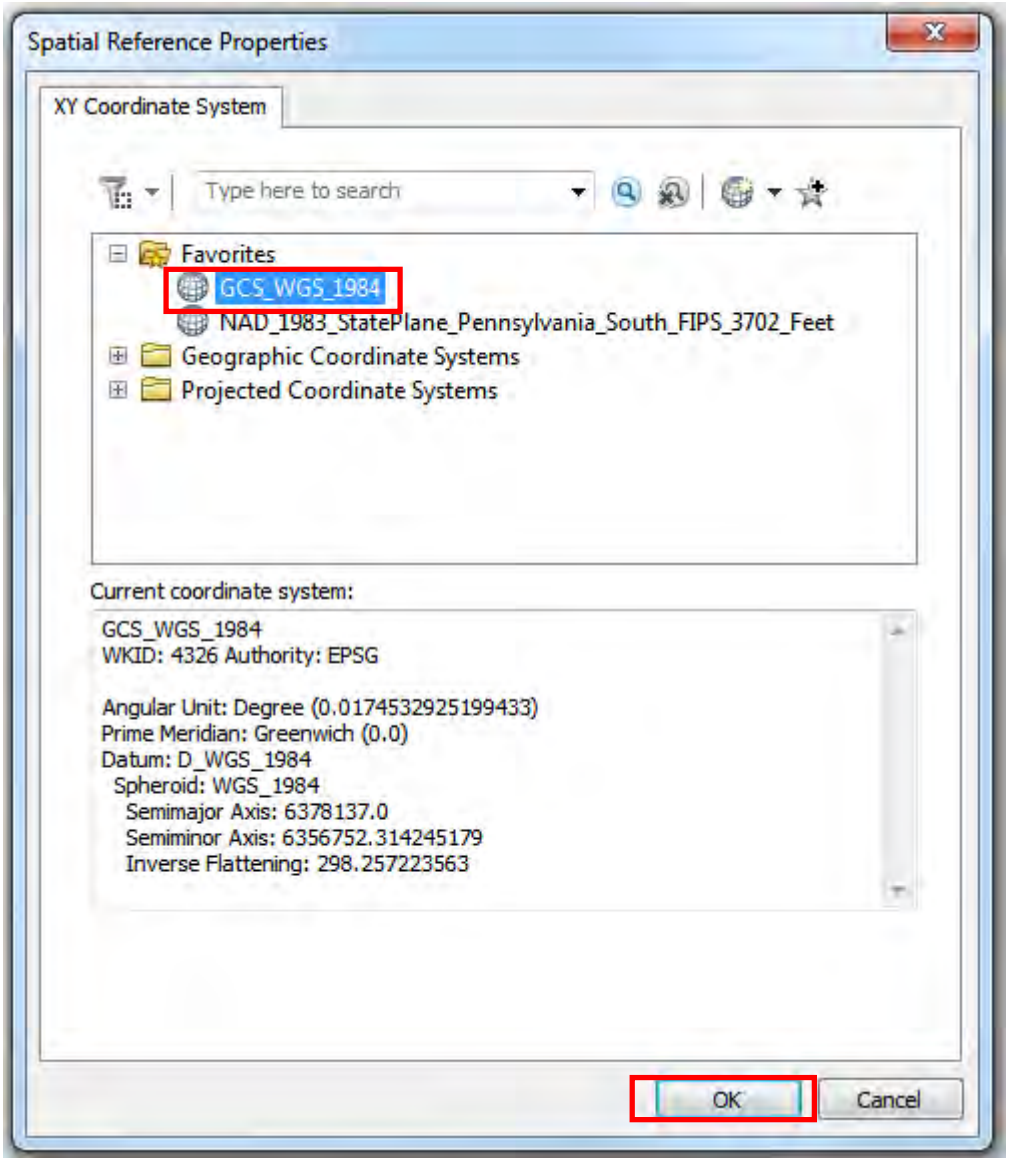
Click ‘import’; navigate to the location of the concession area you are working on.



Click in the concession area shapefile to select it.

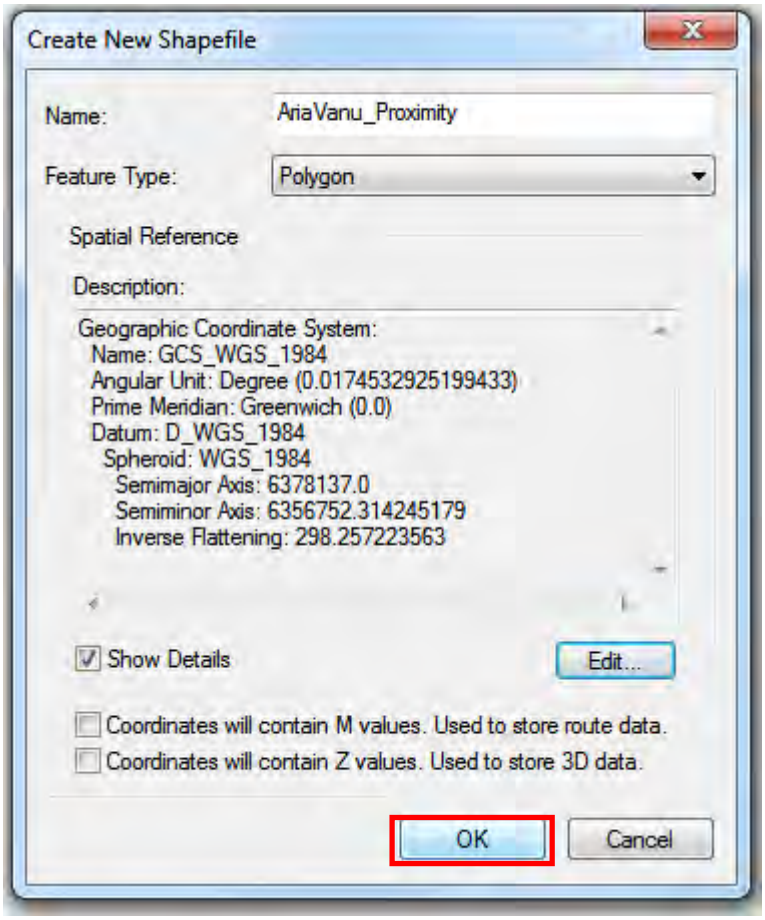
Click ‘Add’.





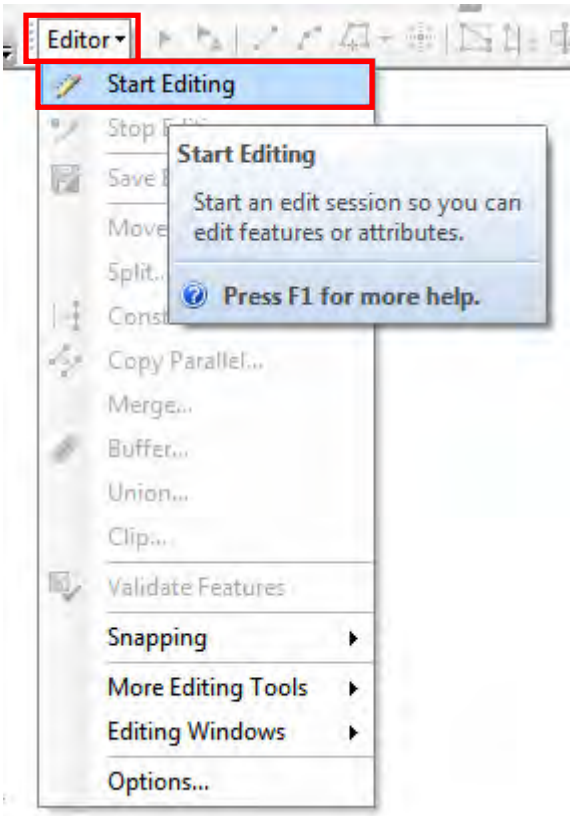
Click on the imported Coordinate System to select it.

Click 'Ok'.

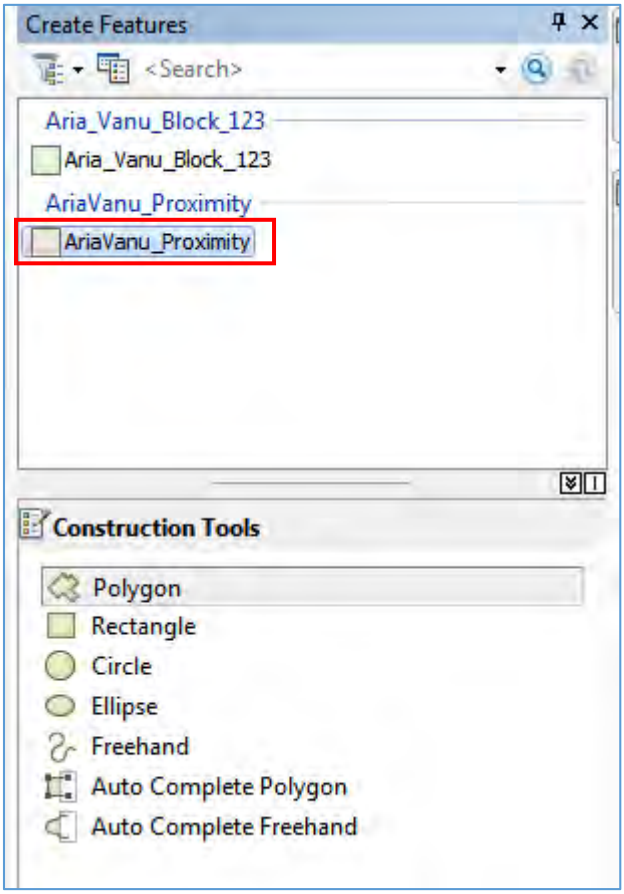

Create New Shapefile
Name:
AriaVanu_Proximity
Feature Type:
Polygon
Spatial Reference
Description:
Geographic Coordinate System:
Name: GCS_WGS_1984
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
Show Details
Edit...
Coordinates will contain M values. Used to store route data.
Coordinates will contain Z values. Used to store 3D data.
OK
Cancel

Click 'Ok'.

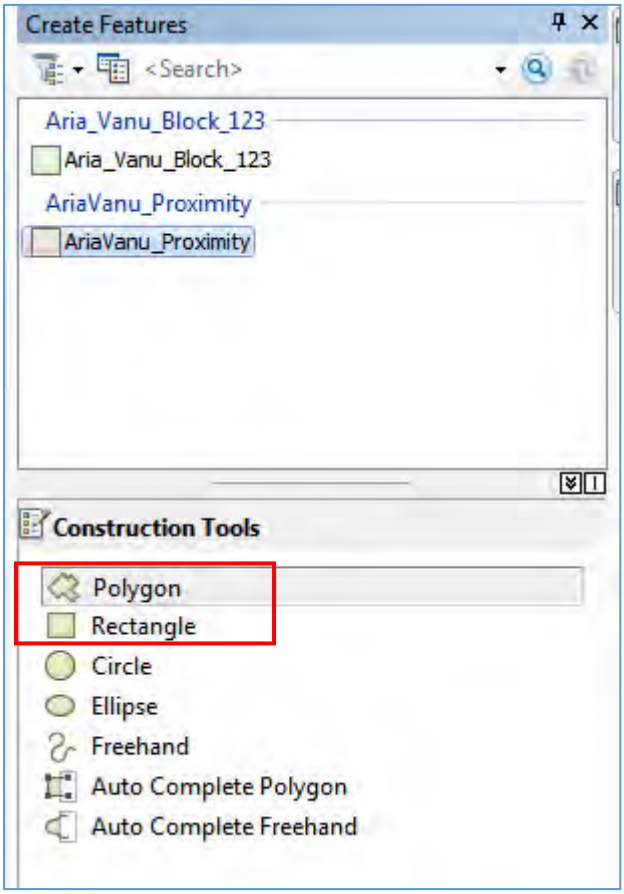
In ArcMap Click on ‘Editor’>Start Editing.



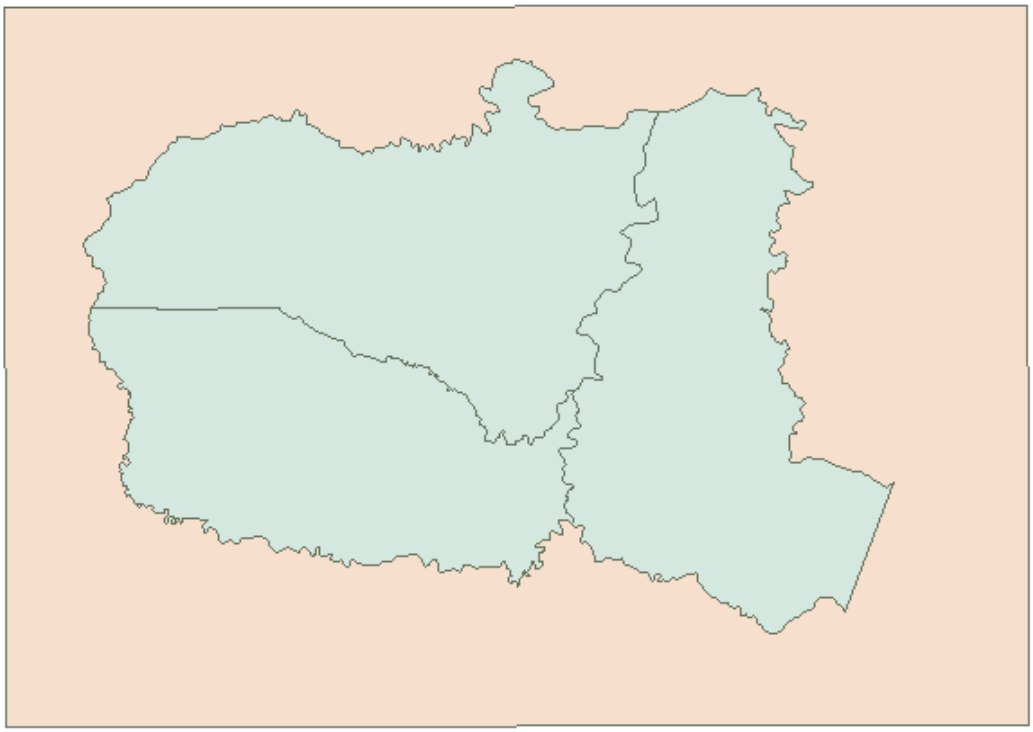
In ‘Create Features’ table select the new shape file that you have created.



Under the ‘Construction Tool’ table, click on either ‘Polygon’ or ‘Rectangle’.



Draw a square/rectangle (or any polygon) around the boundary of your concession area.

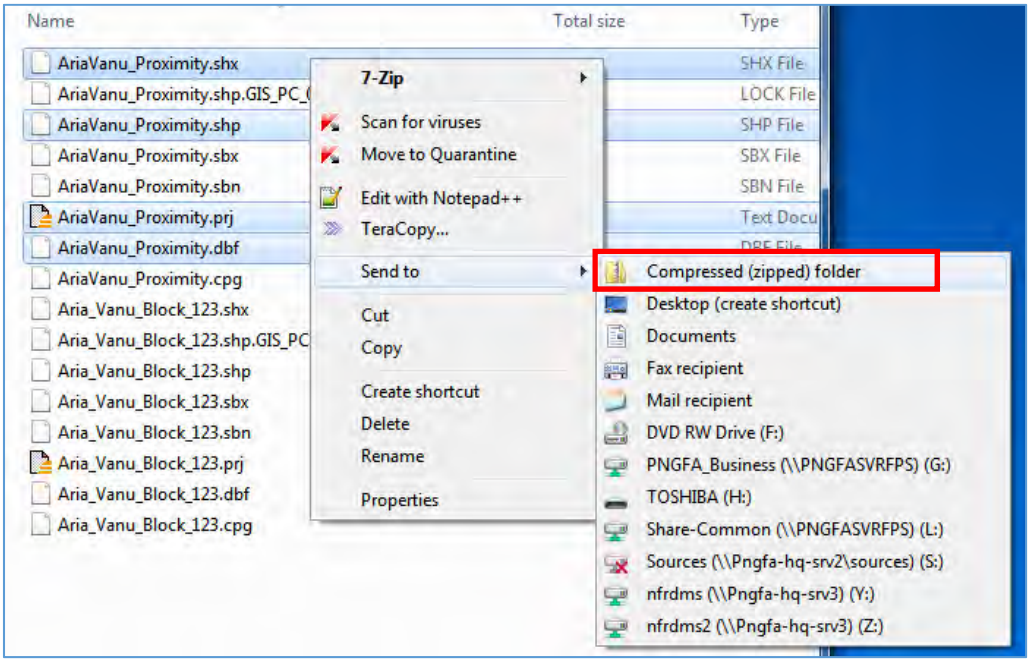


Click on the “Editor” tool on the Editor toolbar, Click ‘Save edit’ click ‘Stop edit’.

After creating the shape file, you need to zip it before you can load it up on to USGS web page.

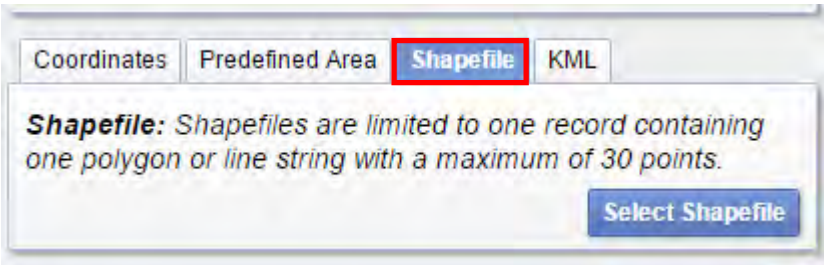
Navigate to the folder containing the shapefile that you have just created (in this case ‘AriaVanu_Proximity’) and select the files there with following extensions:

.dbf
.prj
.shp
.shx

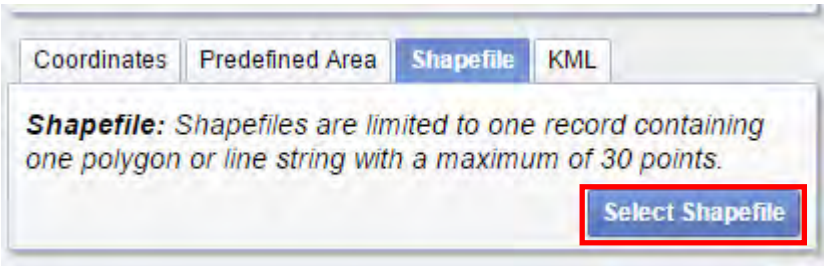


Select all the polygon files with the extensions mentioned above by holding down the control key (Ctrl) while clicking on the files. Release the Ctrl key, right click on a highlighted/selected file, go to 'send', click on 'Zip'.
Automatically a zipped folder containing a copy of the selected files is created.

Bring up the USGS web page, click the 'Shapefile' tab.



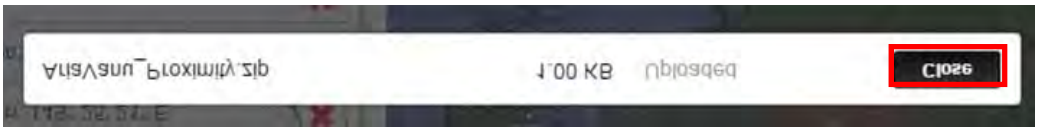
Click on 'Select Shapefile'.



Navigate to the folder where the previously created zip file is located.

Select the zip file and click ‘Open’.

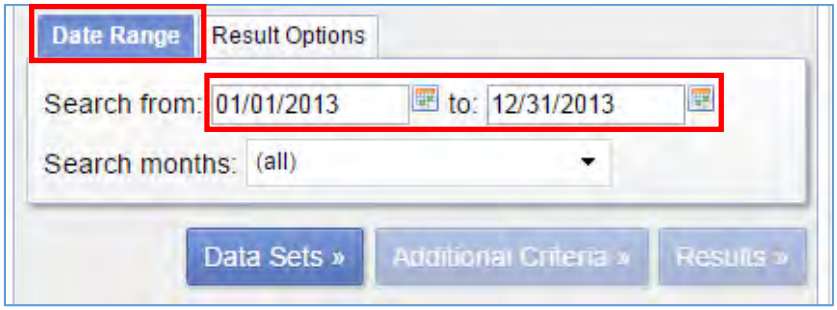
An upload window will pop up. When uploading is completed, close the uploading window.



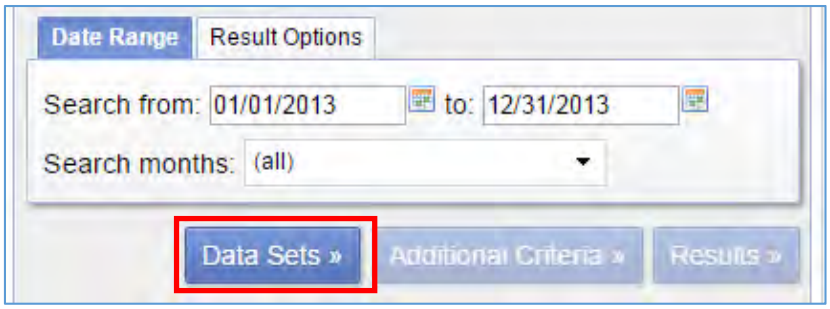
Zoom to the location of your uploaded shapefile.

Downloading of new satellite imagery

Click on the 'Date Range' tab and set the time period of the image. The date format is as follows: month/ day/ year. (In this Example we will use 2013 data so set the date: 01/01/2013 to 12/31/2013)



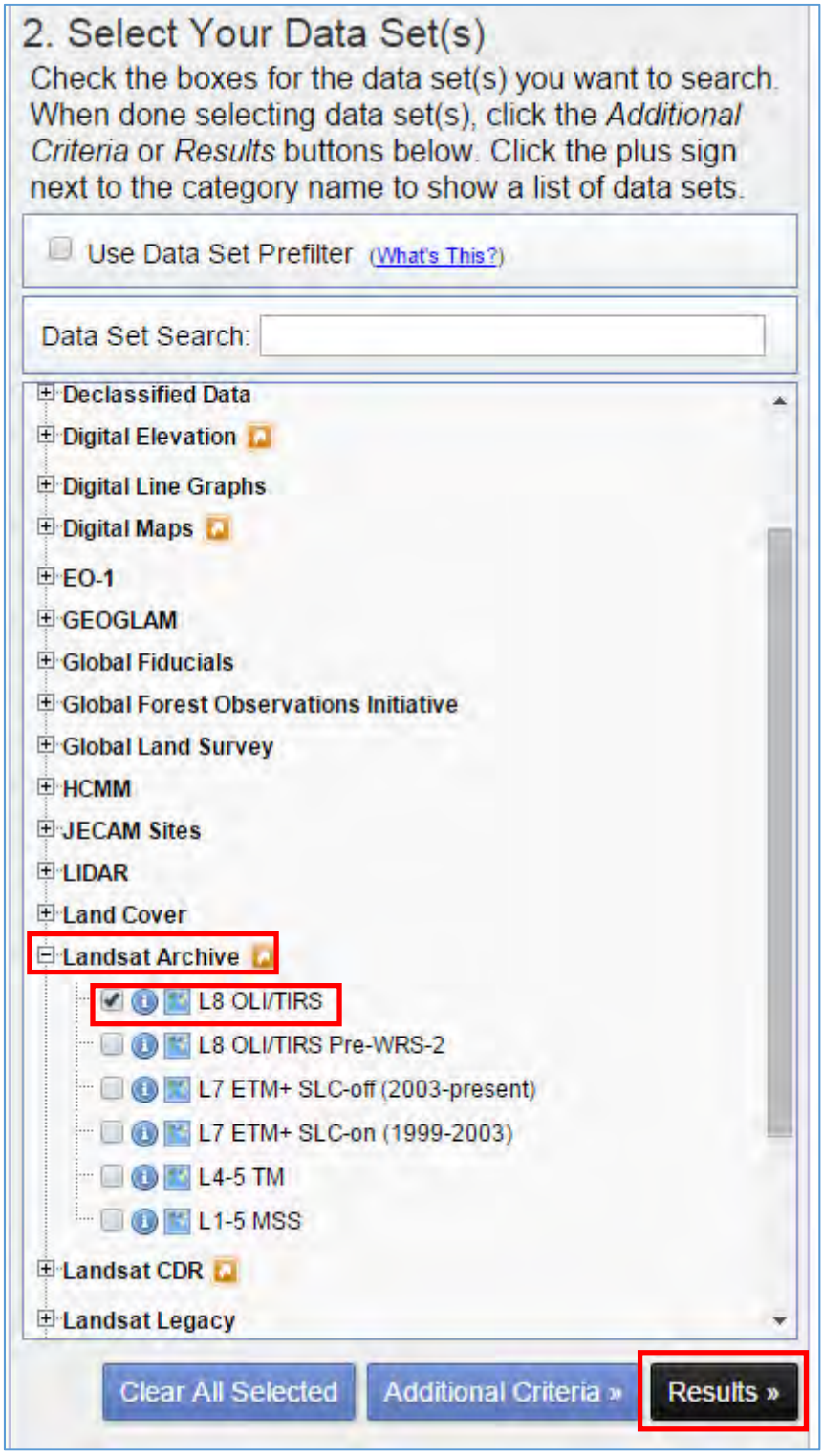
Click on the 'Data Sets' button.



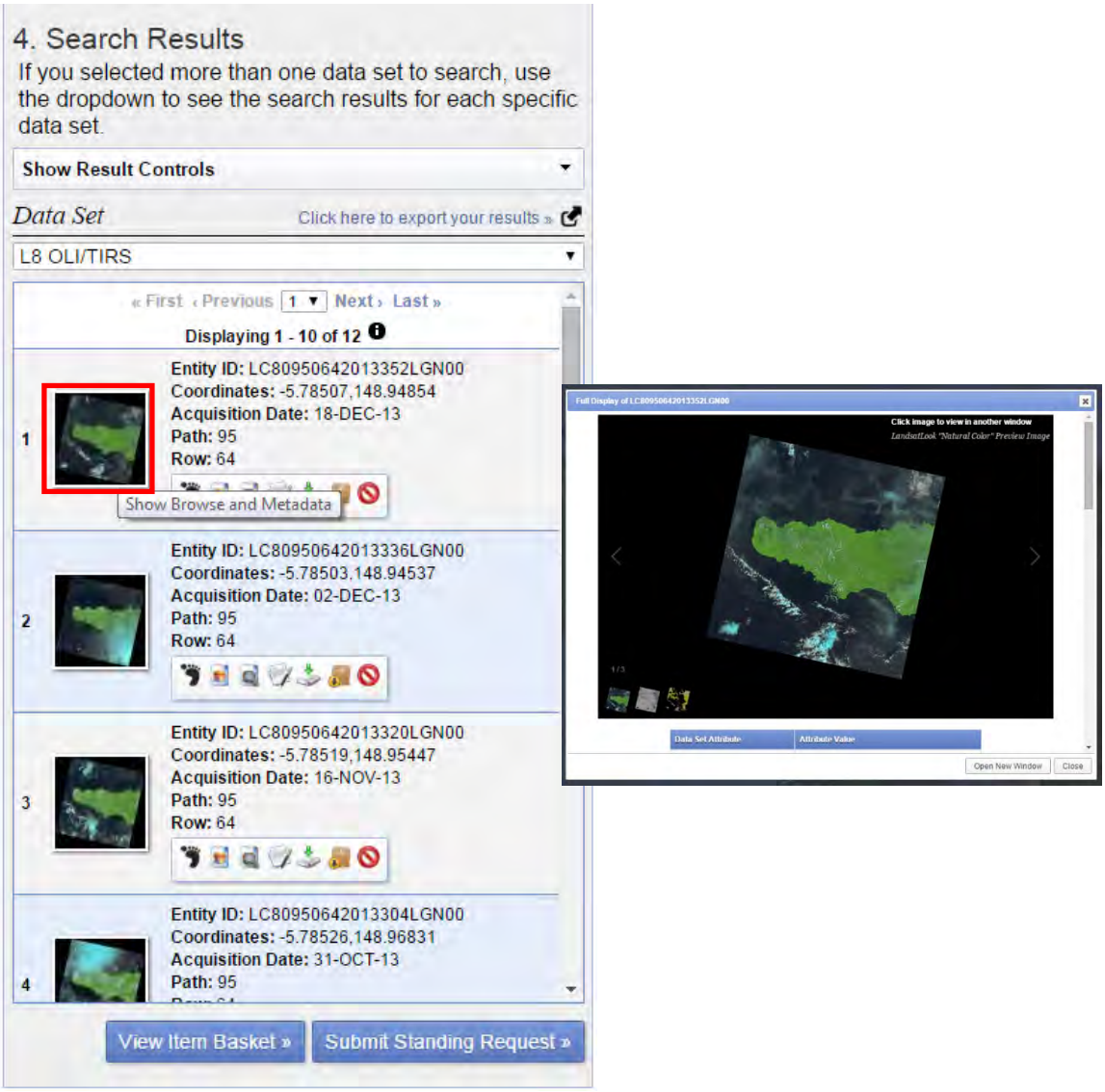
Scroll down to 'Landsat Archive' and expand it by clicking the plus sign.

Check the 'L8 OLI/TIRS' box.

Click on the 'Results' button at the bottom.



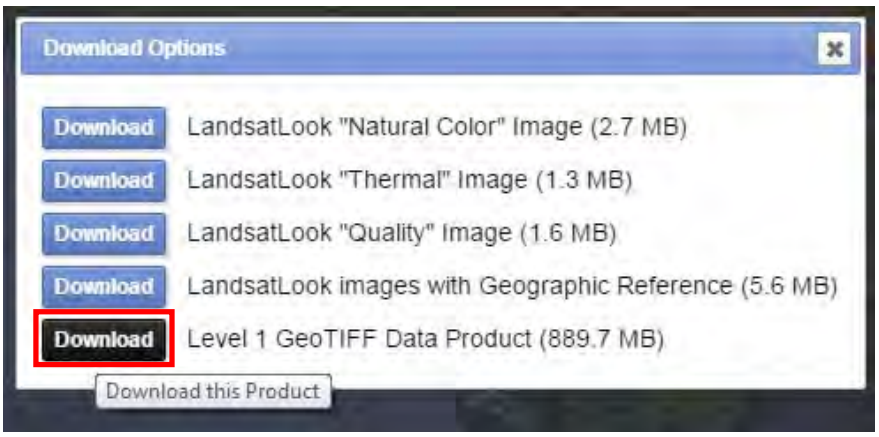
Landsat search results appear.



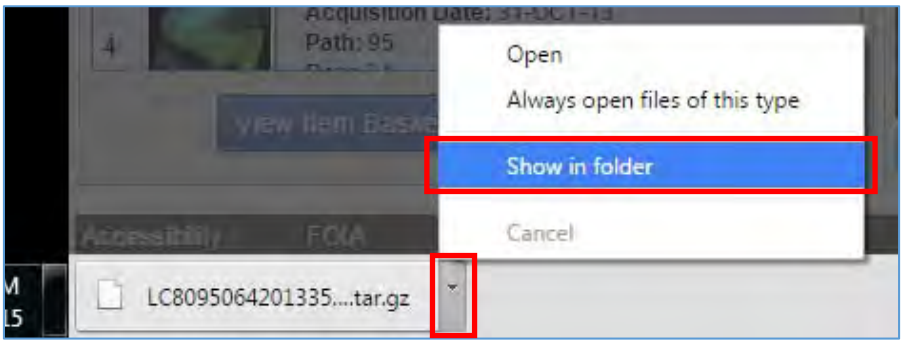
Click on each one to expand and preview it. Try to choose the image with the least cloud cover.

When you are sure about your choice of image, click on the download icon beside it to start the download.

Select 'Level 1 GeoTIFF Data Product'.



The downloading of the image may take some time depending on your internet speed. When the download completes, it shows on the task bar of Google Chrome (web browser).

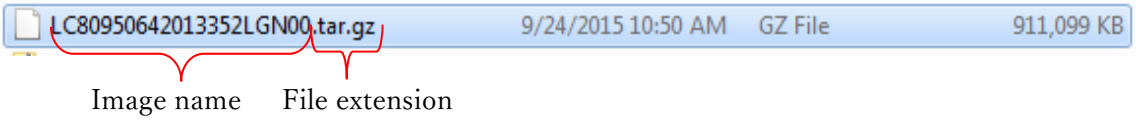


Click on the drop-down arrow.

Click 'Show in folder'.

By default, the image is downloaded into the 'Downloads' folder.

The image has the file extension as such: .tar.gz

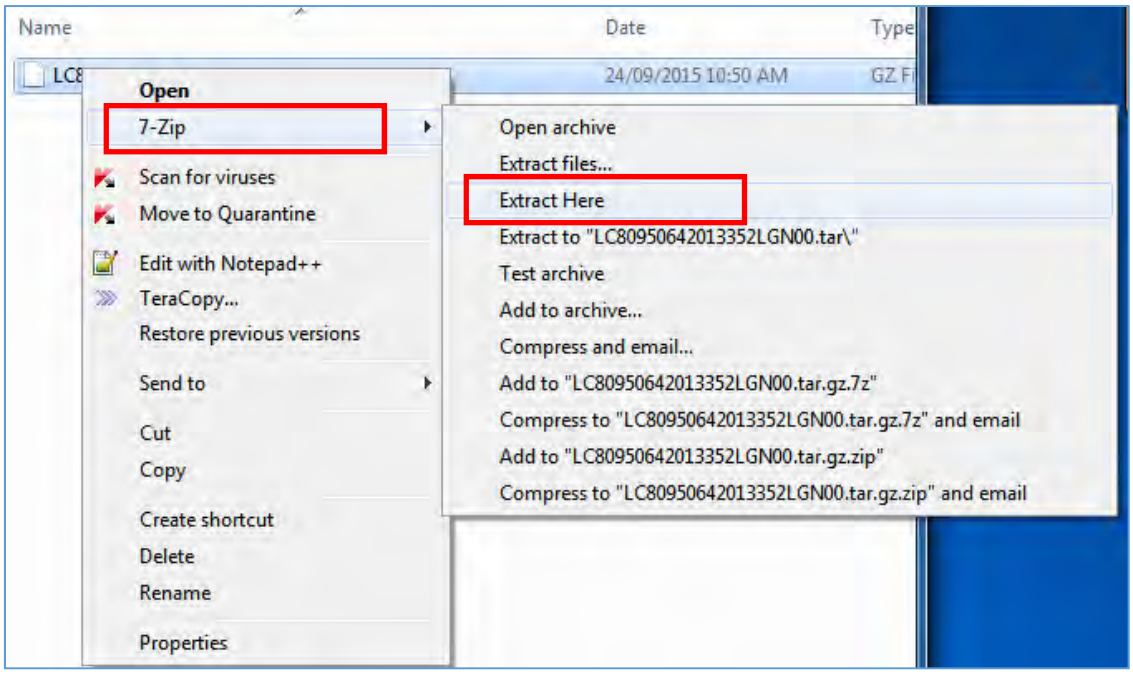


Cut and paste into your desired folder.

Downloading of new satellite imagery

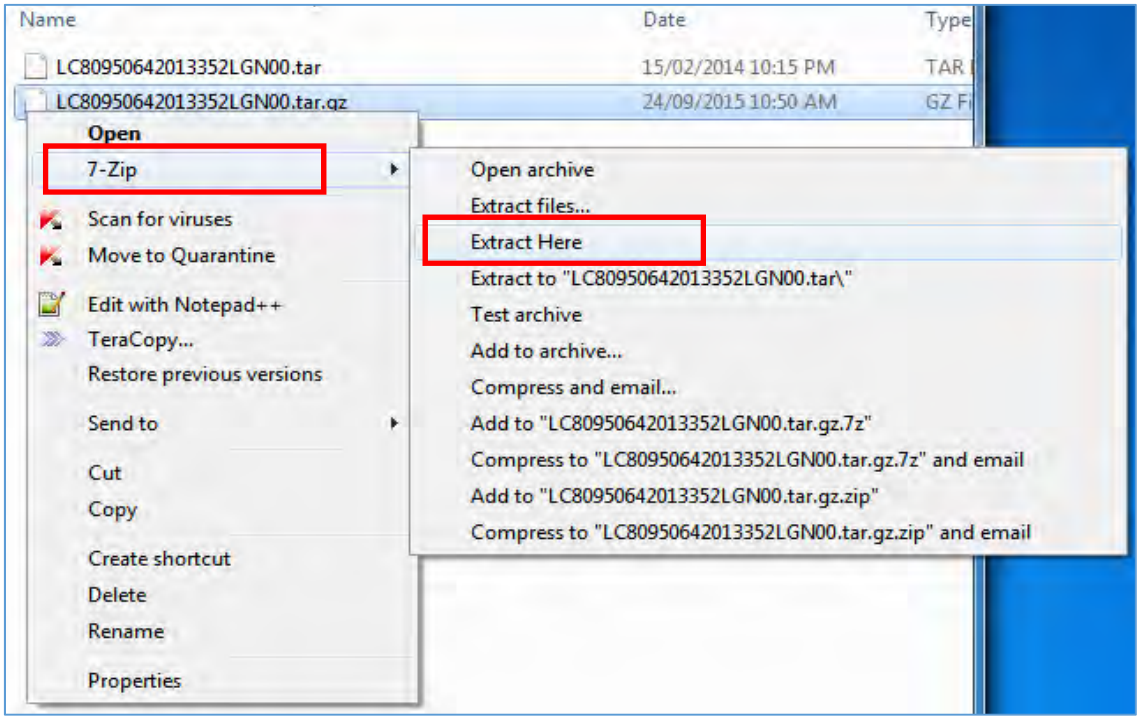
Navigate to the folder containing the downloaded image.

Right click on the image, go to '7-Zip', click 'Extract Here'.



Right click on the file with the extension: .tar

Go to '7-Zip', click 'Extract Here'.



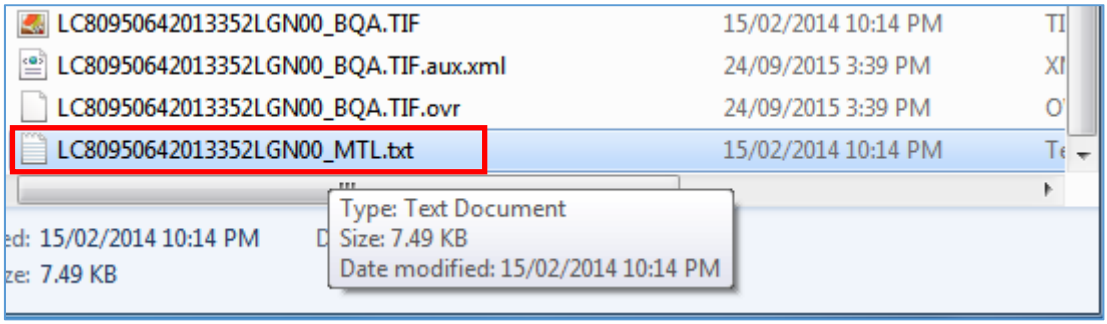
Now all the bands of the images are extracted.

<u>Converting to Reflectance from Digital Number (DN)</u>

Use Landsat8TOA,

Go to USGS webpage, Click Landsat8 conversion to Radiance, Reflectance and At-Satellite Brightness Temperature.

Navigate to your Landsat folder, open the Metadat of the Landsat image, (text file .txt).

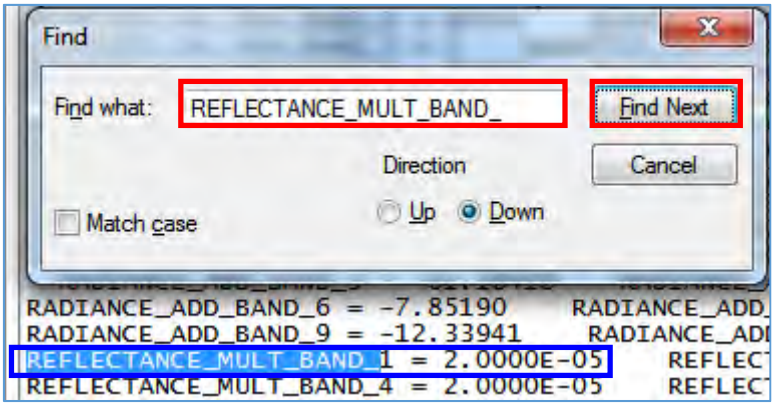


Place the cursor at the top left of the page.

Press Ctrl+F on your keyboard, window pops up.

In the window type in: REFLECTANCE_MULT_BAND_

Press Enter/click 'Find Next'.

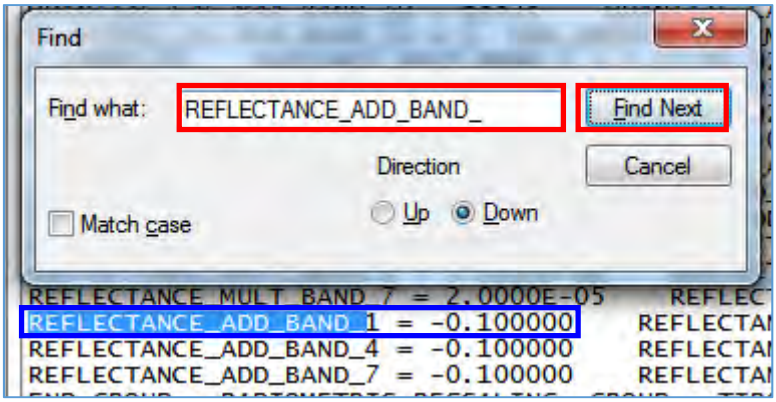


M_p = 2.0000E-5

Close the window. Bring Cursor back to the top of the page.

Press Ctrl+F, window pops up, Type in the window: REFLECTANCE_ADD_BAND_

Press Enter/click 'Find Next'.



A_p = -0.1

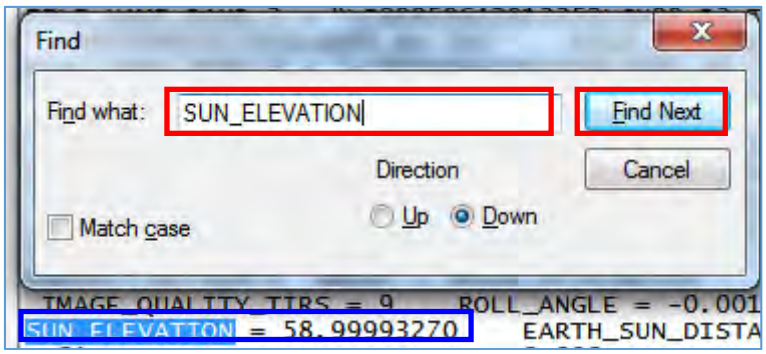
Close the window.

Elevation

Bring Cursor back to the top of the page.

Press Ctrl+F, window pops up. Type in: SUN_ELEVATION

Press Enter/click 'Find Next'.



Sun Elevation = 58.99993270

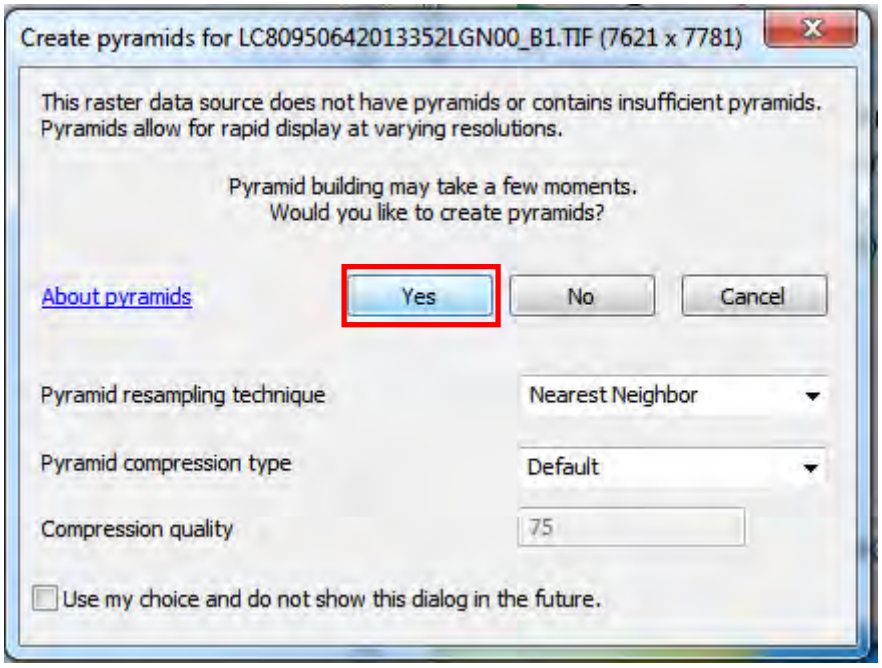
Close the window. Close the text file.

Calibrating Landsat8 Image

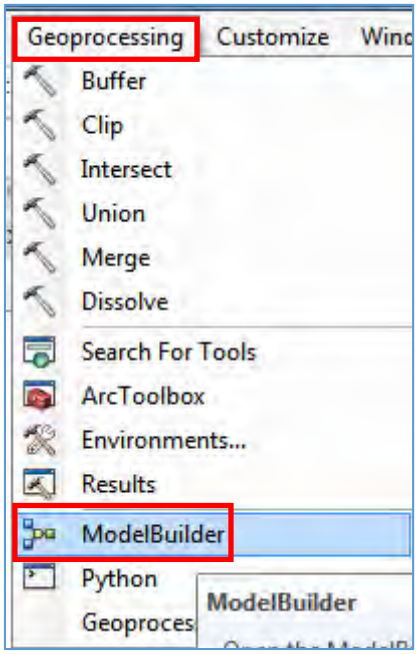
Open Arc Map.

Drag and drop the images into ArcMap for processing (B1 to BQA).

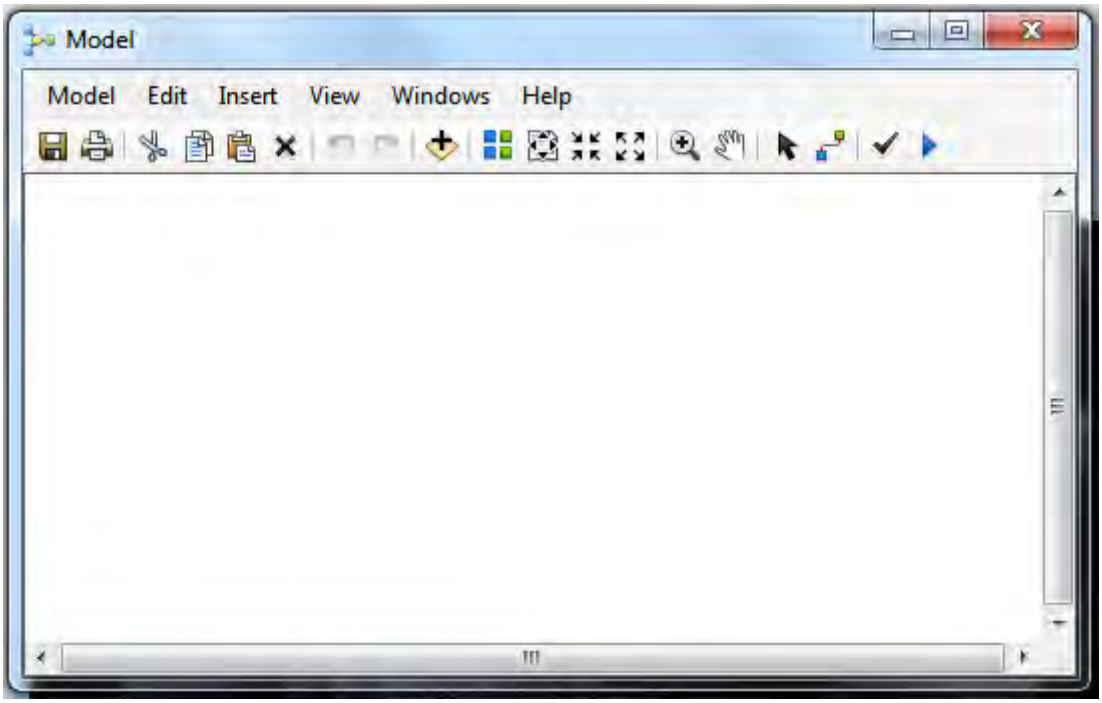
Click 'Yes' if the 'Create pyramids' window pops up.



Click on ‘Geoprocessing’ on tools menu, click on ‘Model Builder’.



Model window pops up.

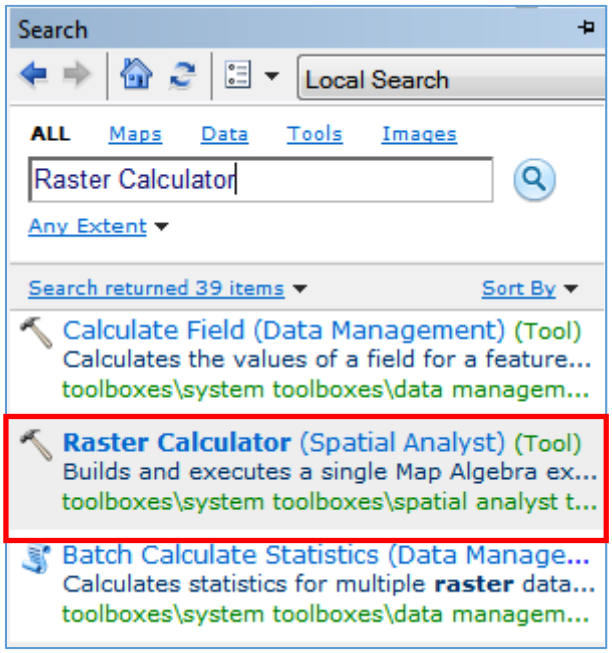


Drag and drop ‘B1.tif’ into Model Builder window.

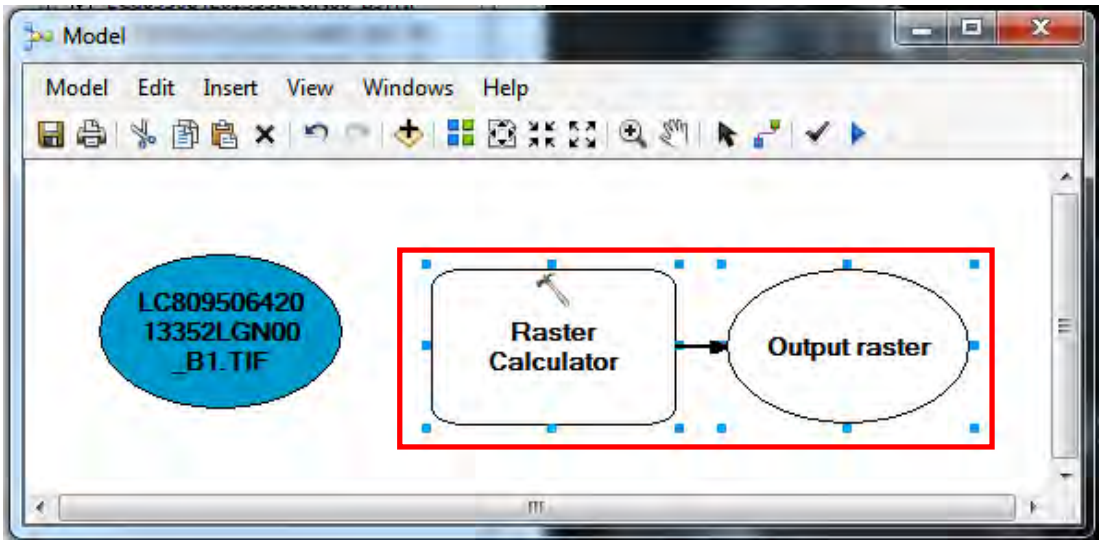
Click windows on the tools menu, Click on ‘Search’. ‘Search’ window pops up.

Type “Raster Calculator”, press enter key on your keyboard.

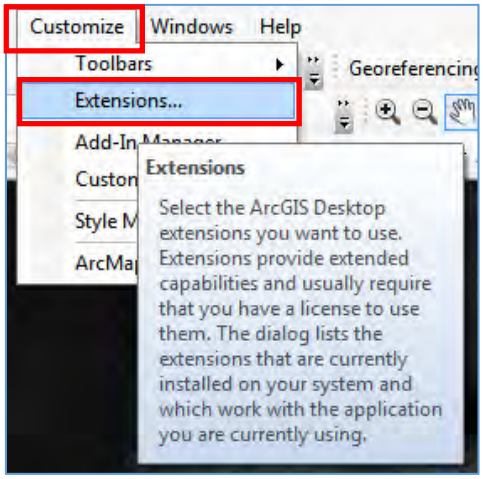
Drag and drop “Raster Calculator (Spatial Analyst)” into ‘Model’ window.



Double click “Raster Calculator” in ‘Model’ window.

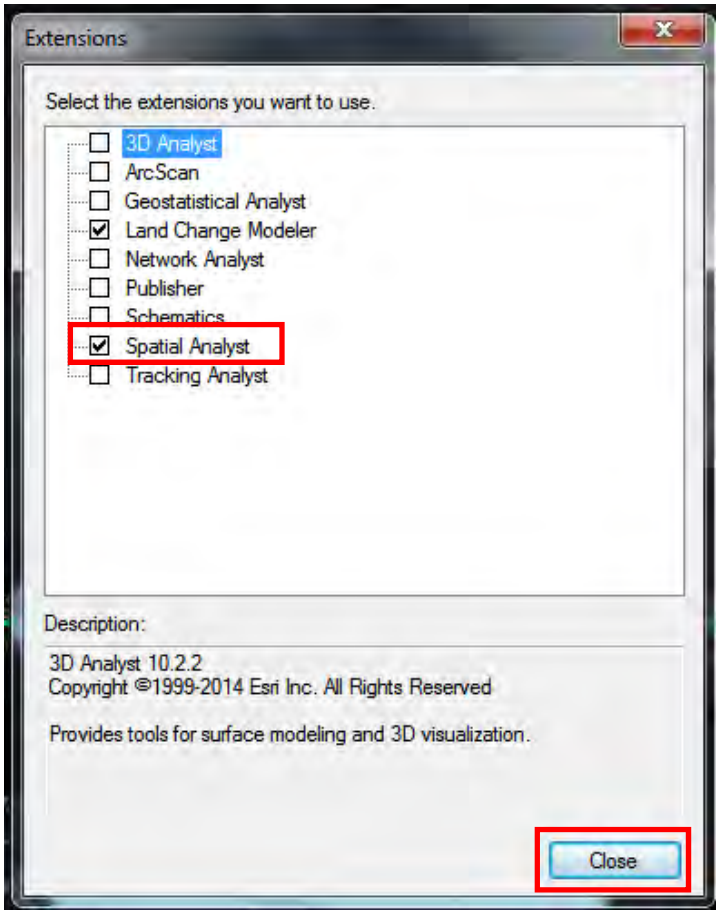


**Note: If ‘License Error’ comes up instead, do the following:



Click on 'Customize', go down and click 'Extensions…'

'Extensions' window pops up.

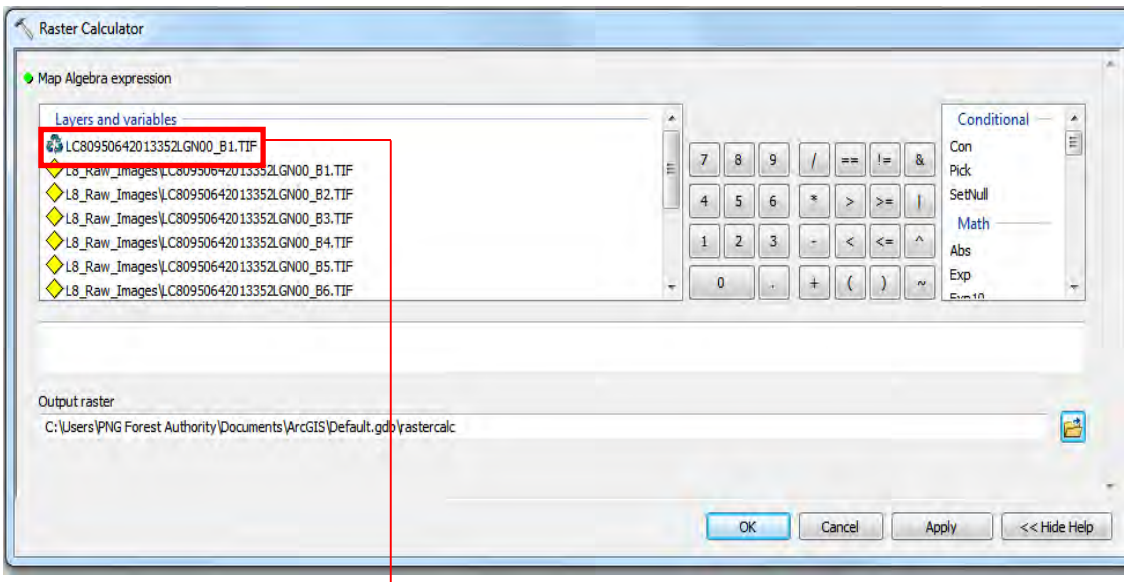


Check the 'Spatial Analyst' box.

Click 'Close'.

*If no error comes up, carry on

Raster Calculator window pops up.



Type in the following formula:

Note: Always convert degrees to radians

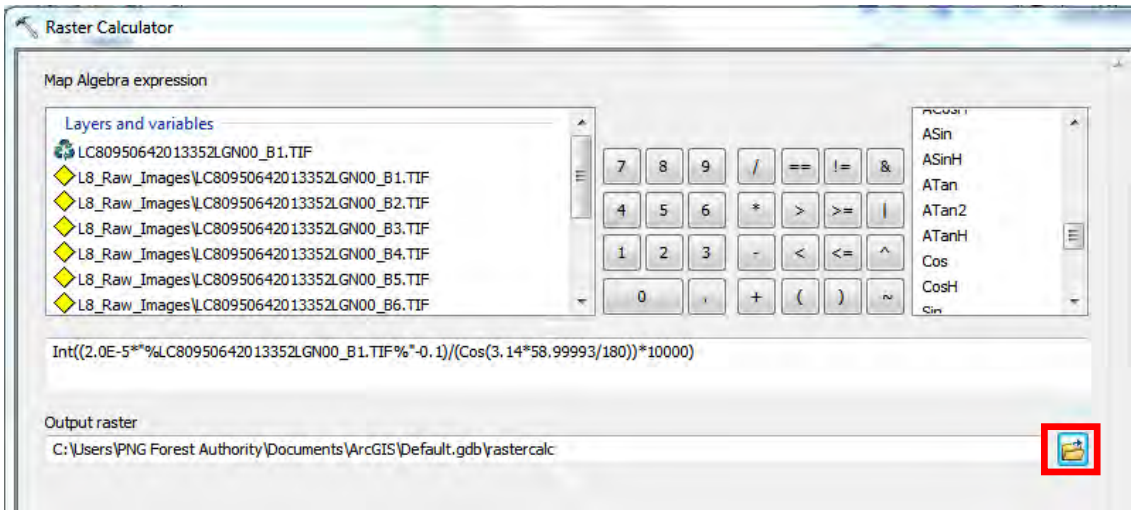
Int((2.0E-5*"%LC80950642013352LGN00_B1.TIF%"-0.1)/(Cos(3.14*58.99993/180))*10000)

Landsat Band 1

REFLECTANCE_MULT_BAND_1 =2.0000e-05

REFLECTANCE_ADD_BAND_1 = -0.1

SUN_ELEVATION = 58.99993

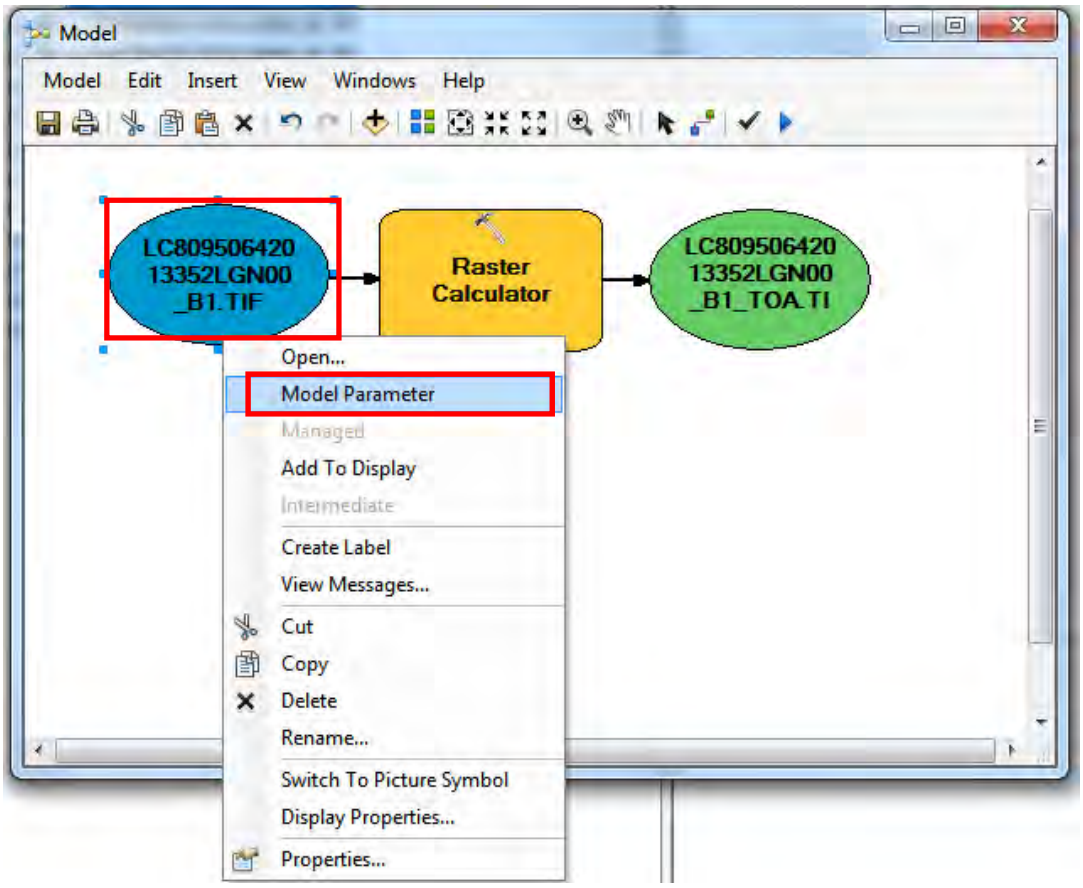


Press the folder icon, navigate to your specific folder, and give a name for the image and save it.

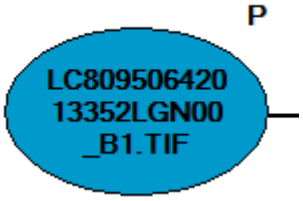
Click 'Ok'.

'Raster Calculator' window closes.

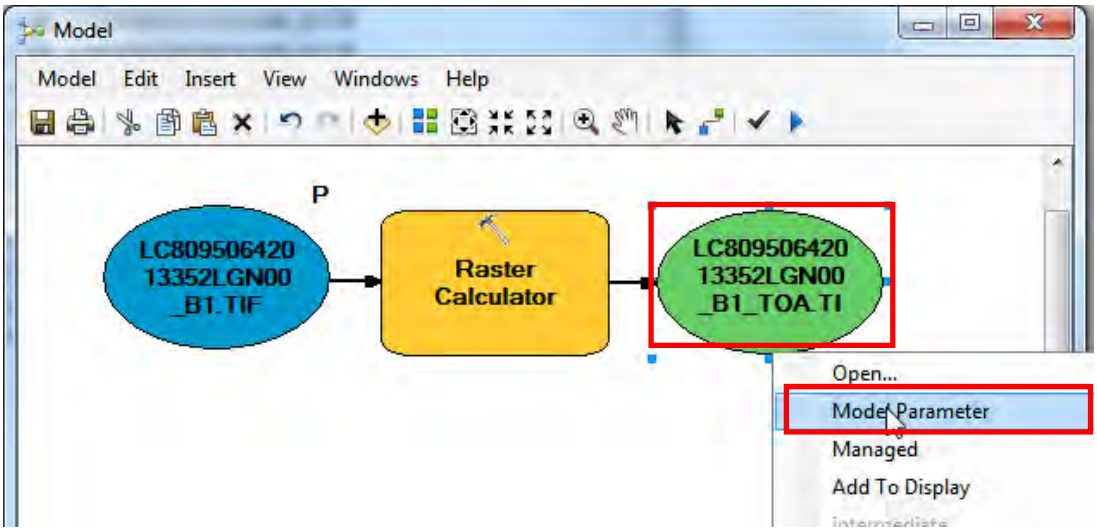
Right Click on the blue circle in the Model window, click "Model Parameter".



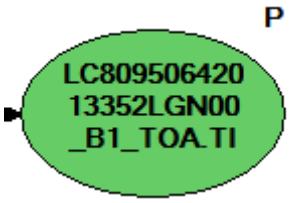
The letter ‘P’ should appear beside the blue circle.



Right Click on the Green circle in the Model window, click “Model Parameter”.

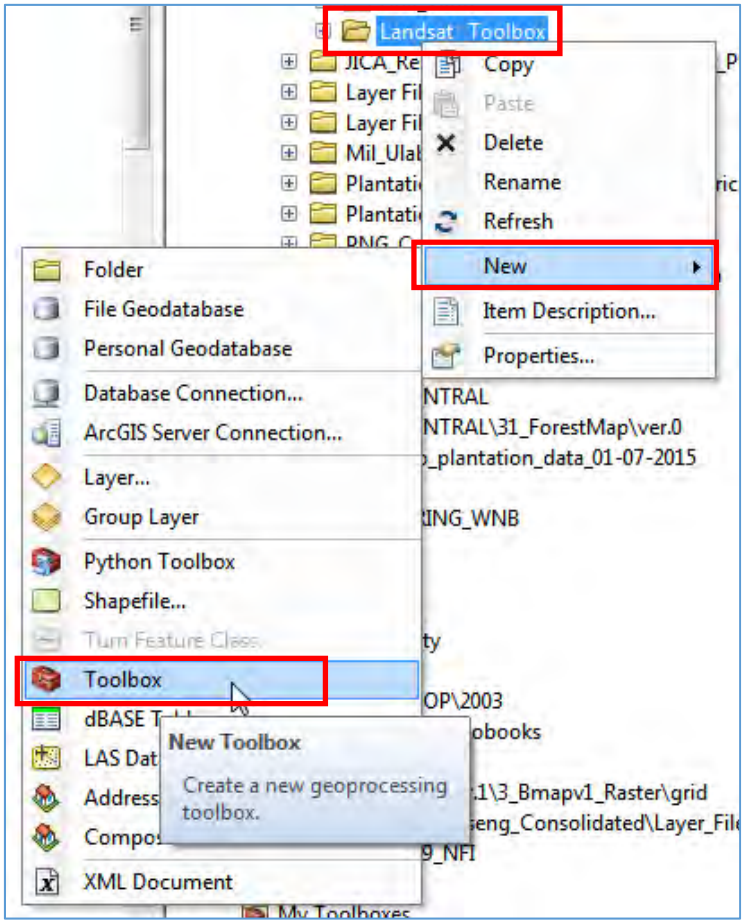


The letter ‘P’ should appear beside the green circle.

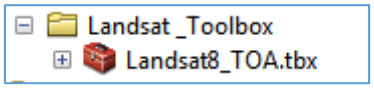


<u>*Create a New Toolbox</u>

Go to ‘Catalogue’, Navigate to where you want to save your new toolbox. (In this example, ‘Landsat_Toolbox’). Right-click on the folder, come down to ‘New’, Click on ‘Toolbox’.

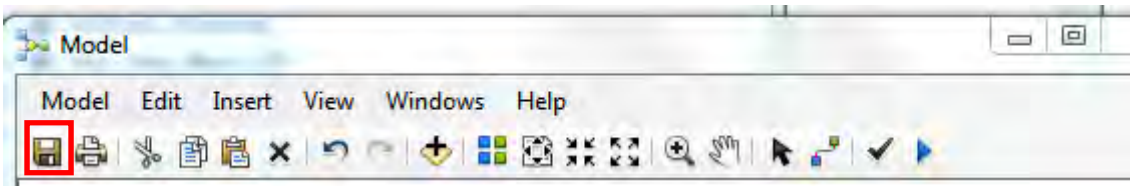


A new |Toolbox appears. Rename the new Toolbox.(In this example, ‘Landsat8_TOA’).



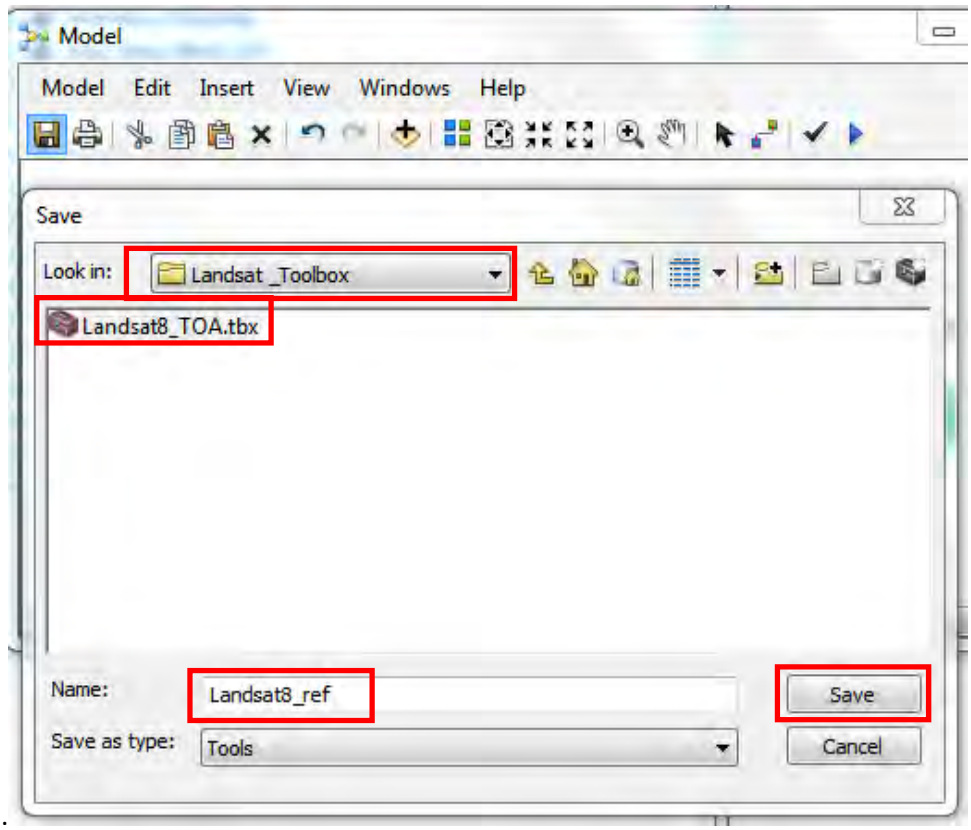
Save this model in the Toolbox ‘Landsat8_TOA’.

Click on the ‘save’ icon on the ‘Model’ window.



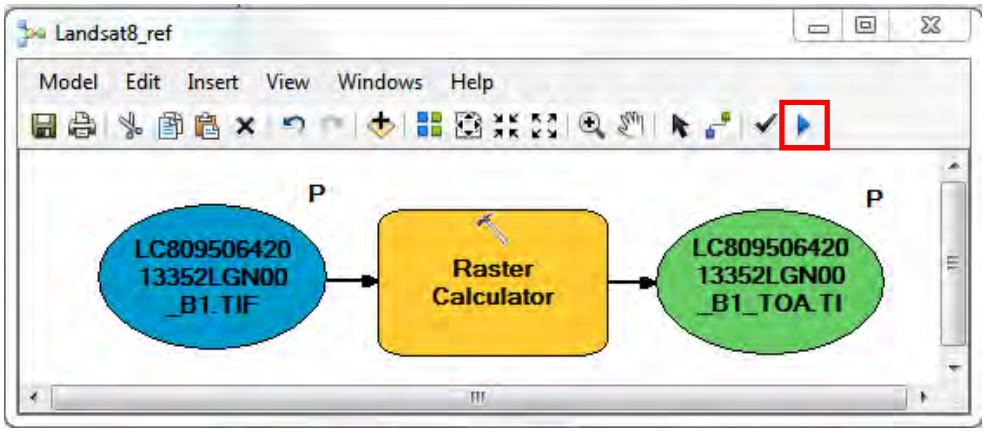
‘Save’ window pops up.

Click on the drop down arrow beside 'Look in:' Navigate to where you have stored 'Landsat8_TOA.tbx'. Double click to enter the toolbox. Change the name of the model window to "Landsat8_ref". Click 'Save'

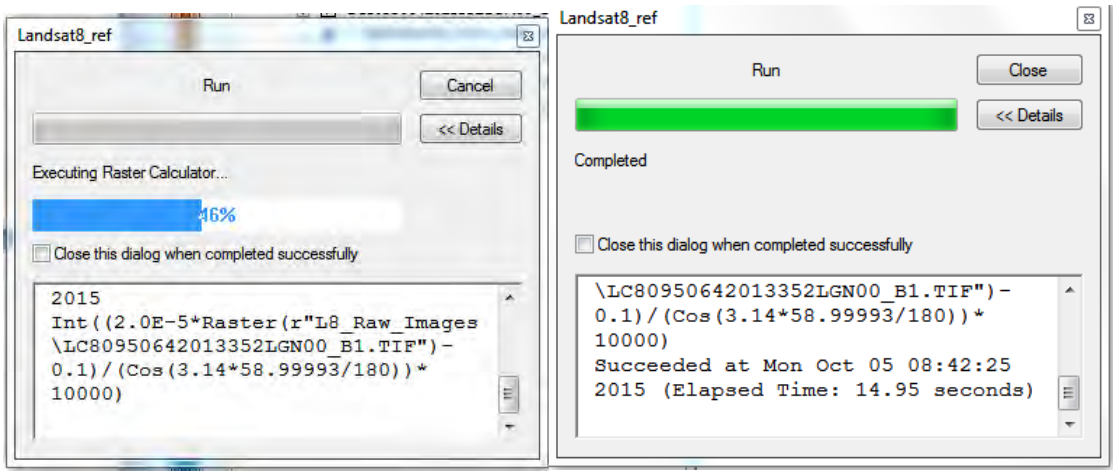


.

To run the calculation, click the run button (small Blue play button) in Model Widow.



Calculating window pops up. Close the calculation window when calculation has completed. Do not close the Model Window (Landsat8_ref).

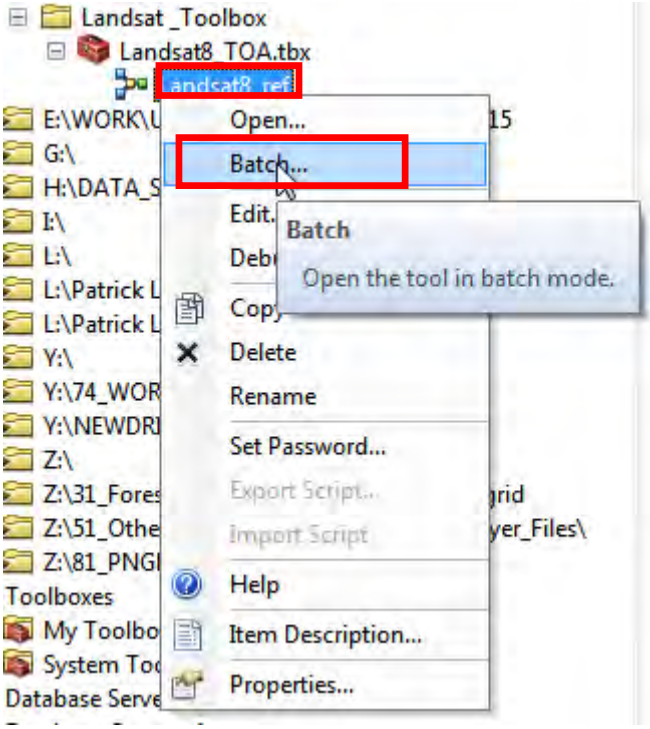


Navigate to the calculated image using 'Catalogue'. Open the image in ArcMap.

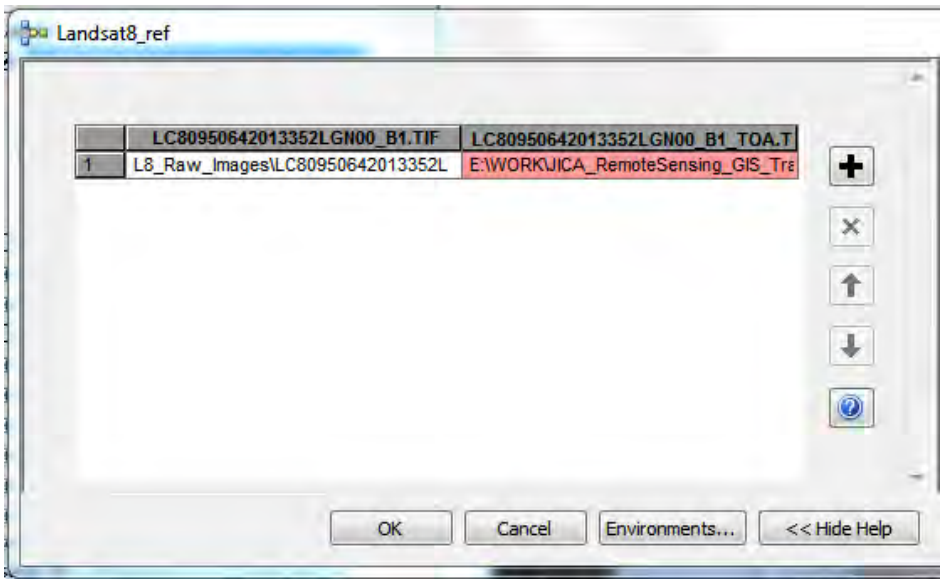
Click 'Yes' if pyramid building window pops up.

Locate the toolbox 'Landsat8_ref' using 'Catalogue' table.

Right click on it and click on 'Batch'.

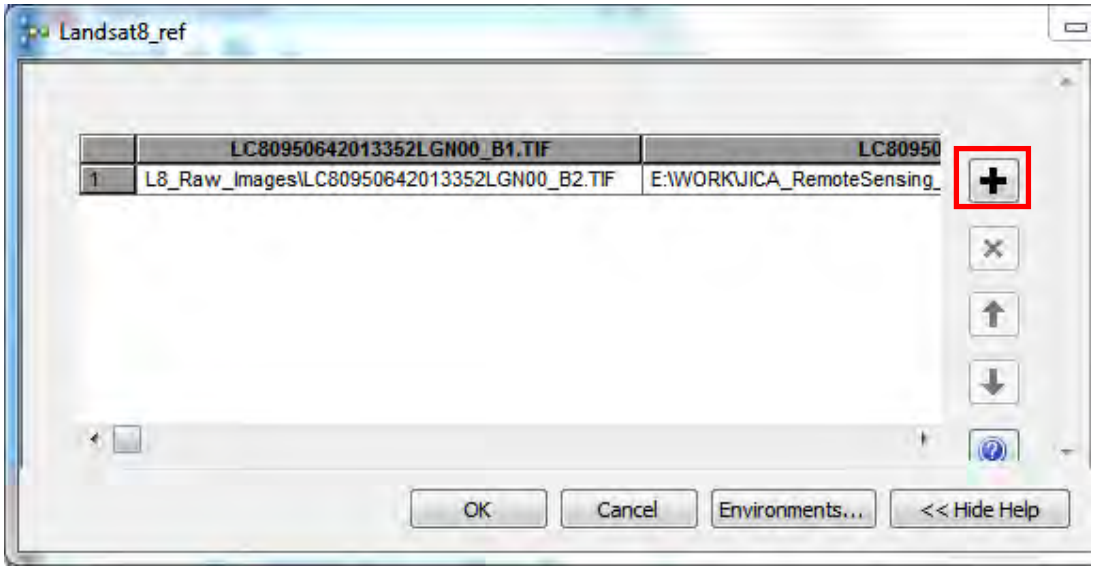


Window pops up,

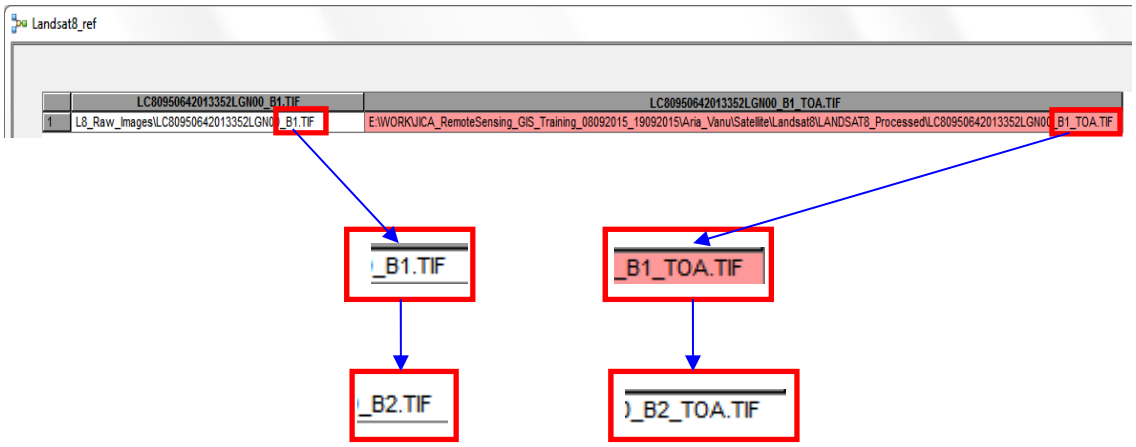


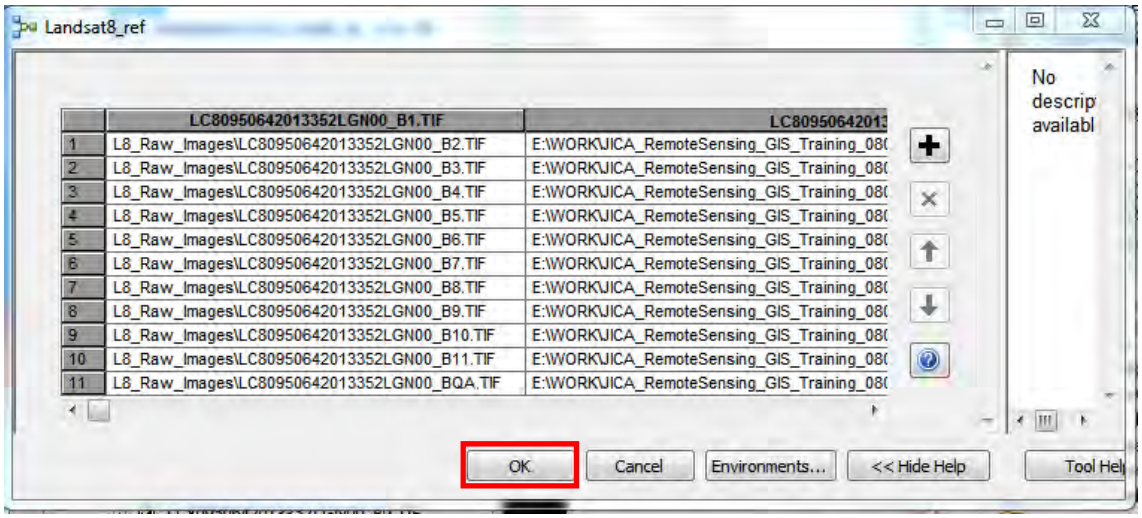
When converting more bands, click the “+” button in the model window. Click the “+” button ten (10) times.

(You click 10 times for Bands 3 to Band QA: B3 to BQA.)



Change the name of the images in each column correspondingly. For example, Landsat8 has 12 bands. You have just converted B1 (Band 1). Change B1 to B2. Correspondingly, change the bands on each column until all the Bands have been completed.

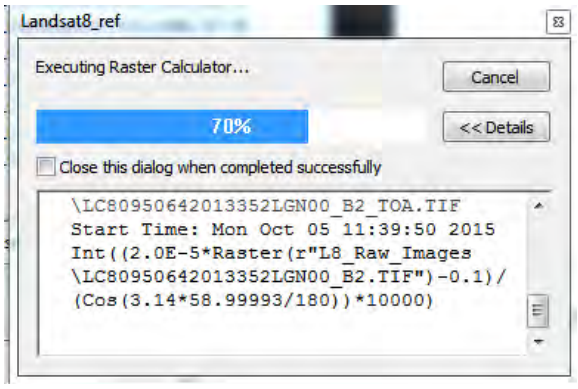


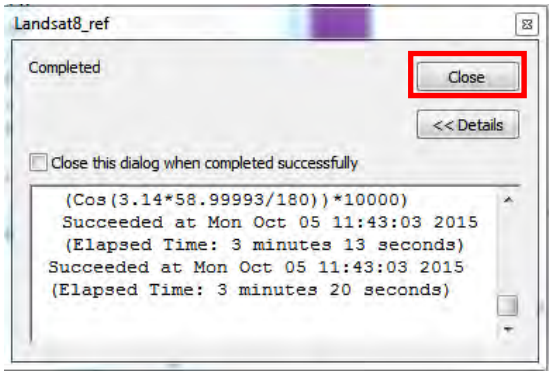


Click ok, 'Processing' window pops up.

Let the Process run.

Close the processing window when processing is complete.

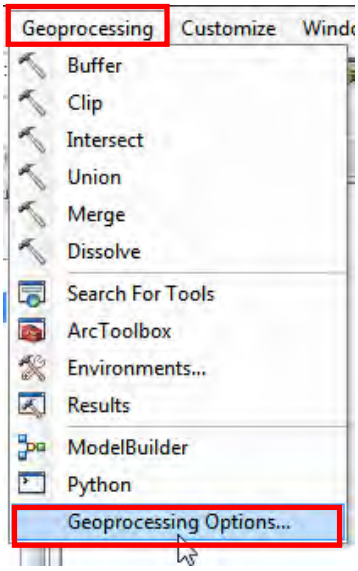




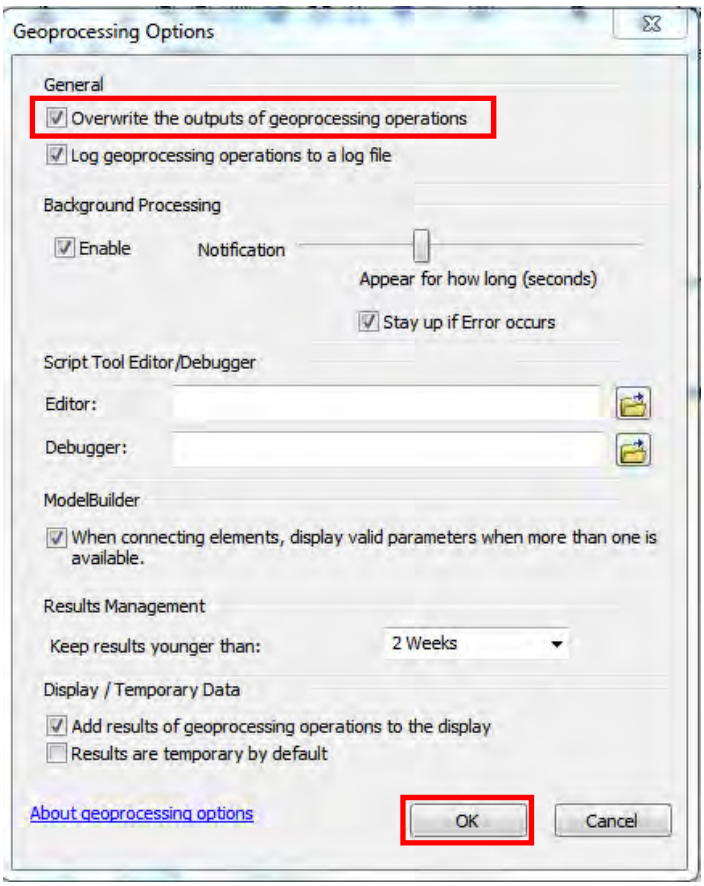
ArcMap automatically adds the processed images on to the 'Table of Contents'.

*Note:

If there is an error message saying that the file already exist: Click on 'Geoprocessing', click on 'Geoprecessing Options'.

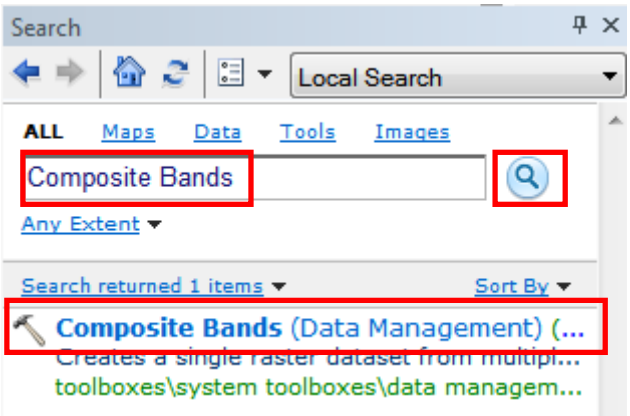


Check 'overwrite the outputs of geoprocessing operations'. Click ok.

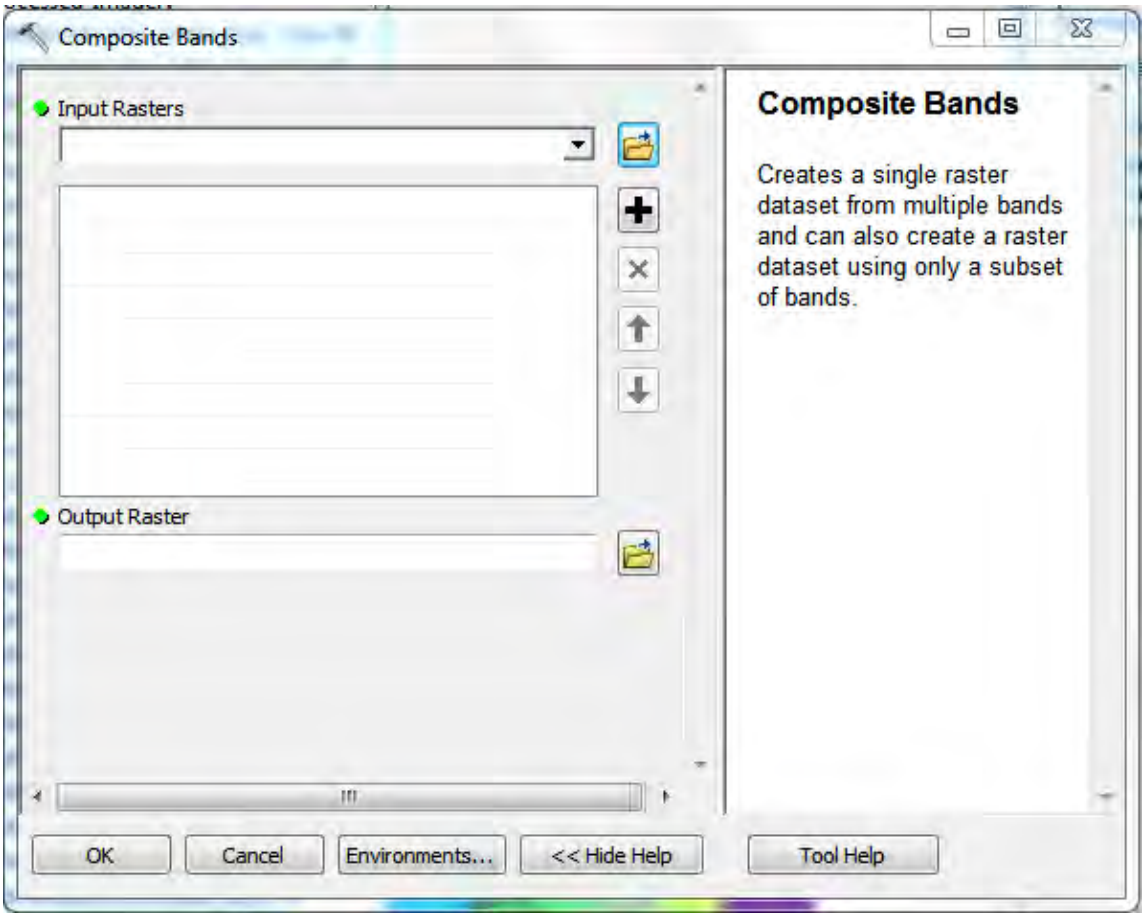


Creating Colour Composite Bands From Landsat8 Imagery

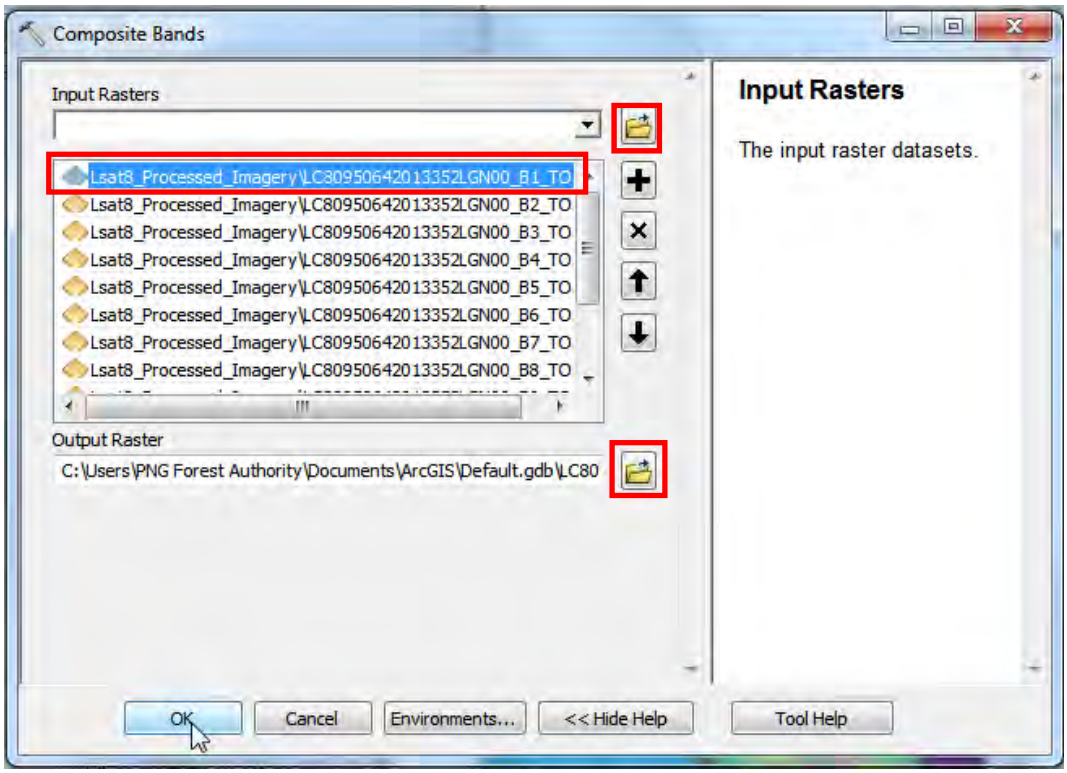
Go to 'Search' table, type in "Composite Bands", click search/press enter.



Click on "Compound Bands (Data Management)". Window pops up.



Under 'Input Raster' click on the drop down arrow, select all the Processed Bands in order of their sequence, e.g, B1, B2, B3, etc.

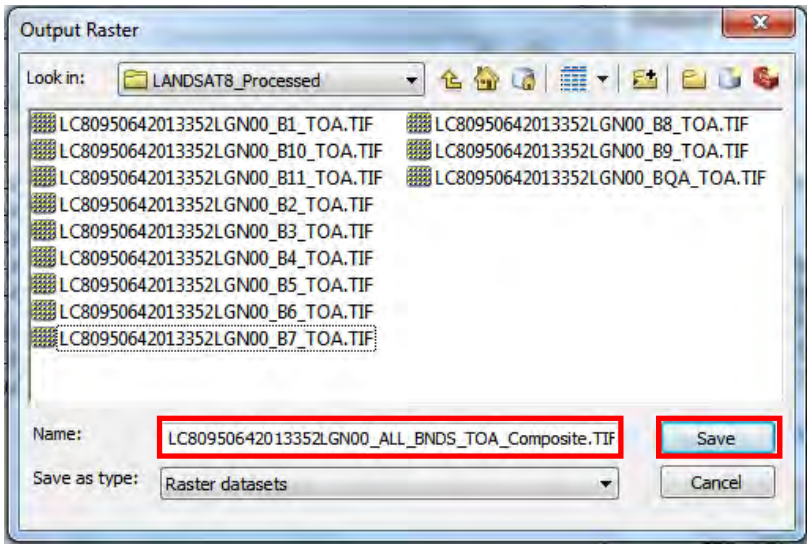


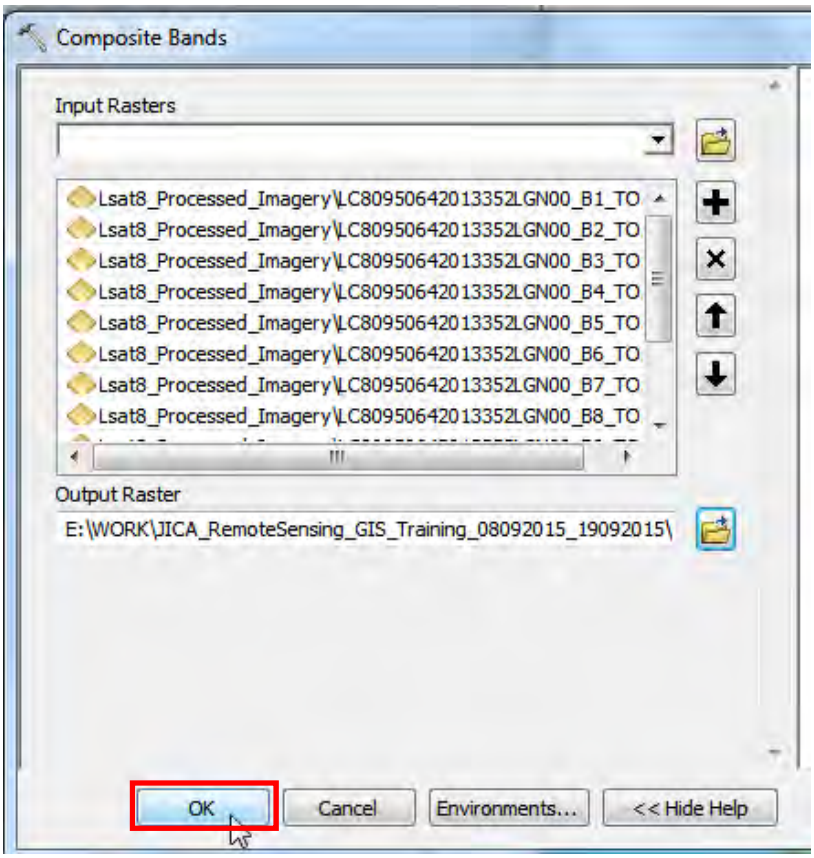
Under 'Output Raster' Navigate to your desired folder, give a name for the Image. (In this example save it in 'Landsat8_Processed' folder).

Type in '.tif' at the end of the image name. This will change the image format to a 'tiff image'.

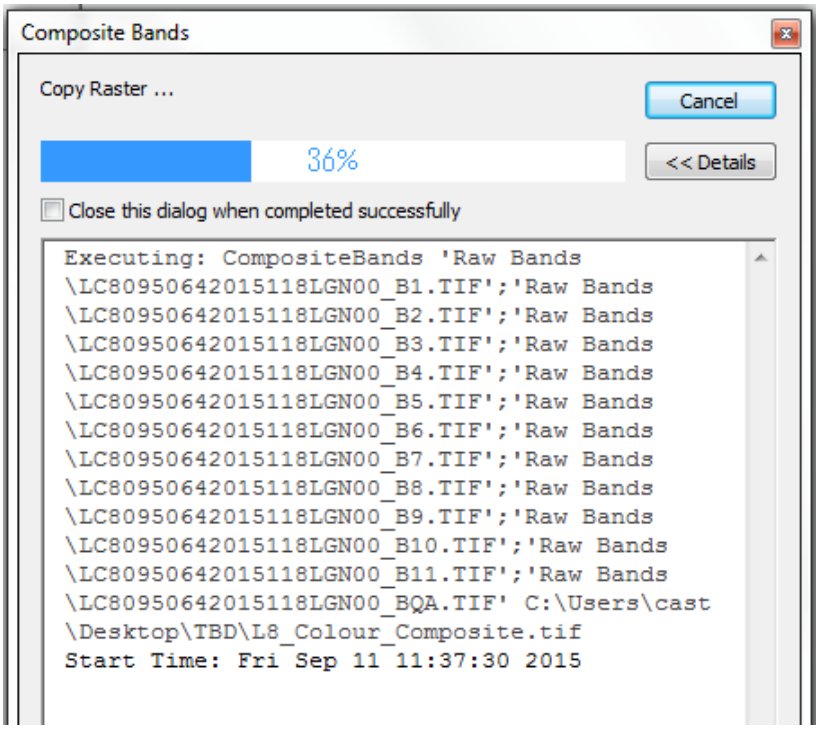
Click on 'Save'.

Click on 'Ok'.



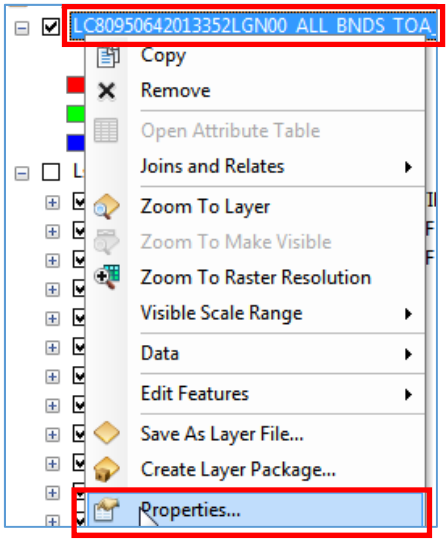


'Composite Bands' Processing window pops up.



Locate the Composite image using 'Catalogue'. Drag and drop the image in ArcMap.

Right-click on the image in 'Table of Contents'. Click on 'Properties'.



Click on the 'Symbology' tab.

To create 'True Colour Composite' change the Bands as follows;

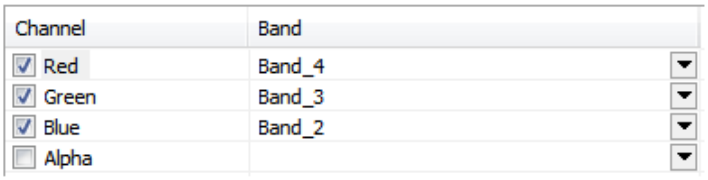
Click on the drop down arrow beside the band and select:

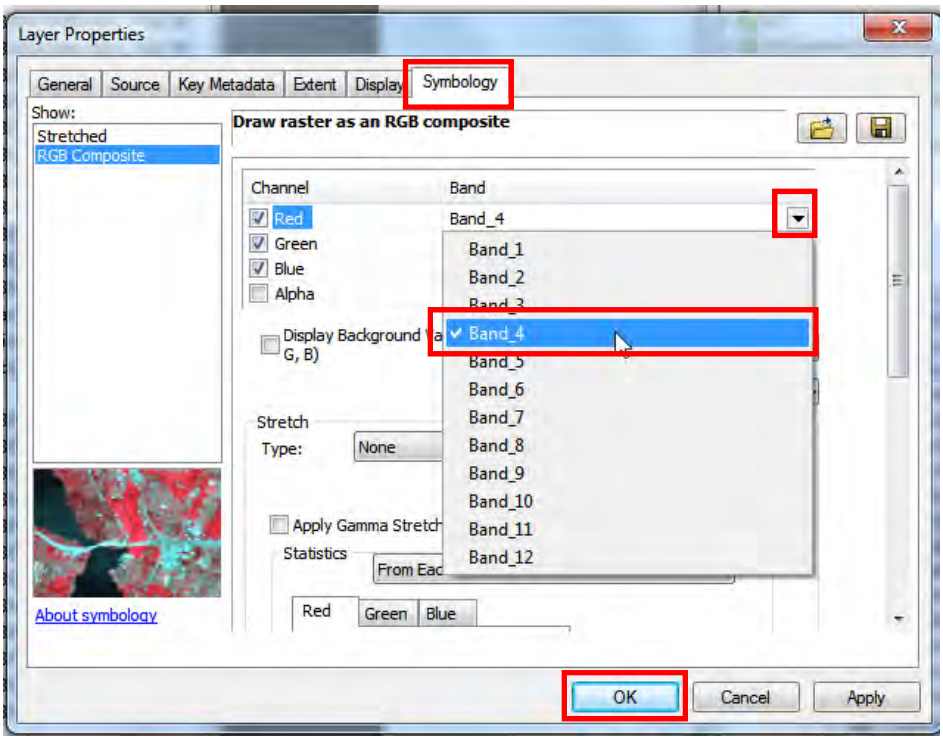
Red = Band 4

Green = Band 3

Blue = Band 2

Click 'Ok'.





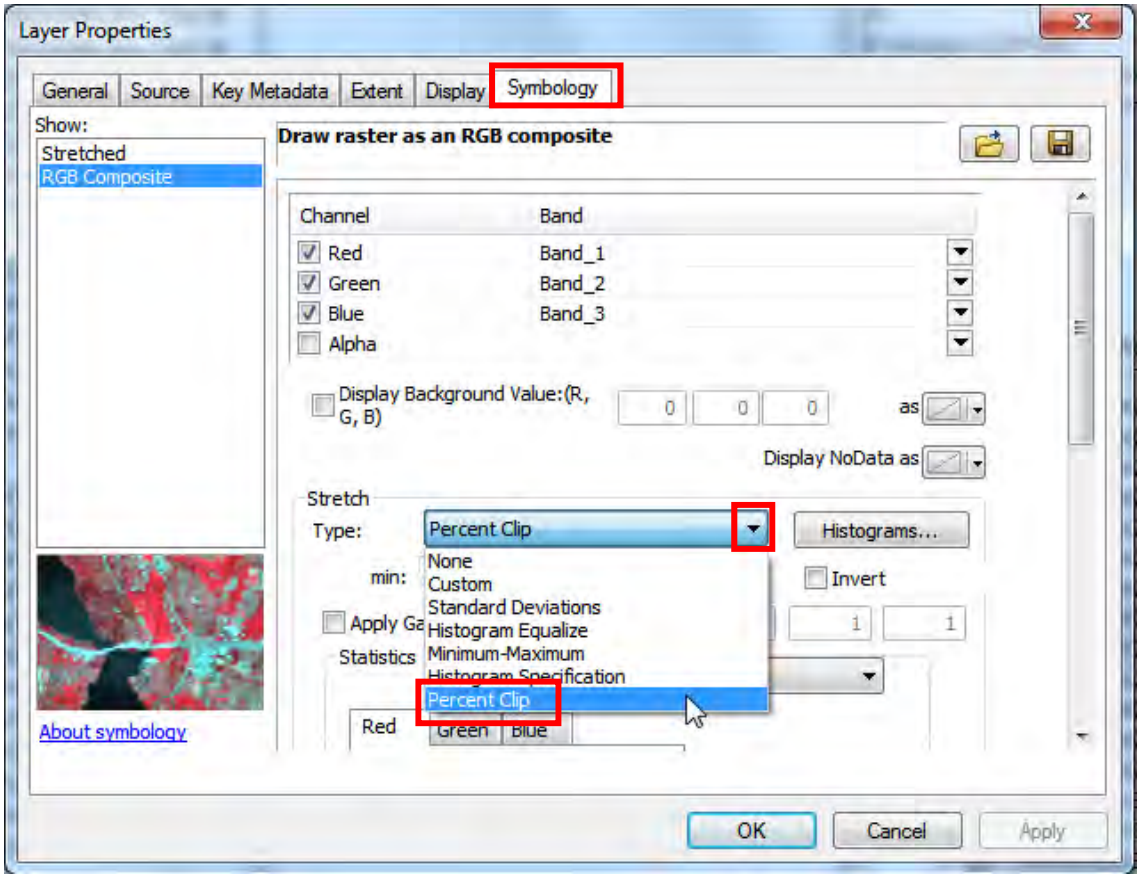
True colour, False colour and natural colour of the image can be obtained by adjusting R, G and B bands as shown on the table below.

Satellite	Colour type	RGB
Landsat8	True Colour	R= Band 4 (Red Band) G= Band 3 (Green Band) B = Band 2 (Blue Band)
	False Colour	R= Band 5 (Near Infrared Band) G= Band 4 (Red Band) B = Band 3 (Green Band)
	Natural Colour	R= Band 4 (Red Band) G= Band 5 (Near Infrared Band) B = Band 3 (Green Band)
Landsat6/7		
Landsat4	True Colour	

When attempting to view Landsat8 image, after setting the appropriate RGB, Do the following: From the table of contents in ArcMap, right click or double click on the landsat image layer name and click 'Properties' to go to its 'Layer Properties'. (double click layer name for short cut)

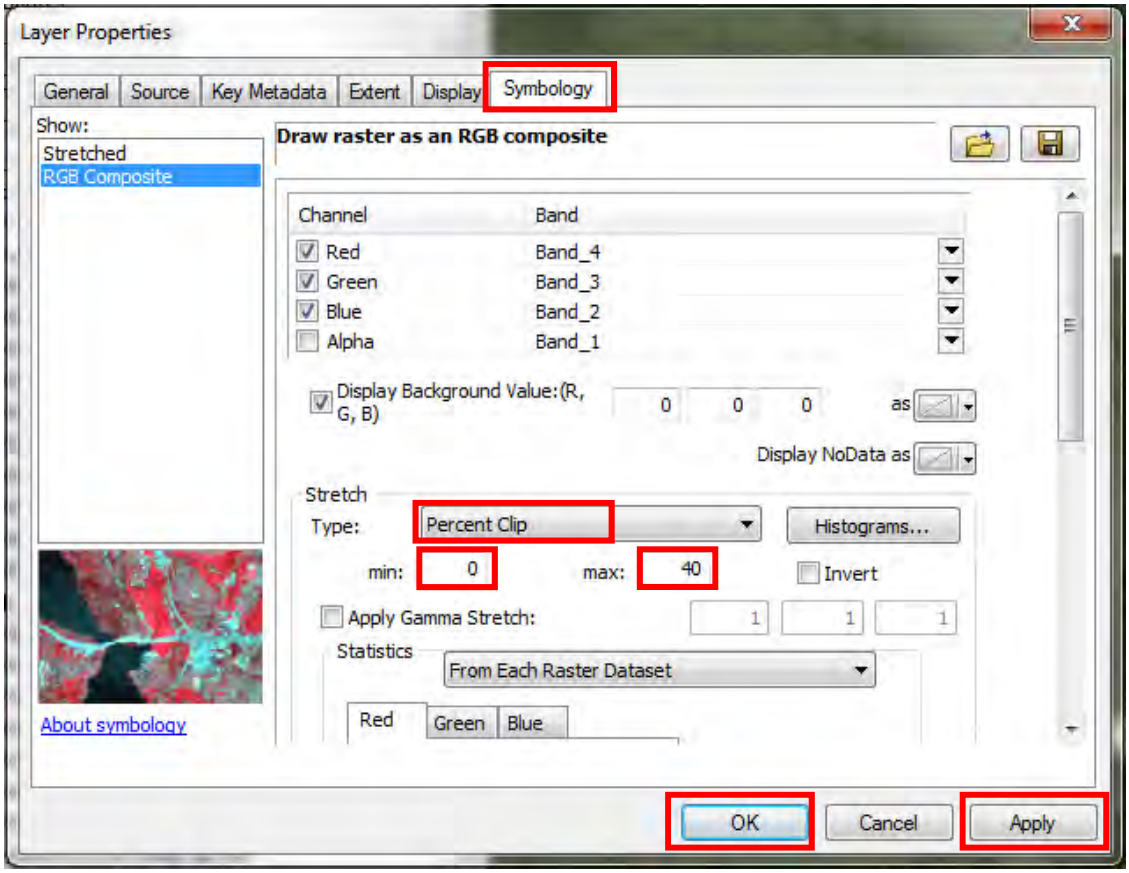
Click the ‘Symbology’ tab.

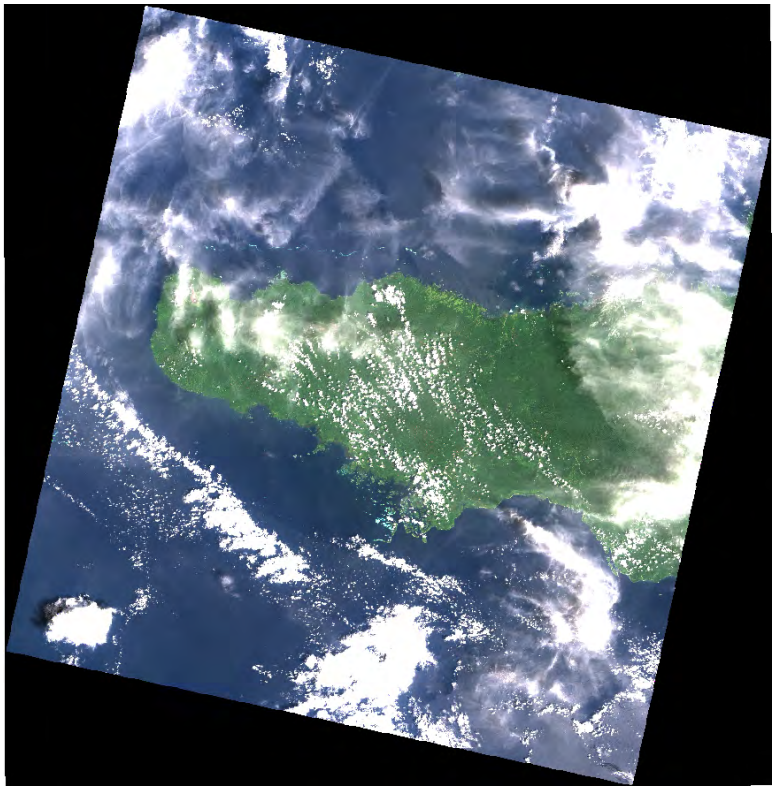
Under ‘Stretch’ click the drop down arrow and select ‘Percent Clip’. Set ‘min’ to zero (0). For max, increase the value and click ‘Apply’ every time you increase.



Repeat until you are satisfied with the visual appearance of the image.

Click ‘OK’.

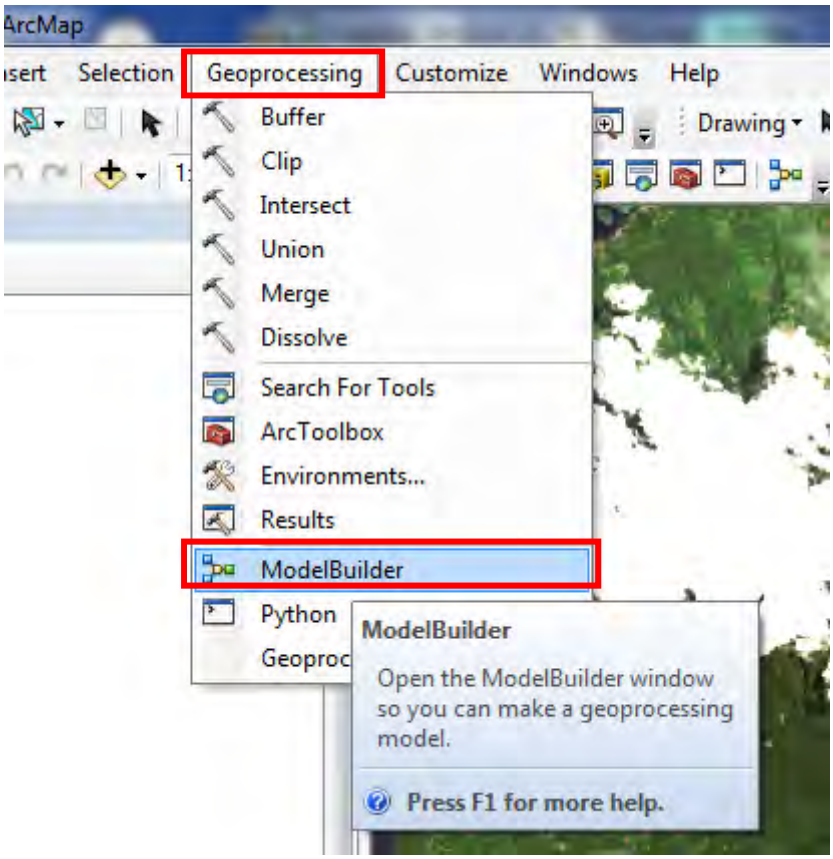


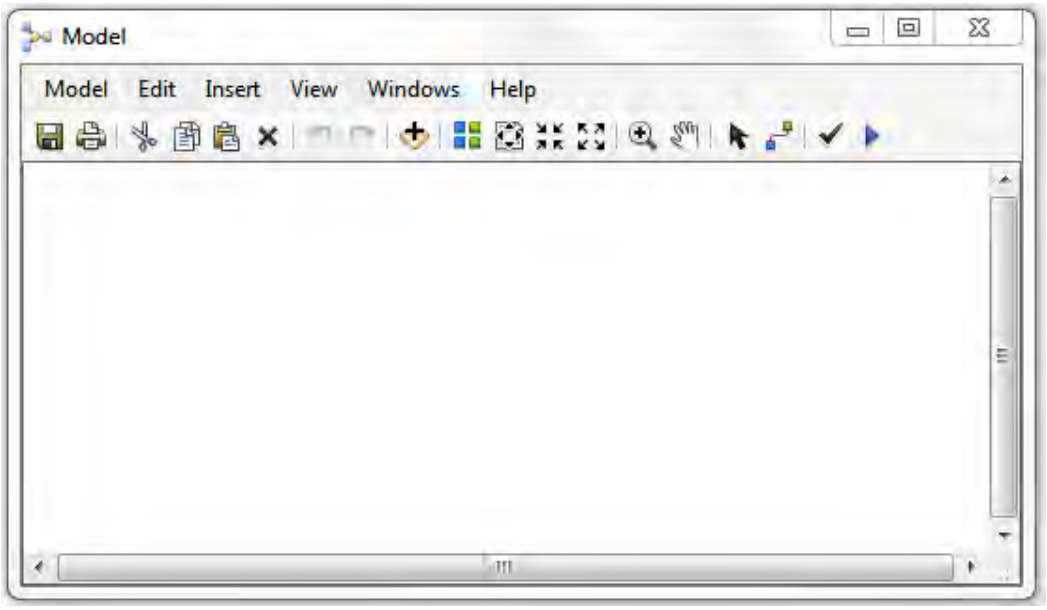


Calculating NDVI and NDWI using Landsat 8 imagery

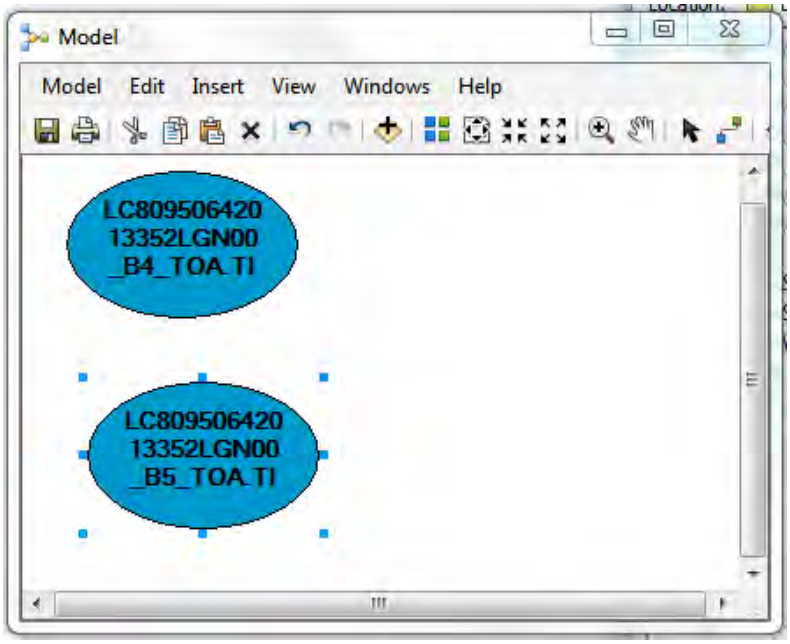
Click on 'Geoprocessing' on the menu bar, click 'Model Builder'.

Model window pops up.



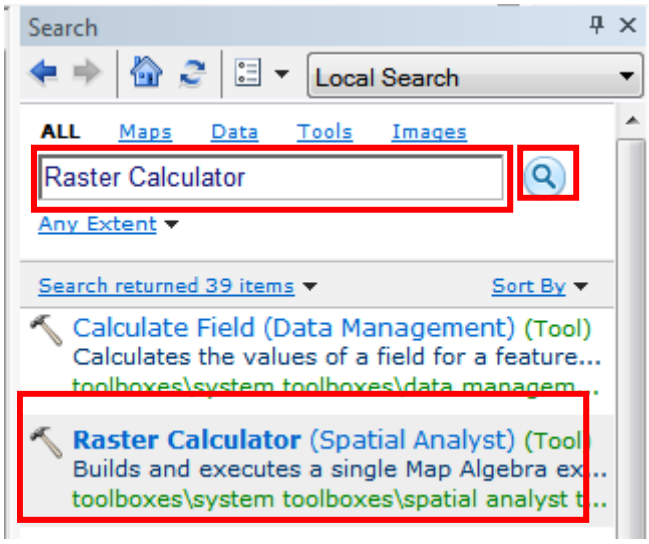


Drag and Drop B4 and B5 into 'Model Builder' window from the 'Table of Contents' or the 'Catalogue'. Make sure that B4 and B5 are the values which you have converted to reflectance from digital number.



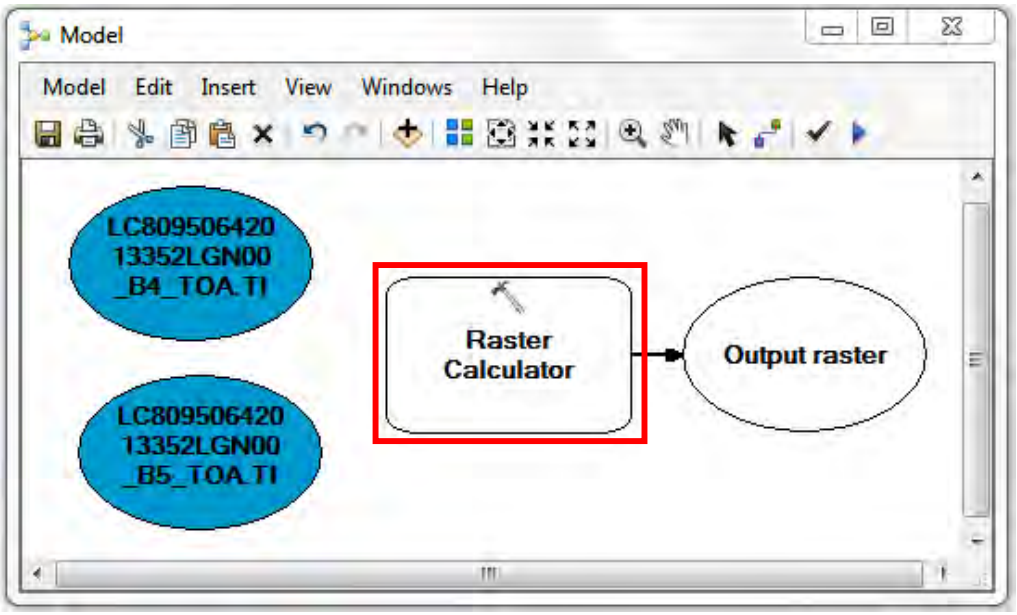
Go to 'Search' table, type in "Raster Calculator" click "Search" of press "Enter" key on the keyboard.

Drag and drop the "Raster Calculator (Spatial Analyst)" into the "Model Builder" window.



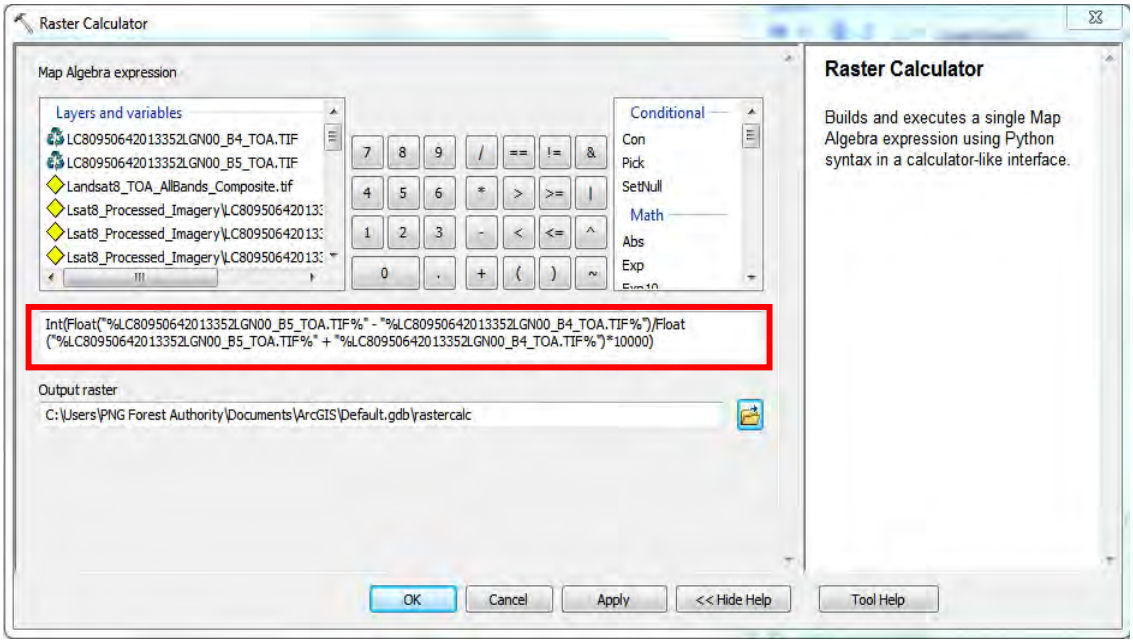
The concept of NDVI formula is as follows: NDVI = $\frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$

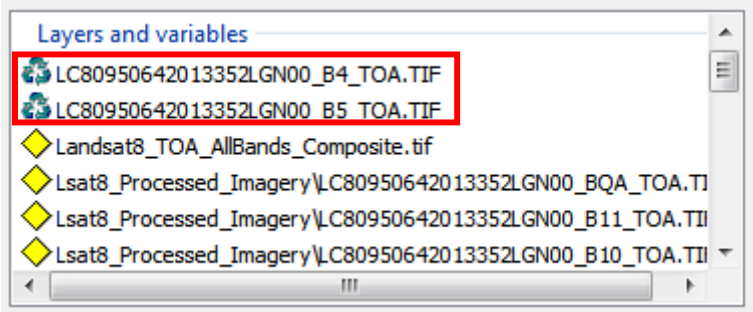
Double click on the Raster calculator:



Enter the following formula:

$$Int\left(\frac{Float(Band\ \ 5 - Band\ \ 4)}{Float\ \ (Band\ \ 5 + Band\ \ 4)} * 10000\right)$$



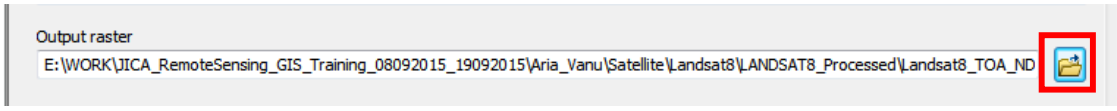


To enter Band 5 and Band 4 into the formula, Double click on the Band names under the 'Layers and Variables'.

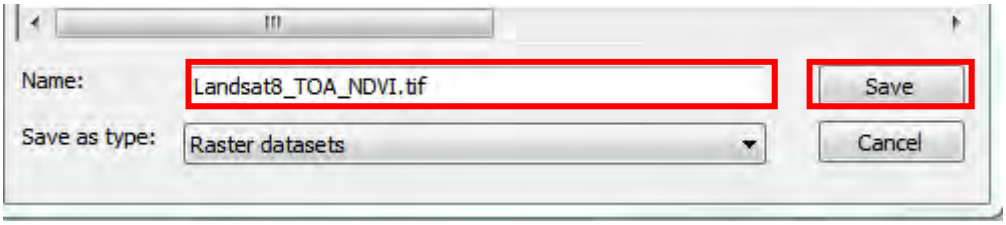
The formula will look similar to this:

Int(Float("%LC80950642013352LGN00_B5_TOA.TIF%" - "%LC80950642013352LGN00_B4_TOA.TIF%")/Float("%LC80950642013352LGN00_B5_TOA.TIF%" + "%LC80950642013352LGN00_B4_TOA.TIF%")*10000)

Save the output raster in your desired folder.



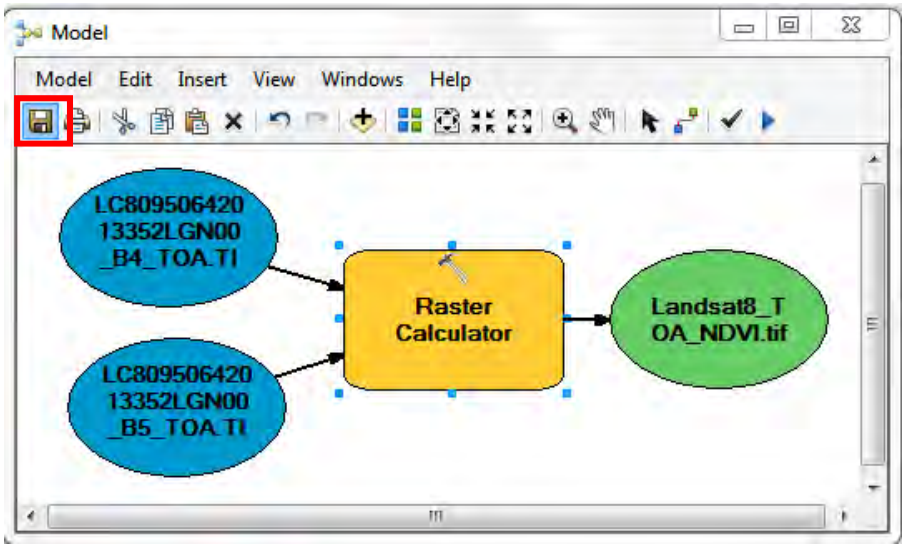
Give it a name. Add '.tif' at the end of the name.



Click 'Save'.

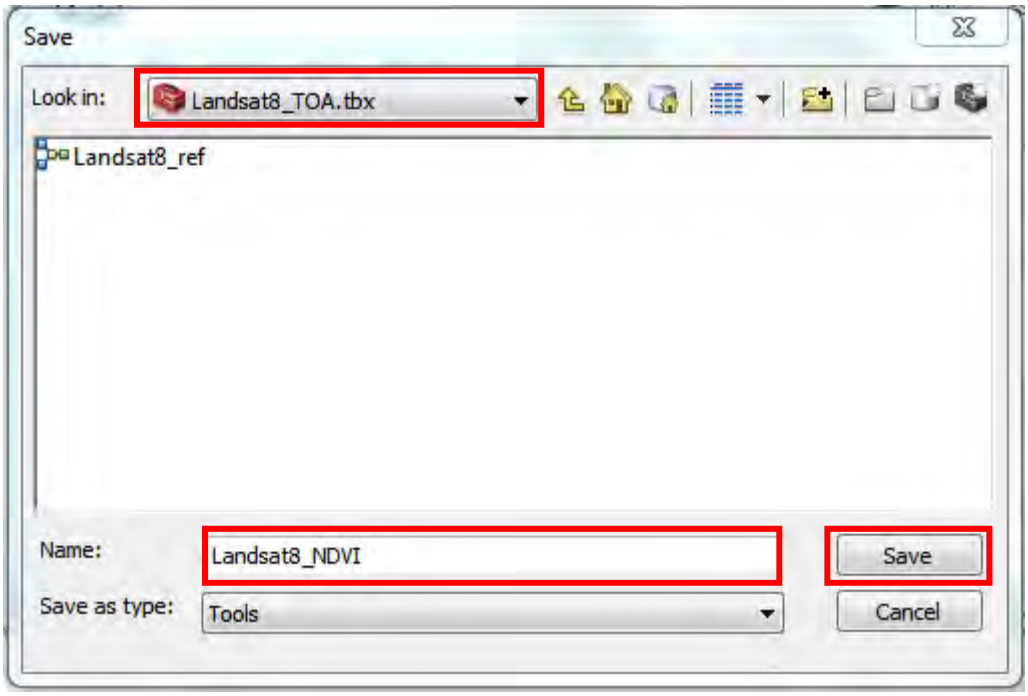
Click 'OK'.

Save the model under ‘Landsat8_TOA.tbx’ toolbox.

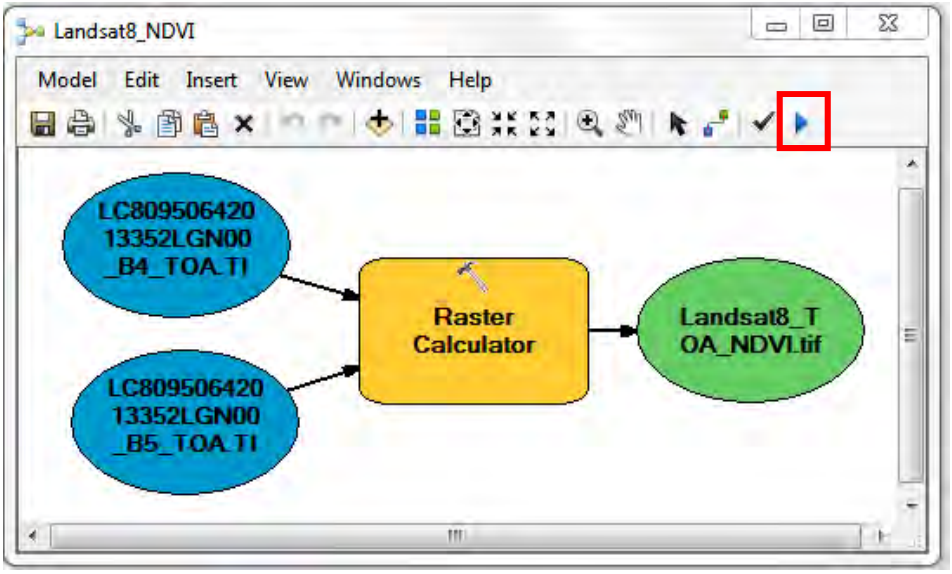


Give it a new name: e.g ‘Landsat8_NDVI’.]

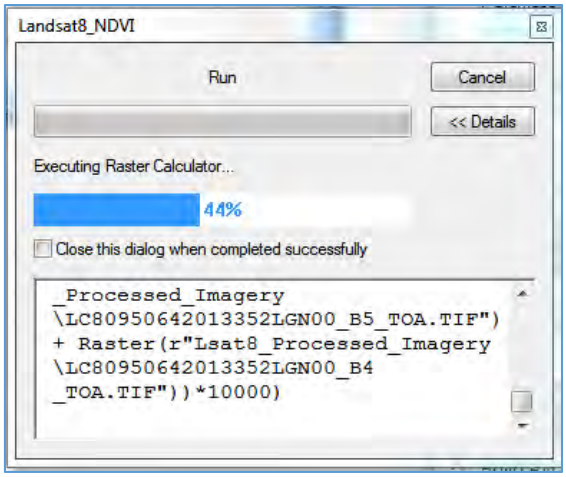
Click ‘Save’.

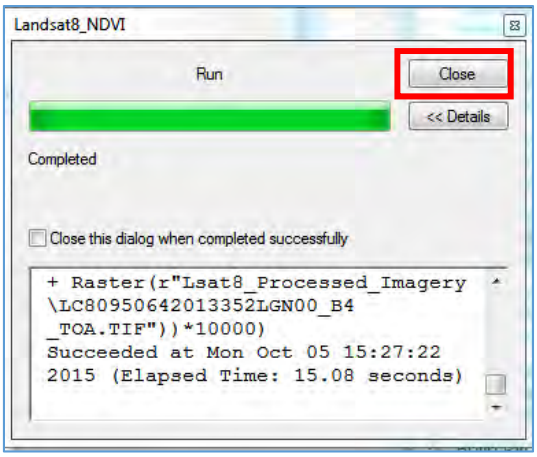


Click the “run” button.



Processing window pops up.

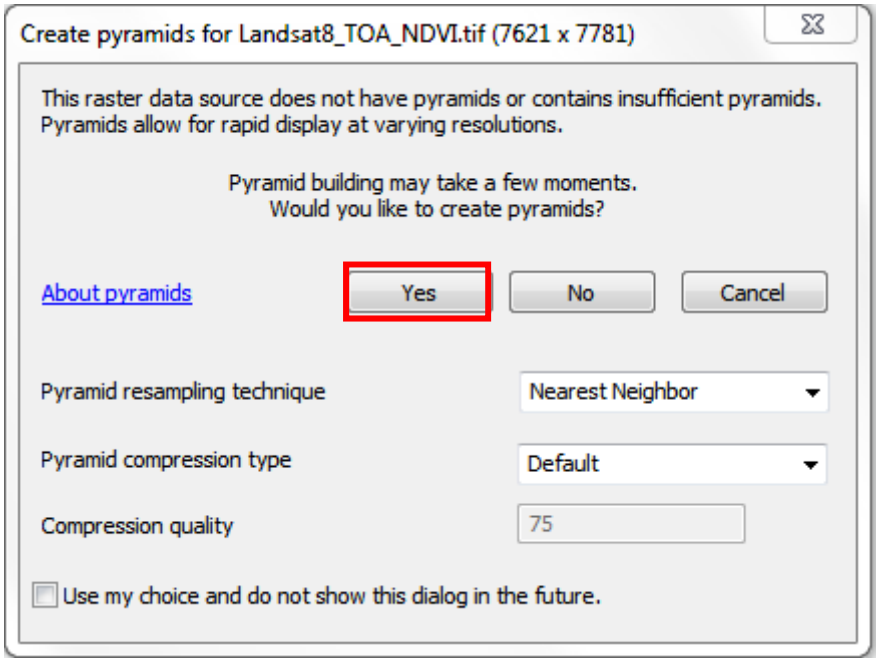




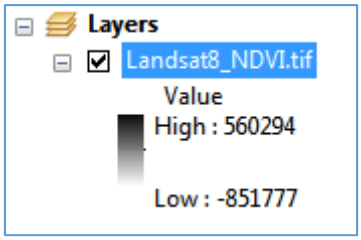
Close the window when the processing is complete.

Close the model window.

Open the Image in ArcMap. Click yes if Pyramid window pops up.



The NDVI image will show positive and negative values. Positive values indicate healthy vegetation/just vegetation. Negative values indicate un healthy vegetation or non-vegetated areas such as structures, water bodies, etc.

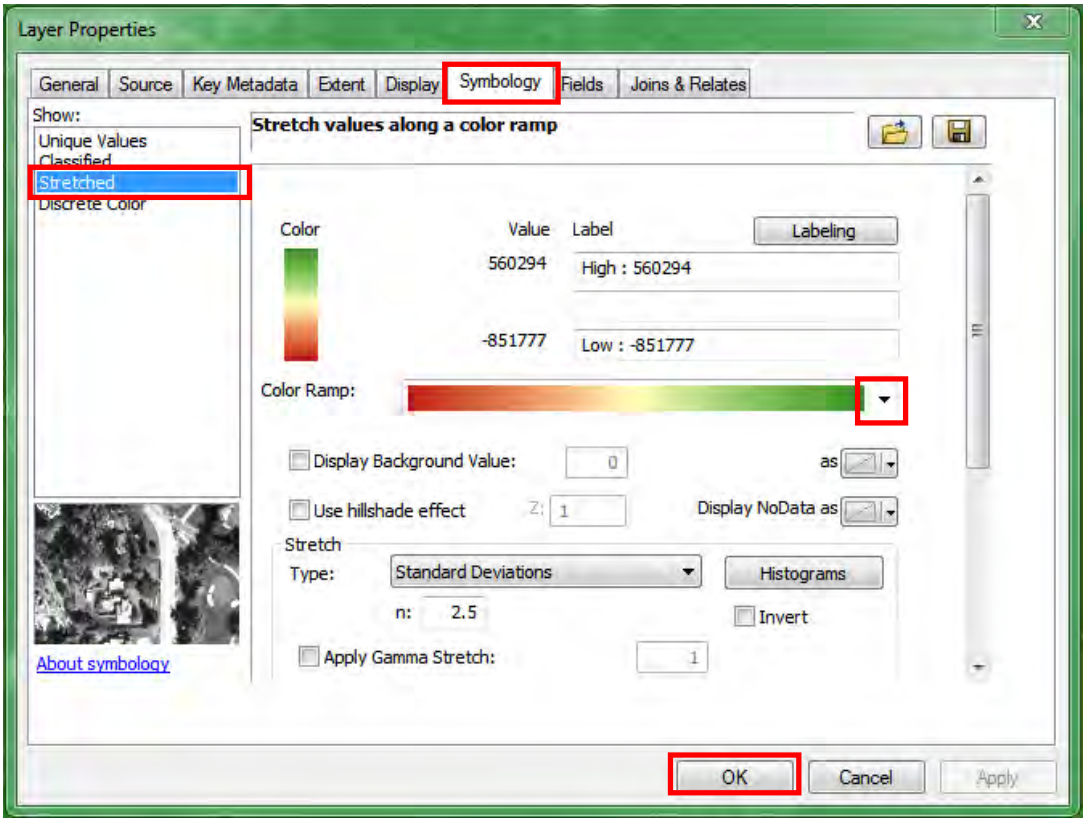


Double click on the NDVI image layer name to go to its 'Layer Properties'.

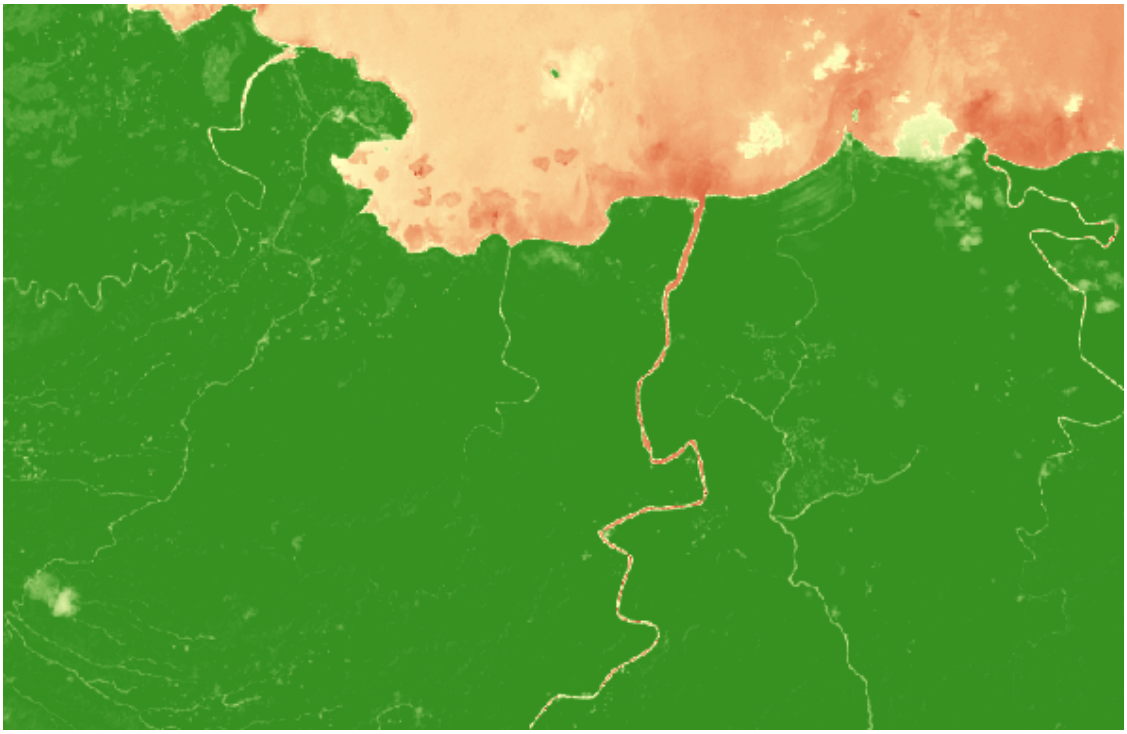
Click the 'Symbology' tab. Select 'Stretched' under 'Show' column.

Click the 'Colour Ramp' drop down arrow and choose your desired colour.

Click 'Apply/OK'.



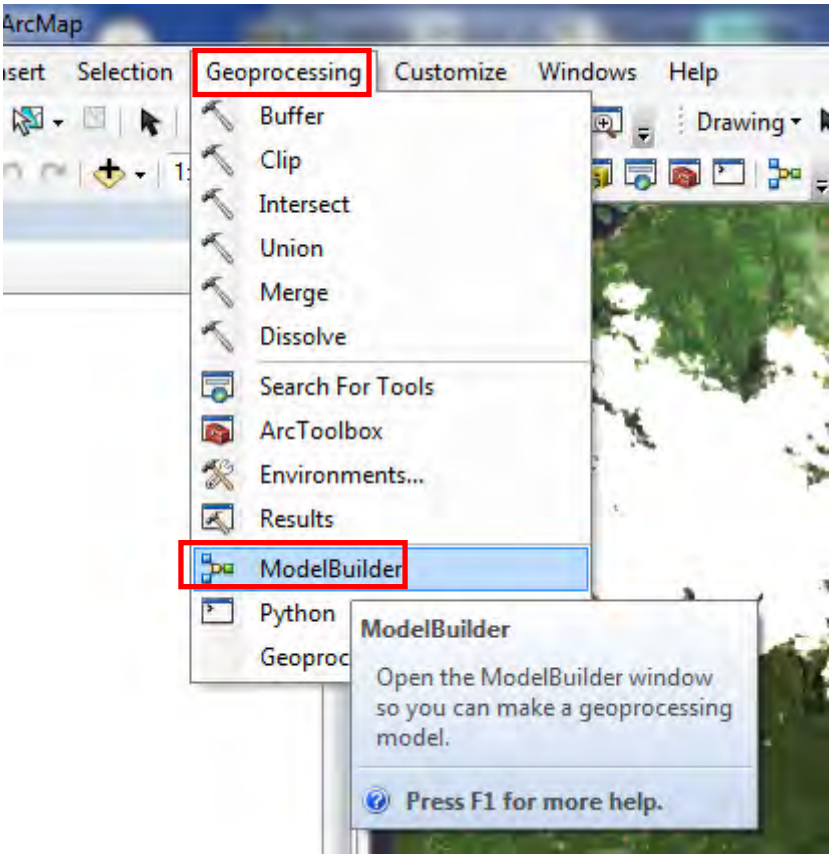
Zoom down to your area of interest to view.



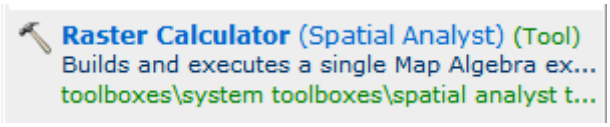
Calculating NDWI using Landsat 8 imagery

The calculation of NDWI (Normalized Difference Water Index) is similar to NDVI.
This time however, Bands 5 and Bands 6 are used.

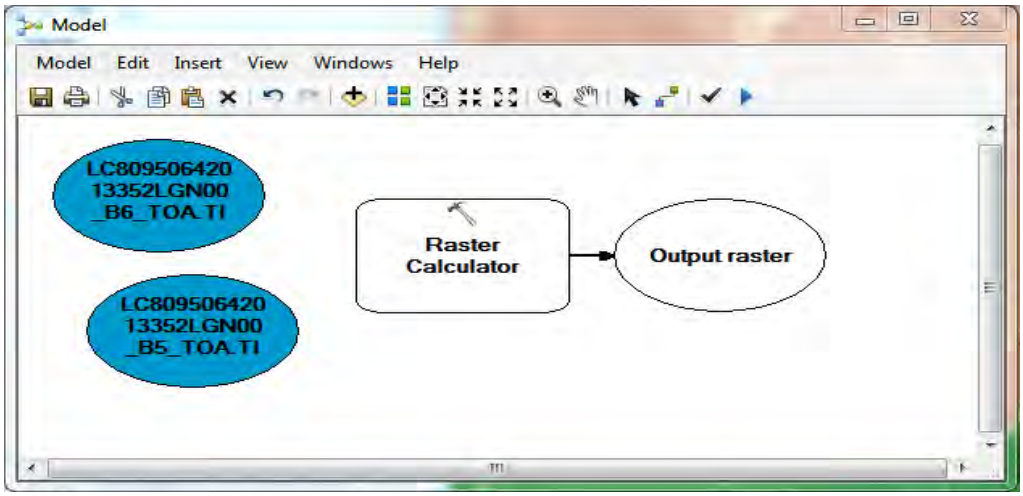
Click on 'Geoprocessing' on the menu bar, click 'Model Builder'.
Model window pops up.



Drag and Drop B5 and B6 into 'Model Builder' window. Make sure that B5 and B6 are the values which you have converted to reflectance from digital number.
Go to the 'Search' table, type in "Raster Calculator" click "Search" or press "Enter" key on the keyboard.



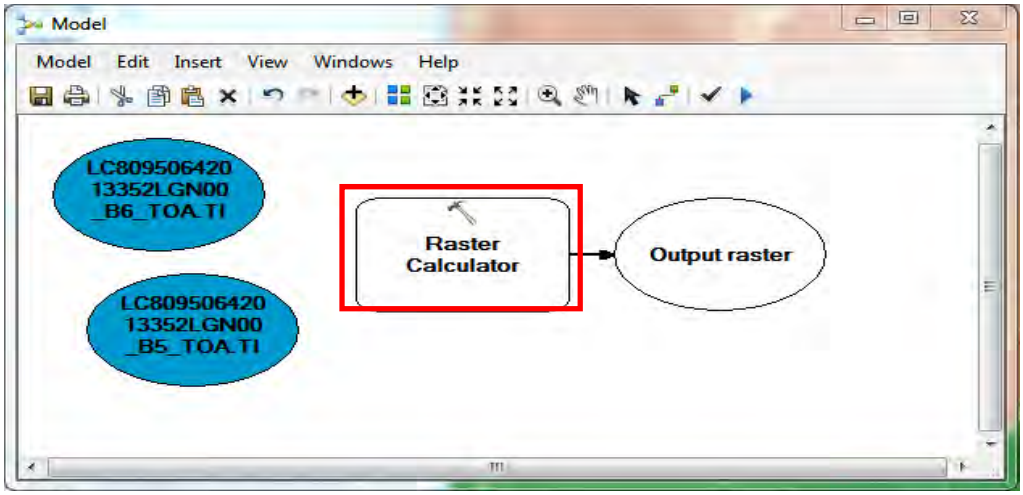
Drag and drop the "Raster Calculator" into the "Model Builder" window.



The concept of NDWI calculation is as follows:

NDWI = $\frac{Band\ \ 5 - Band\ \ 6}{Band\ \ 5 + Band\ \ 6}$

Double click on the Raster calculator.



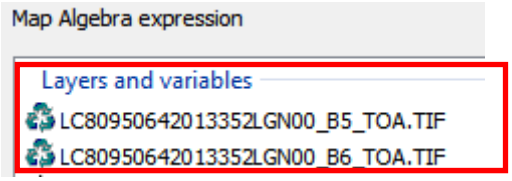
Enter the following formula:

$$Int\left(\frac{Float(Band\ \ 5 - Band\ \ 4)}{Float\ \ (Band\ \ 5 + Band\ \ 4)} * 10000\right)$$

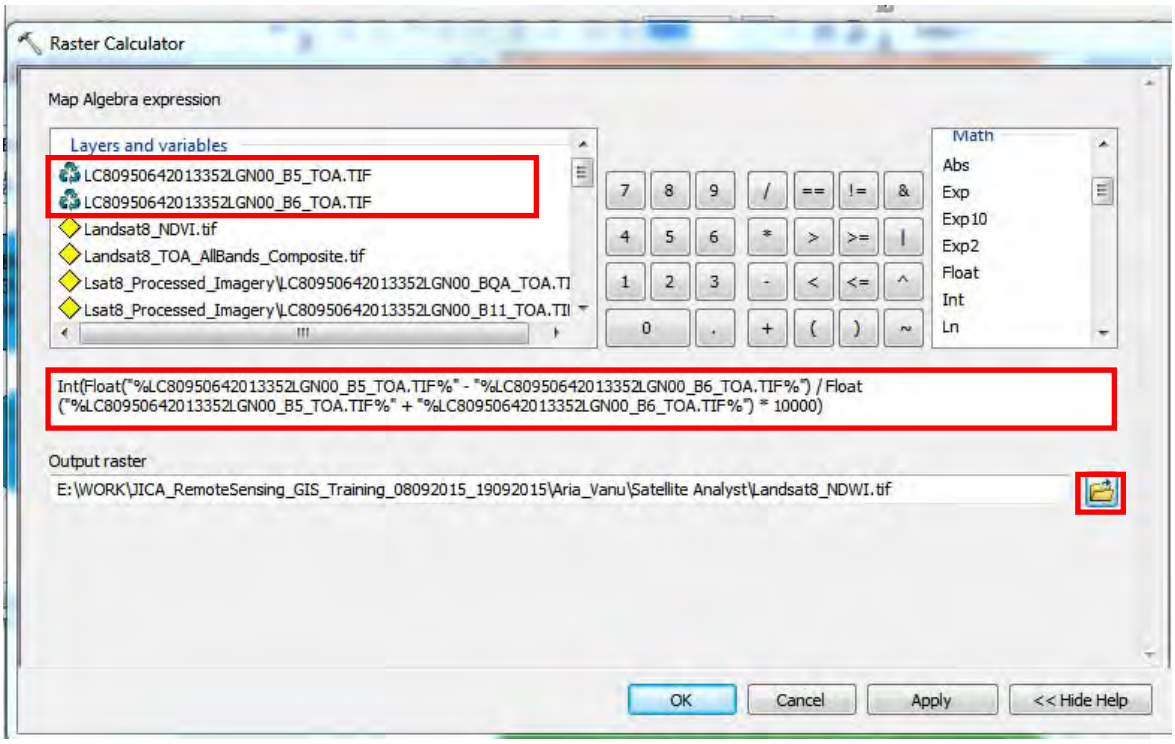
The formula entered should look similar to the following:

```
Int(Float("%LC80950642013352LGN00_B5_TOA.TIF%" -
"%LC80950642013352LGN00_B6_TOA.TIF%") /
Float("%LC80950642013352LGN00_B5_TOA.TIF%" +
"%LC80950642013352LGN00_B6_TOA.TIF%") * 10000)
```

When entering Bands 6 and Bands 6 into the formula, double click on these two bands:



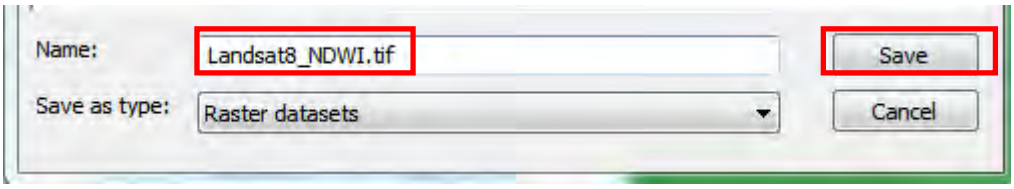
Not the other bands beneath.



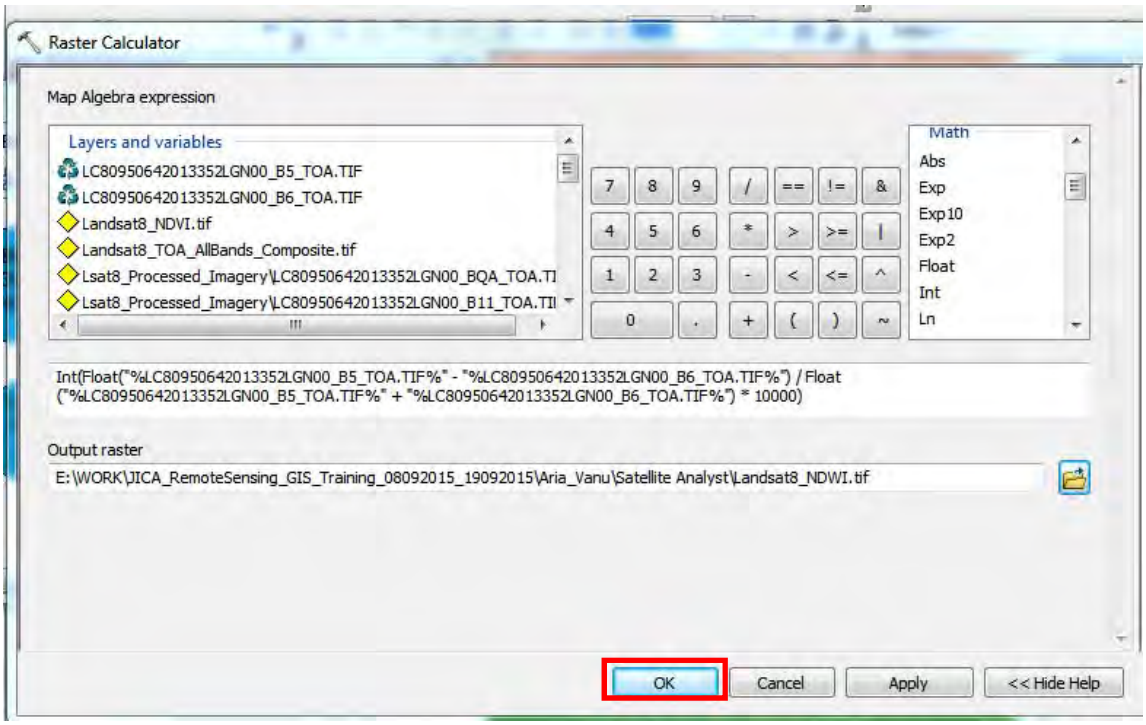
Save the NDWI in your desired folder. Give it a new Name: e.g Landsat8_NDWI.

Add .tif at the end of the image name.

Click 'Save'.



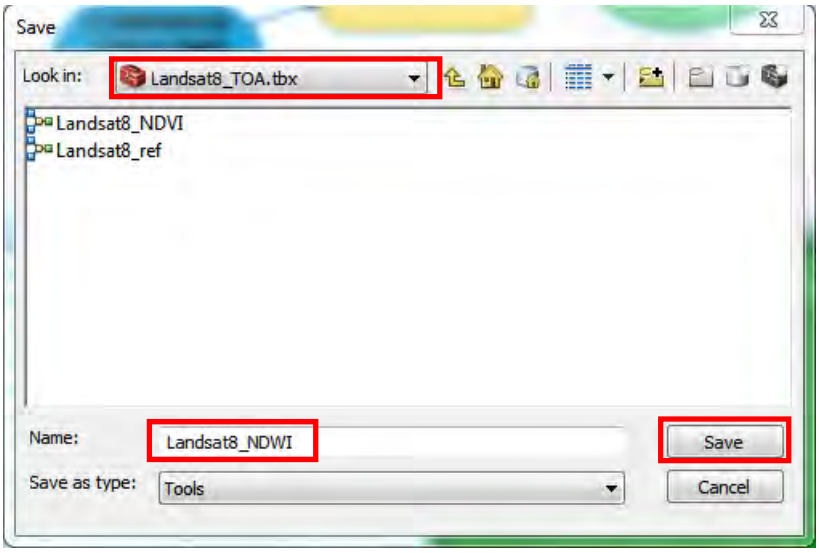
Click ‘Ok in “Raster Calculator’.



Save the model in ‘Landsat8_TOA.tbx’.

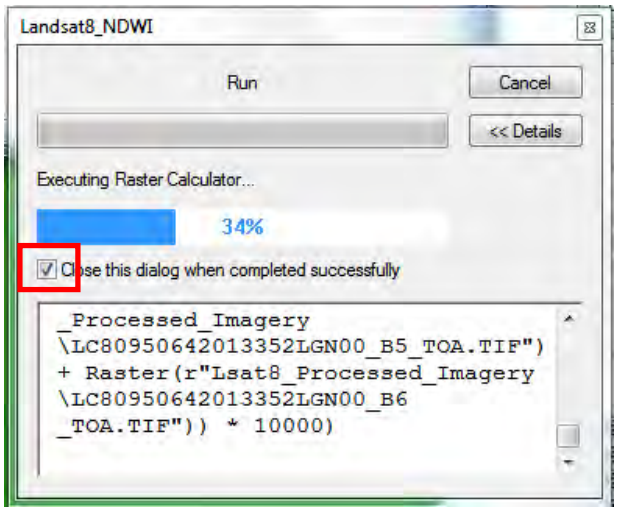
Navigate to ‘Landsat8_TOA.tbx’ by clicking the drop down arrow beside ‘Look in’.

Rename the Model and save it.



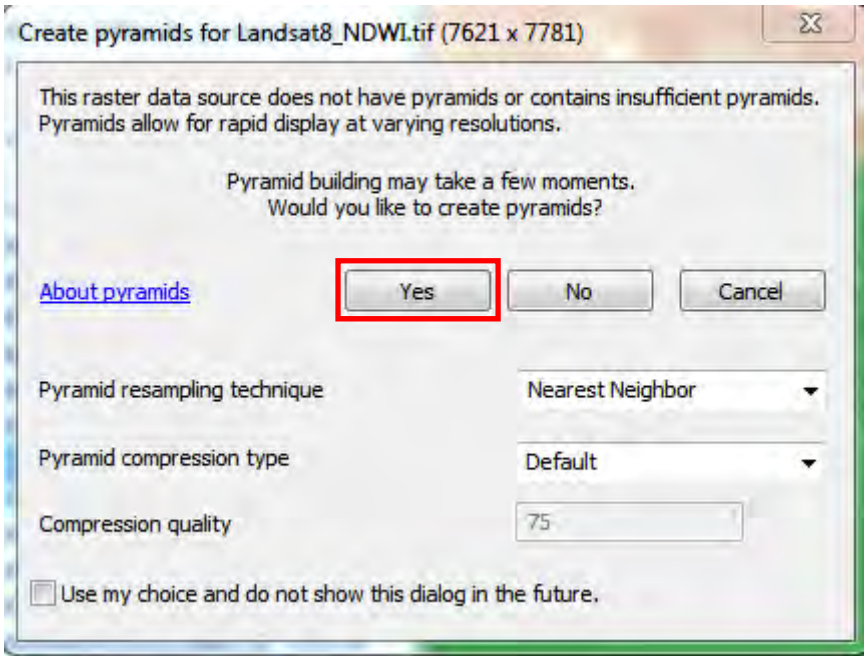
Click the “run” button in the ‘Model window.

Processing window pops up.

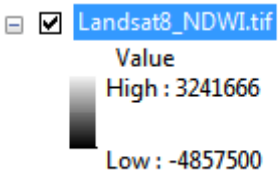


Open the image in ArcMap.

Click ‘Yes’ when pyramid building window pops up.



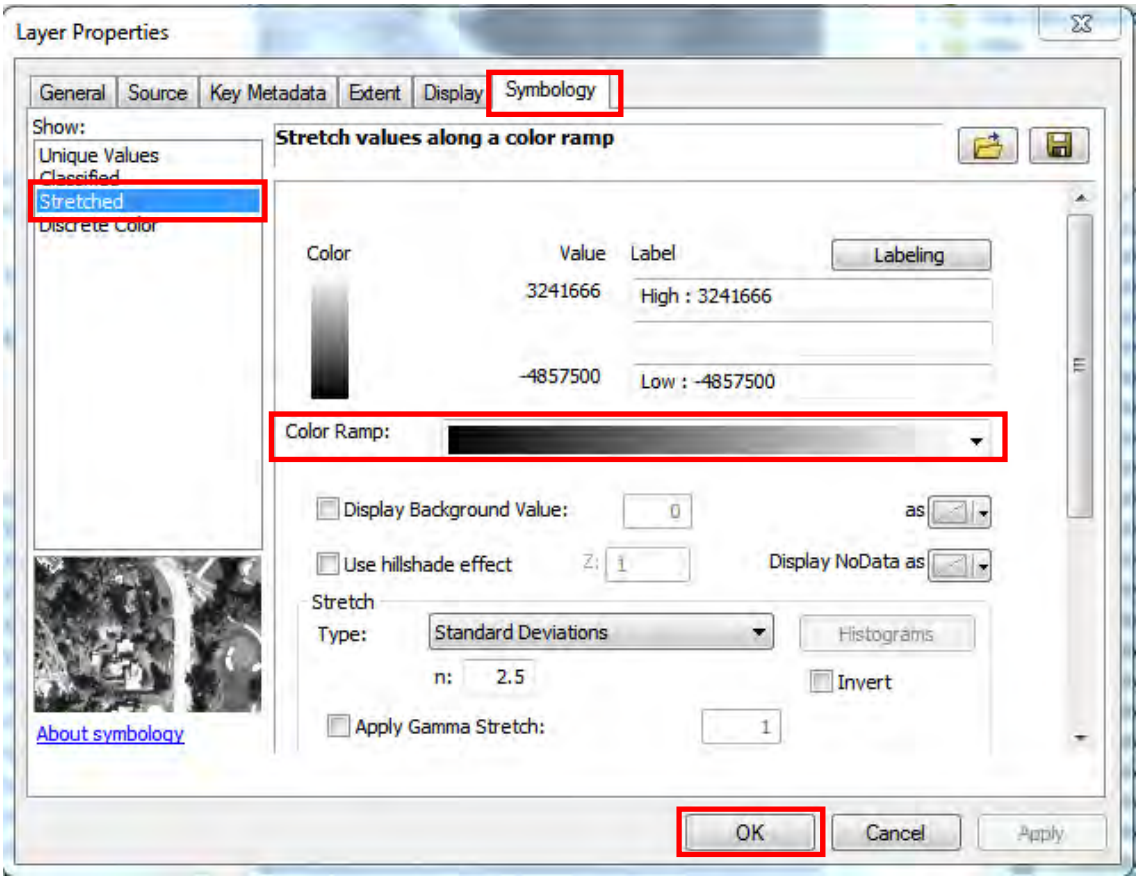
The NDWI displays negative and positive values.



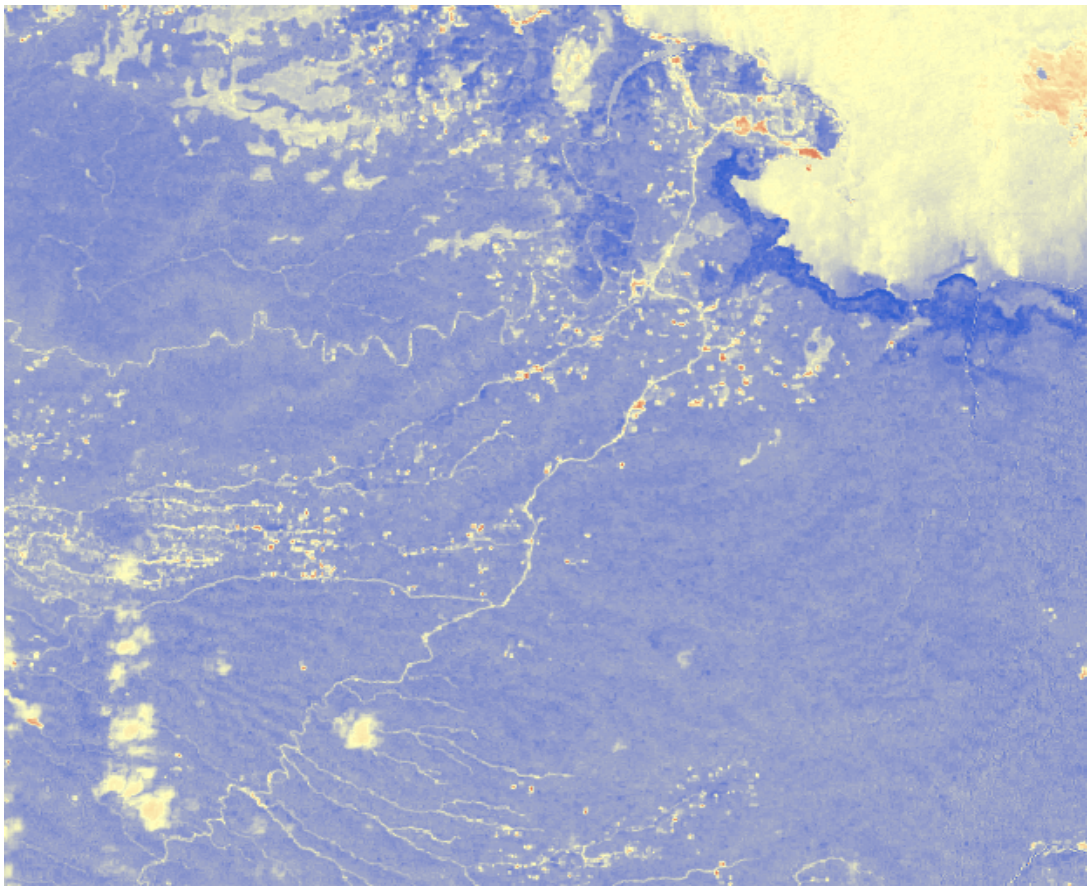
Go to the NDWI's 'Layer Properties'. Click the 'Symbology' tab.

Select 'Stretched'. Change the colour in 'Colour Ramp'.

Click 'Apply/OK'.



View your image.



E. Downloading and Processing SAR

Downloading and Processing SAR

Synthetic Aperture Radar (SAR) Images

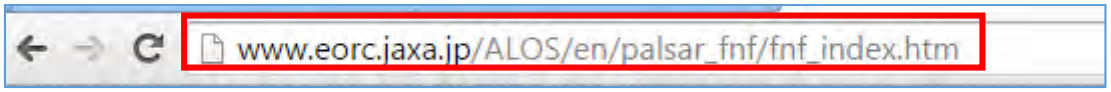
Downloading 25m resolution SAR image from JAXA.

Open up your web browser (Google Chrome, Firefox, etc)

Type in the following address:

http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

Go to search or Press 'Enter' key.

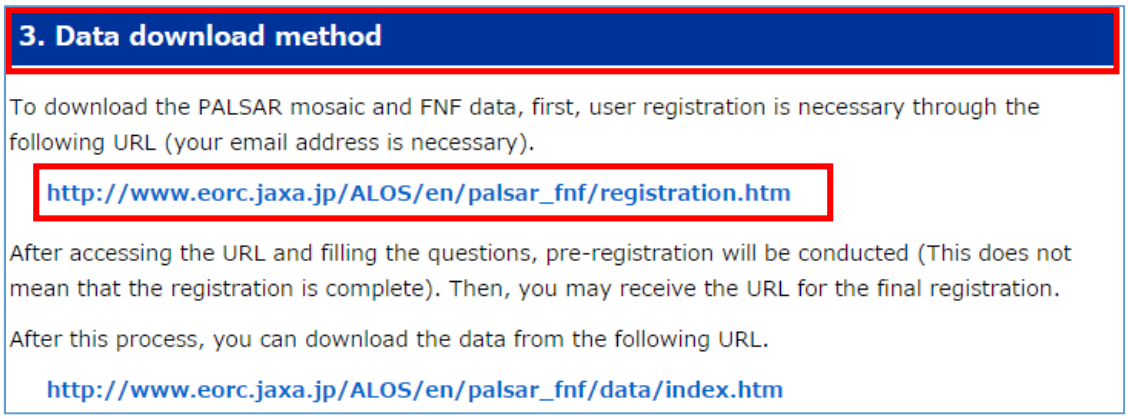


ALOS web page appears.

Scroll down to the third point.

'3.Data Download method.'

Click on the first URL address.



3. Data download method

To download the PALSAR mosaic and FNF data, first, user registration is necessary through the following URL (your email address is necessary).

http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/registration.htm

After accessing the URL and filling the questions, pre-registration will be conducted (This does not mean that the registration is complete). Then, you may receive the URL for the final registration.

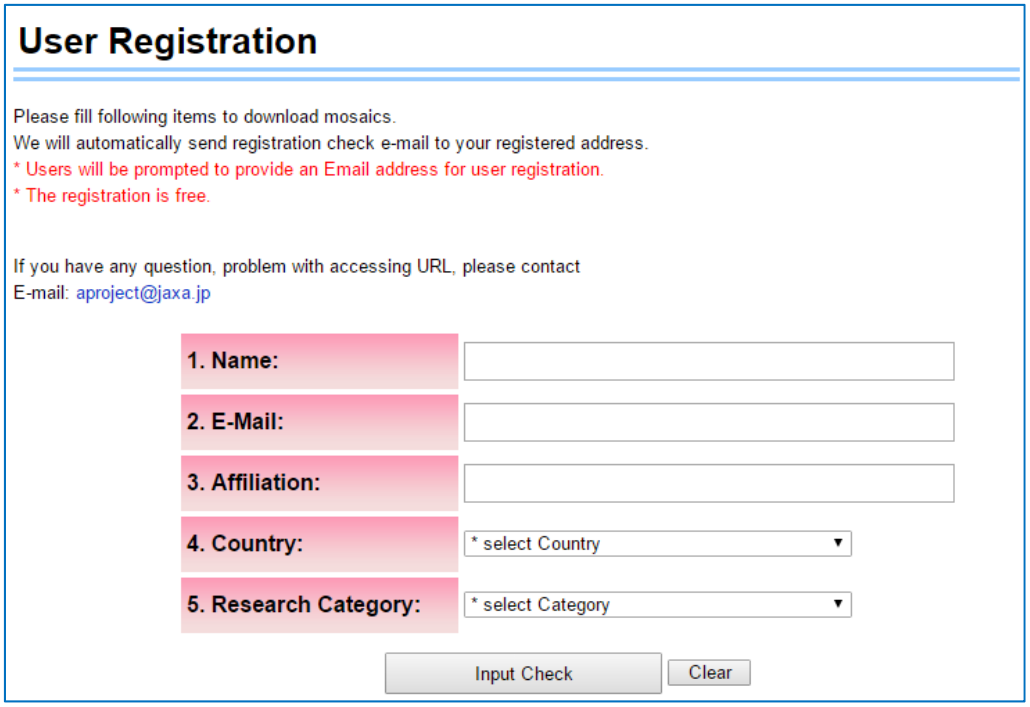
After this process, you can download the data from the following URL.

http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm

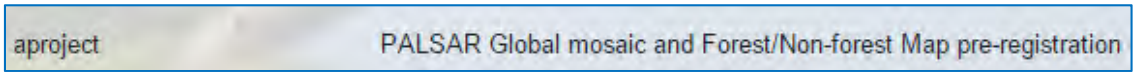
Enter Your details:

For 'Research Category' choose 'Vegetation_Forest and Wetland'

Click 'Input Check'. Click 'Send Email'.



Go to your Gmail to receive your confirmation email.



Open your Confirmation email. Click on the URL given.

Thank you for your pre-registration.
In order to activate your account, you need to do one more action bellow.

Please access to the following URL, and click "Confirm registration" button.
After that, your account will be activated and the notification of registration completion will be sent to your e-mail address

http://www.eorc.jaxa.jp//cgi-bin/ALOS/palsar_fnf/comp_reg.cgi?lang=en&id=881509100055622

*This e-mail is generated automatically.
If you are not the person who registered using this e-mail address, please ignore this e-mail.

Earth Observation Research Center /JAXA
JAXA/EORC aproject@jaxa.jp

Go back to your Gmail. Open the new email sent to you by JAXA and check for your user name and password.

aproject PALSAR Global mosaic and Forest/Non-forest Map registration -

Click on the URL in your confirmation email.

PALSAR Global mosaic and Forest/Non-forest Map registration Inbox x

aproject@jaxa.jp
to me

Dear

You are successfully registered to download PALSAR global mosaic and Forest/Non-forest Map.

The registered information are as follows:

Name:

E-mail:

Affiliation:

Country:Papua New Guinea

Research Category:Vegetation, Forest & Wetland

You can access to the data from the following URL by entering your ID and Password.

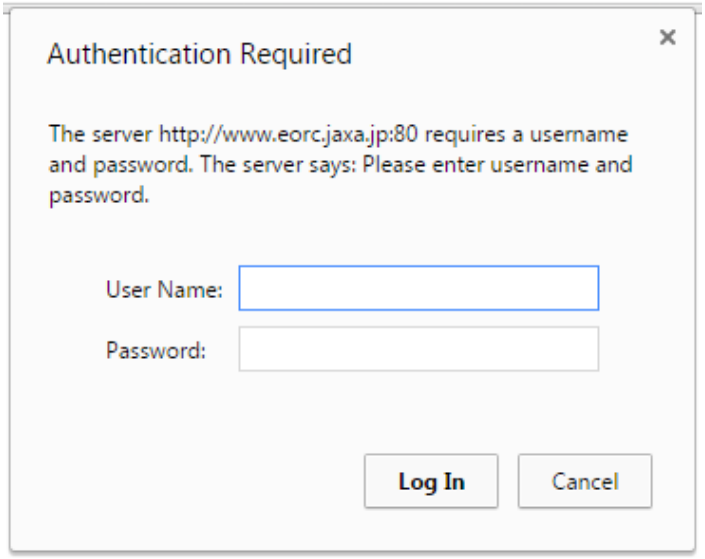
http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm

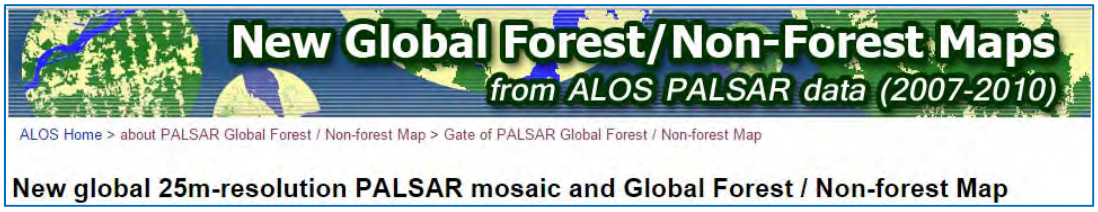
ID:
Password:

If you have any question or problem, please contact the following address.

Earth Observation Research Center /JAXA
JAXA/EORC aproject@jaxa.jp

Web page appears. Enter your username and password to log in.



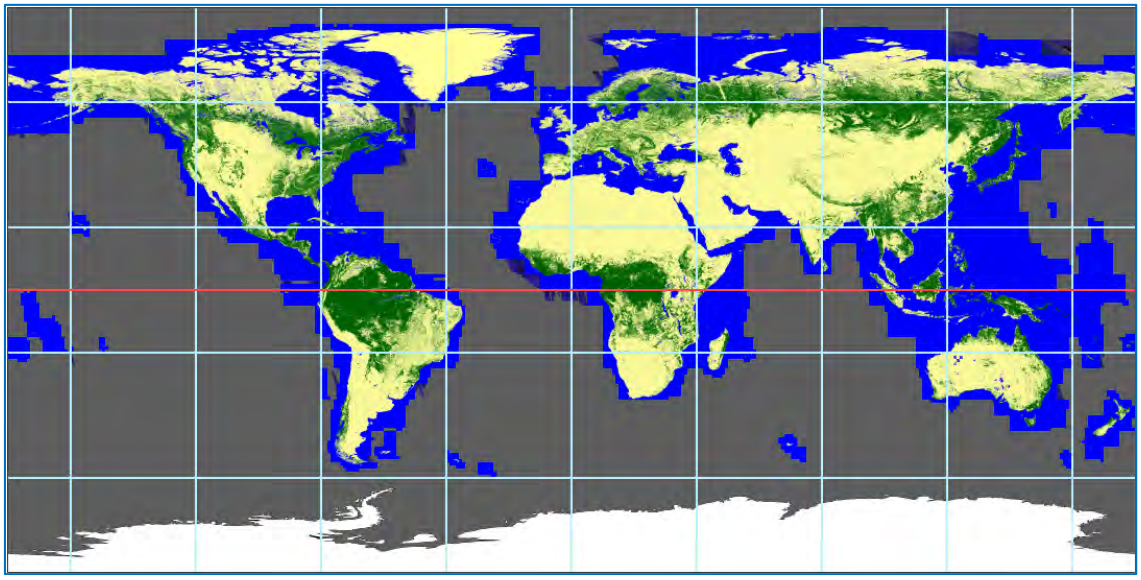


Download 2010 SAR Imagery

Click on '2010 under '25m resolution Original Data,'.

Click on the grid where PNG is located.

Zoom down and click on the grid where your area of interest is.

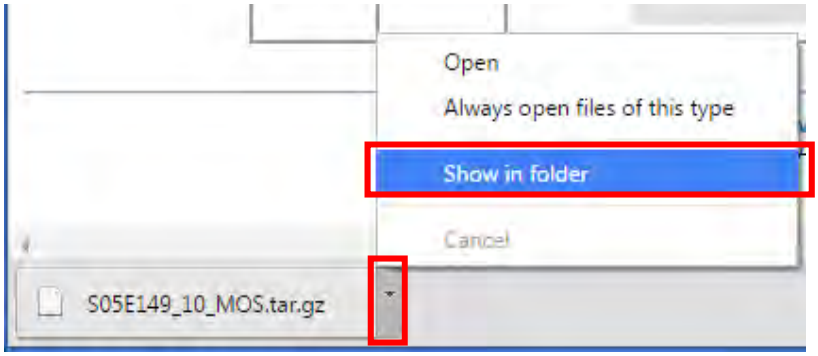


Click on the download link for both images (HH, HV).

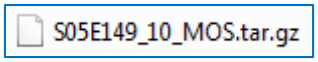
Image downloads.

Click on the drop-down arrow on the side of the image on the status bar.

Click 'Show in folder'.

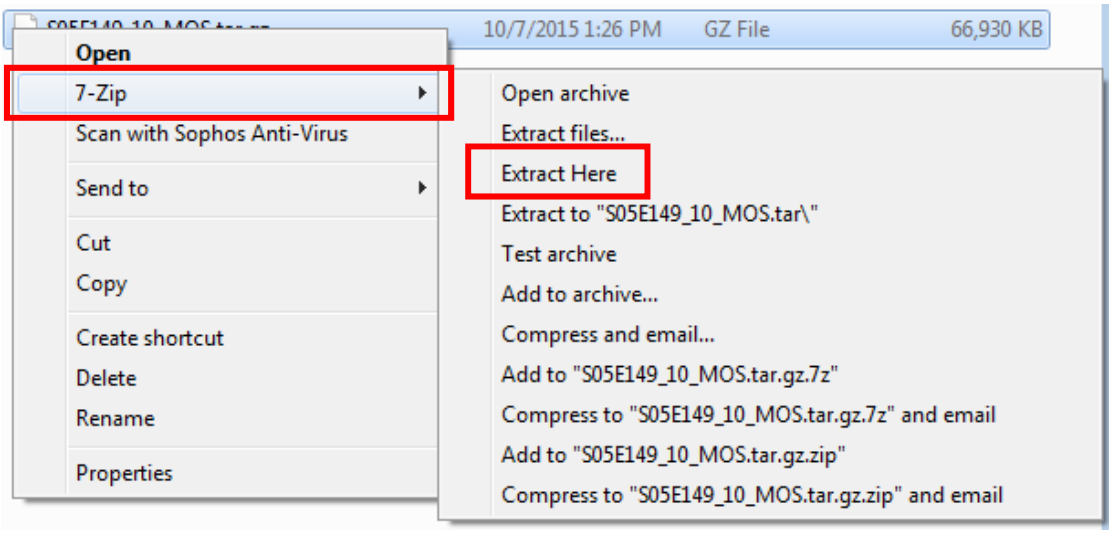


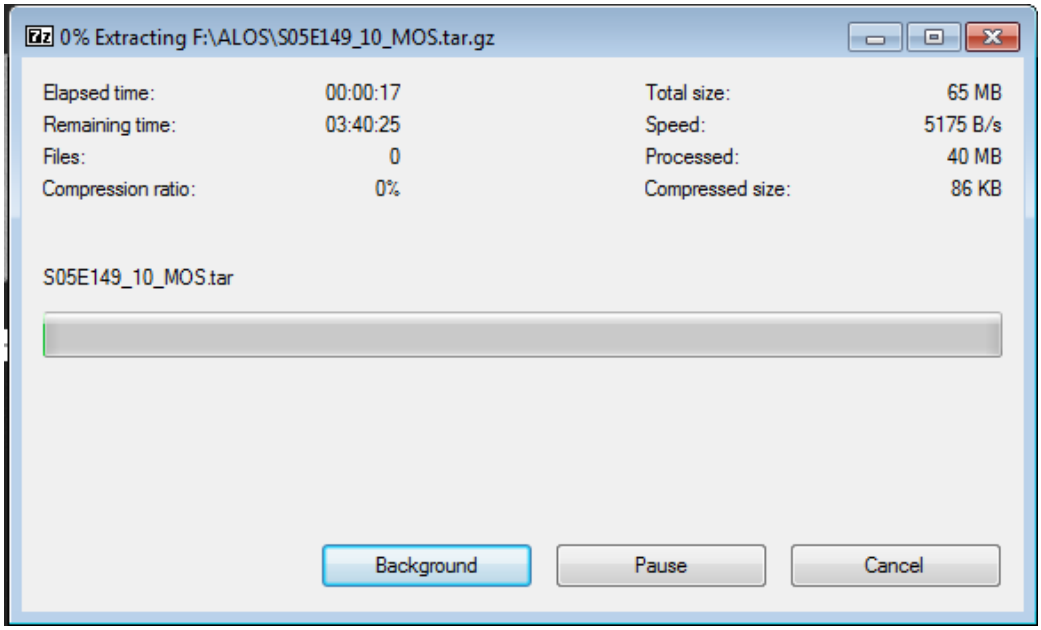
Locate your downloaded file. It will have the extension '.tar.gx'.



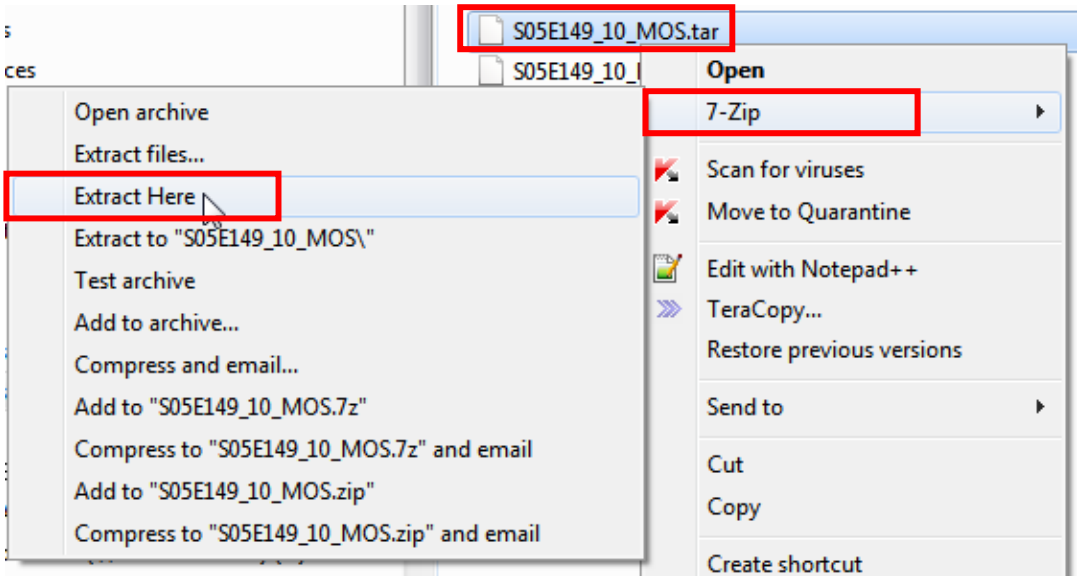
Cut and paste the image in your specific folder.

Unzip the files.



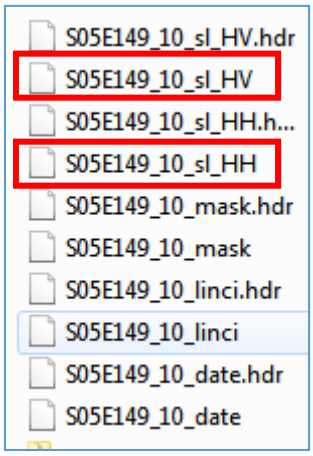


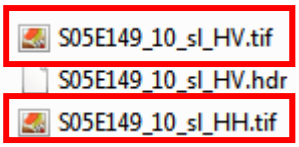
Right click and extract the file with the extension '.tar'.



Add '.tif" to the "HH" and "HV" files.

These two files have no file extensions.



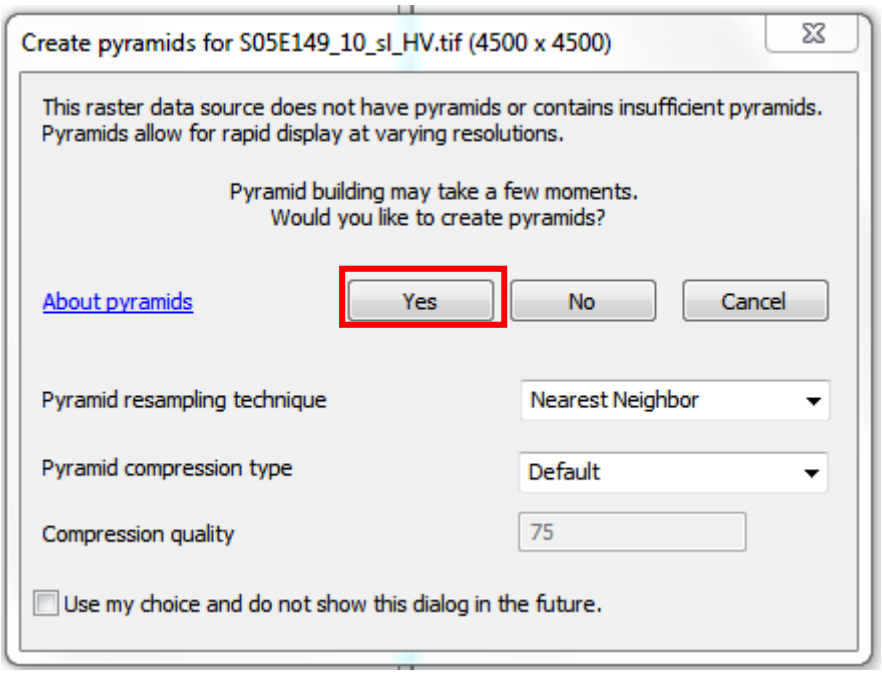


Open ArcMap

Open up the SAR image (the one where you have just add .tif) in ArcMap.

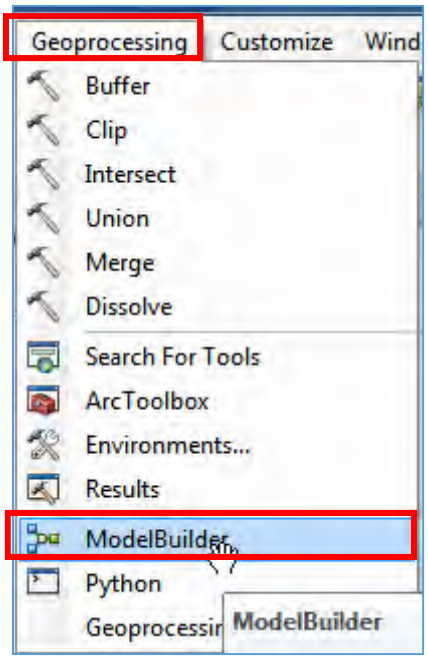
(You can either use Catalogue or just drag and drop the image from its folder into the ArcMap window.)

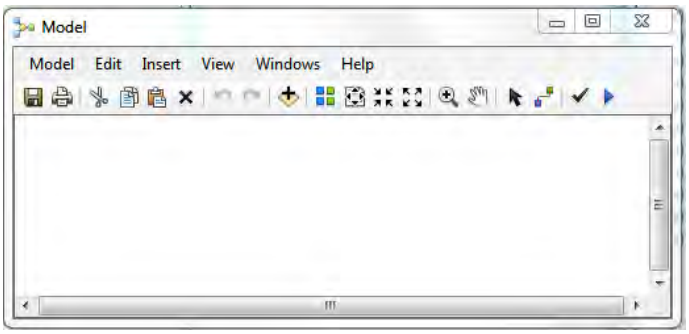
Click 'Yes' if pyramid window pops up.



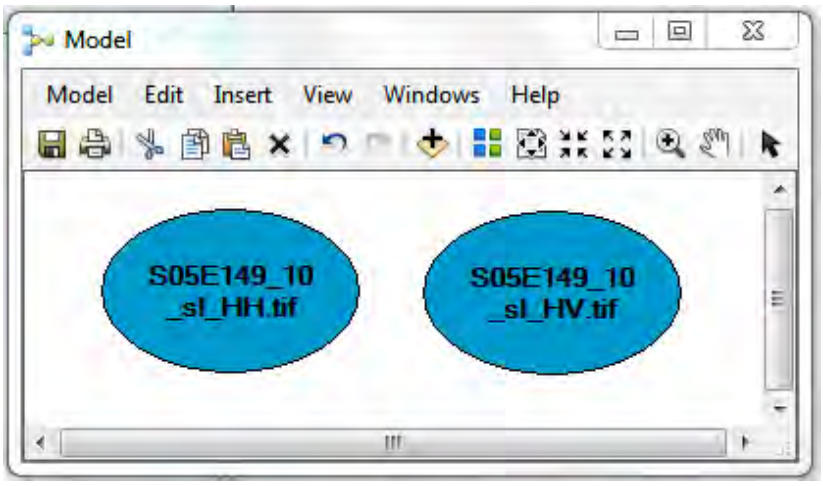
This image currently has ‘Digital Number’; therefore we must convert it to Radiance.
We will use ‘Model Builder’ to do this conversion.

Click on ‘Geoprocessing’ on the tools menu.
Click ‘Model Builder’, window pops up.

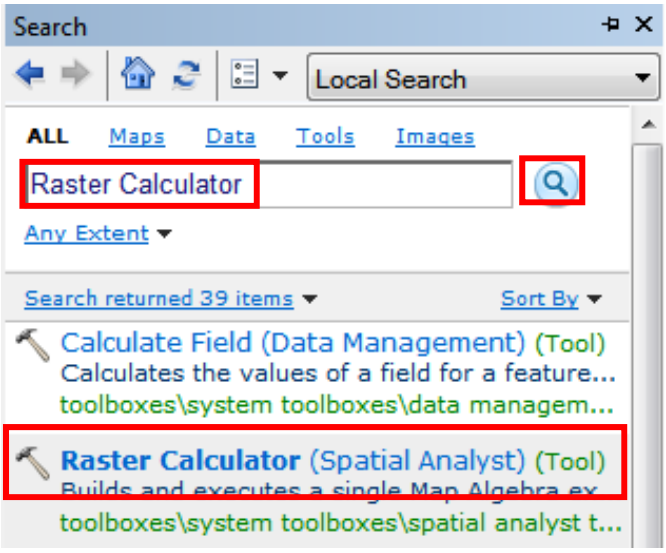


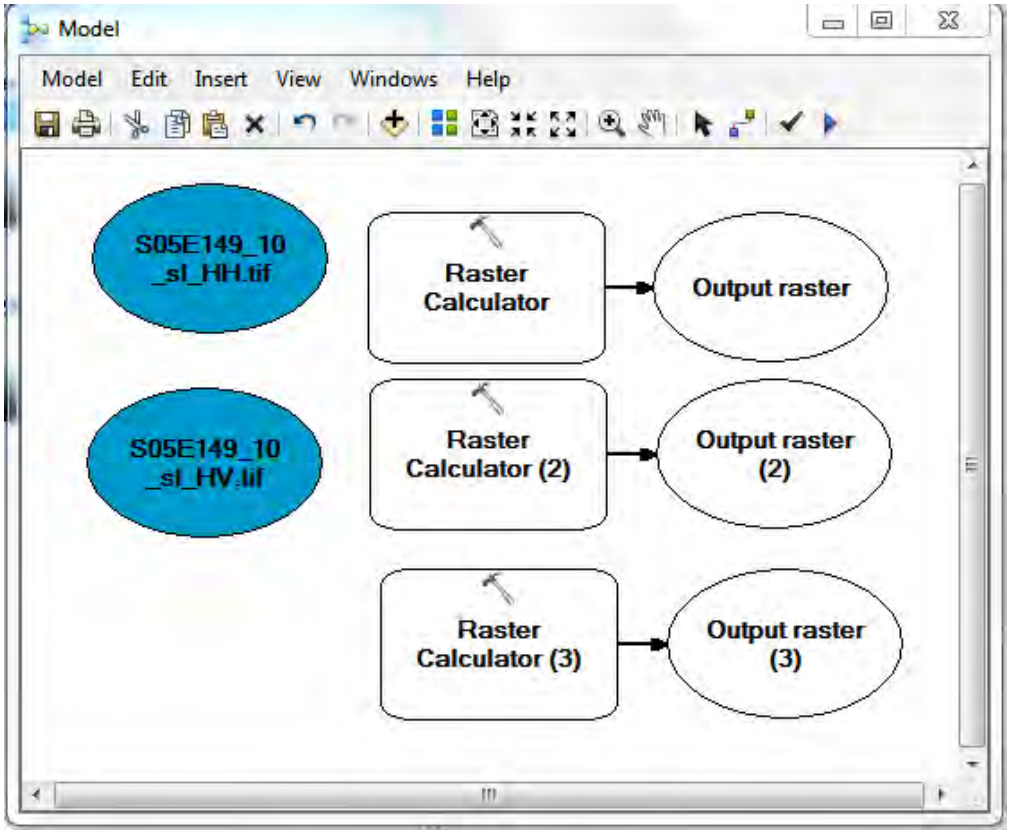


Drag and drop both images (HH.tif and HV.tif) into the ‘Model Window’ from the table of contents.

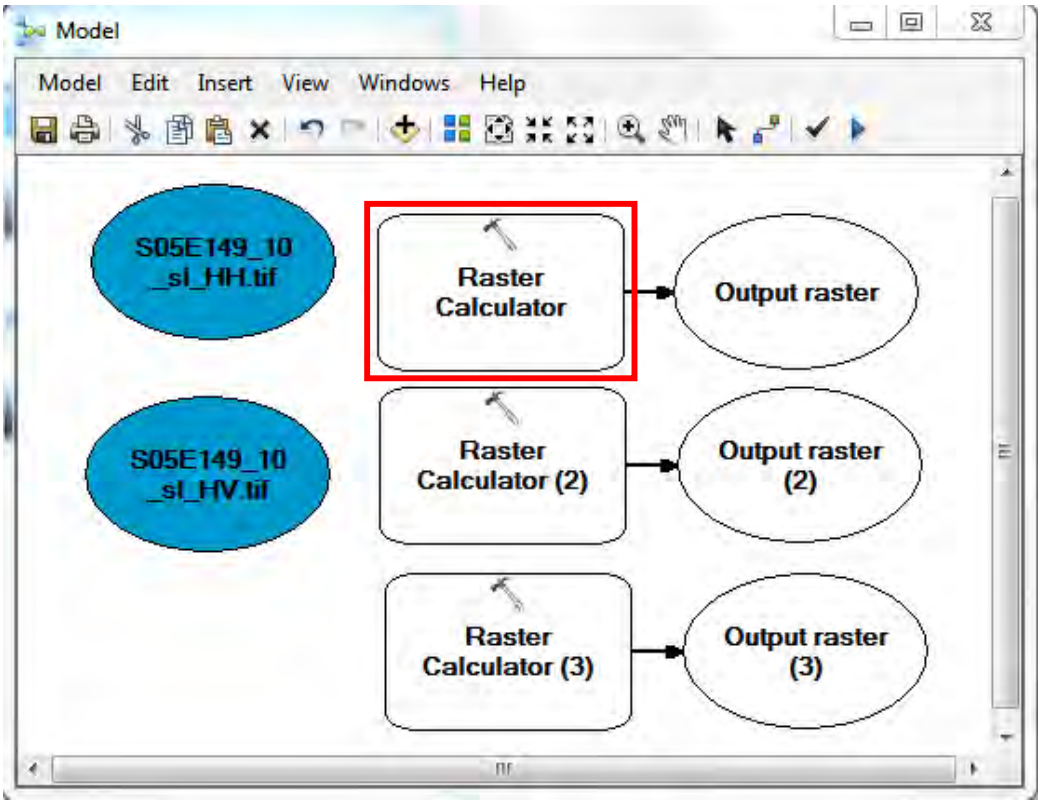


Go to the 'Search' window. Type in 'Raster Calculator' click 'Search'. Drag and drop 'Raster Calculator' three times into the 'Model Builder' window. (Three Raster calculator is needed to compute HH, HV and HH/HV). Drag and Drop the 'Raster Calculator' 3 times.





Double click on the first ‘Raster Calculator’.



Window opens.

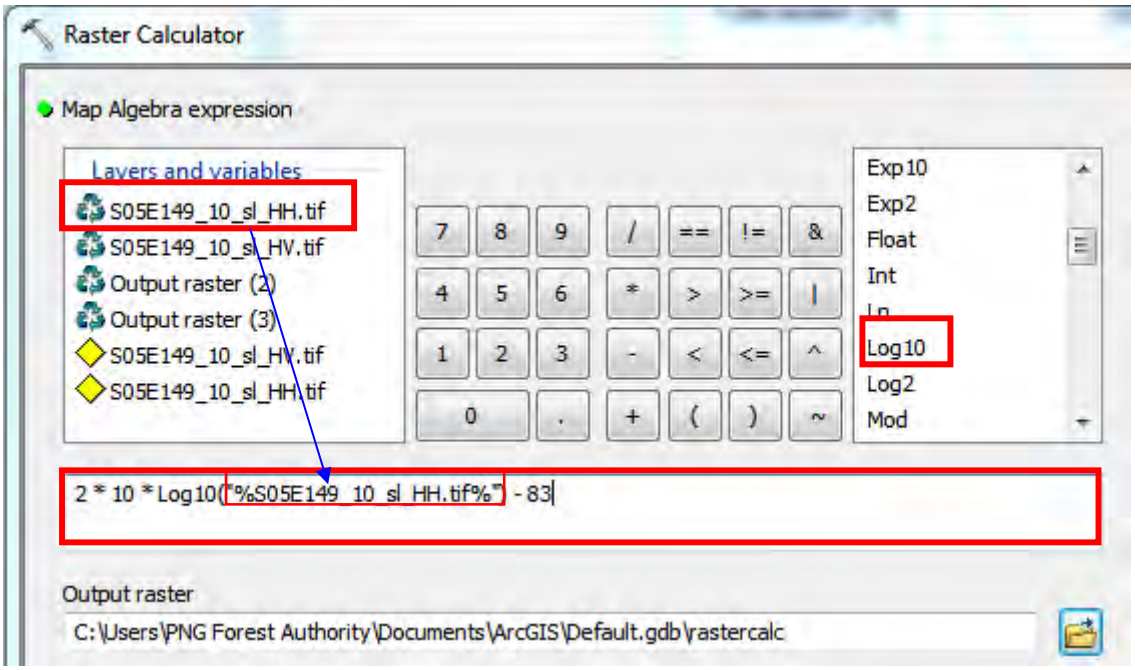
Type in the following equation:

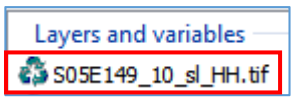
The Concept of the equation: 2*10*Log10(DN)-83

DN=HH

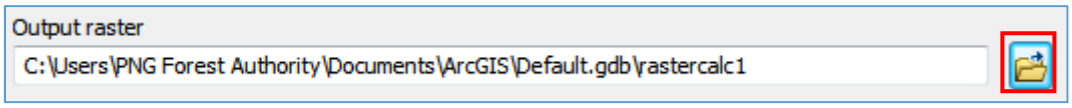
2 * 10 * Log10("%S05E149_10_sl_HH.tif%") - 83

(This calculation is for ‘HH’)



To put 'HH" into the formula, double click 

Under 'Output raster' navigate to your desired folder.

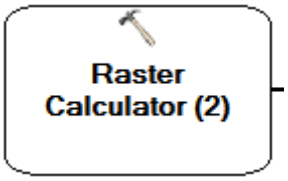


Give a name to your file and add the extension '.tif'.

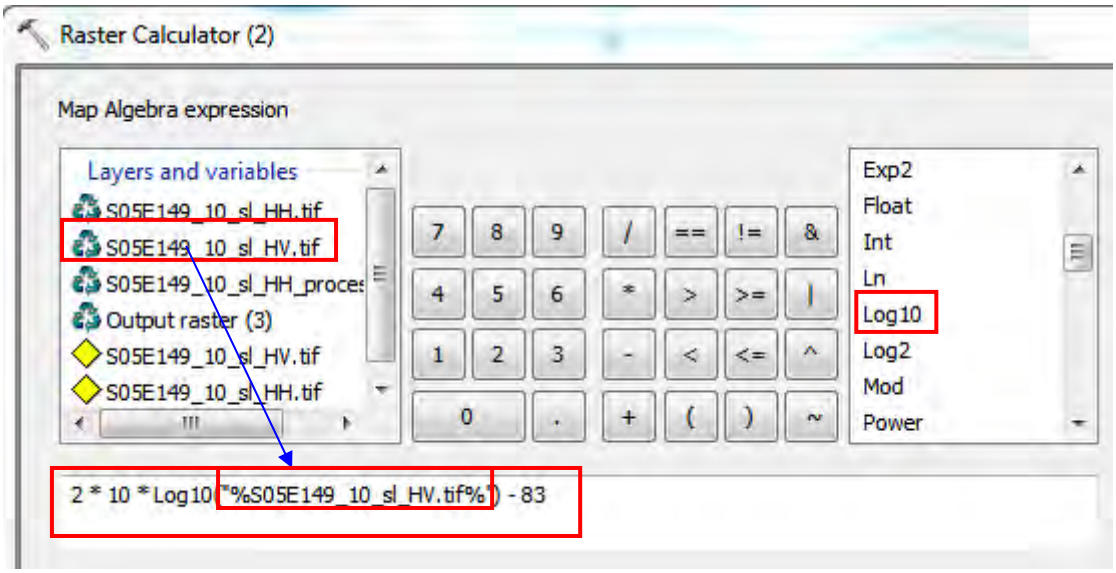
Click 'Save'.

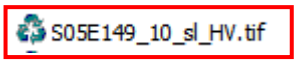
Click 'Ok".

Double click on "Raster Calculator 2', Type in the same equation where this time, DN = HV

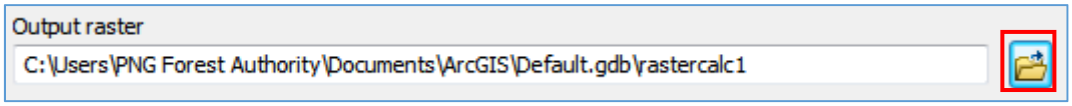


2 * 10 * Log10("%S05E149_10_sl_HV.tif%") – 83\



To put 'HH" into the formula, double click 

Under 'Output raster' navigate to your desired folder.

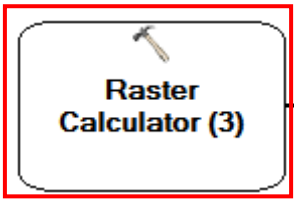


Give a name to your file and add the extension '.tif'.

Click 'Save'.

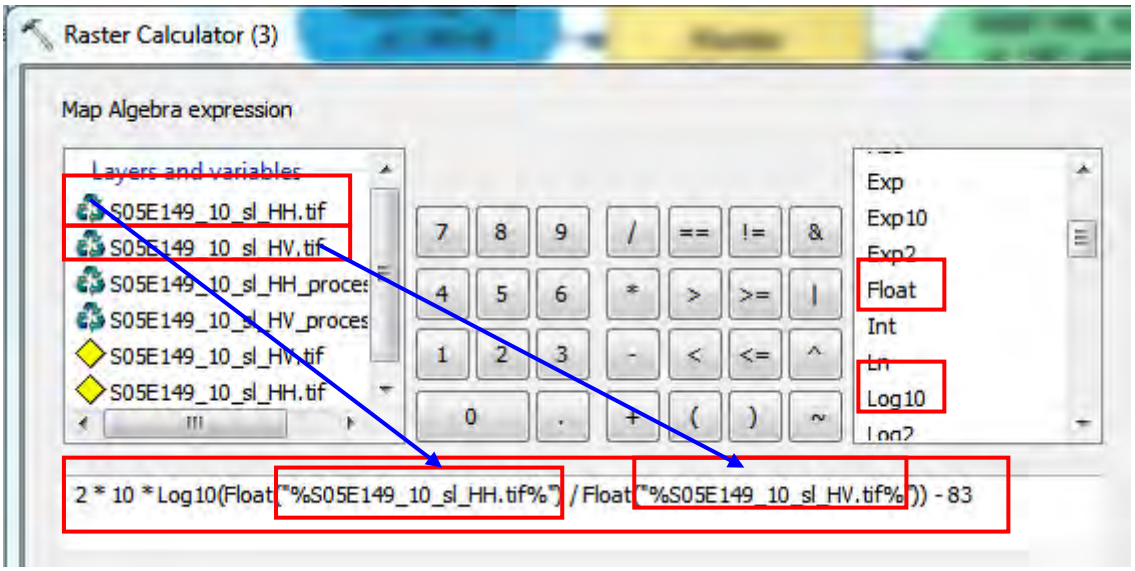
Click 'Ok".

Double click on "Raster Calculator 3".



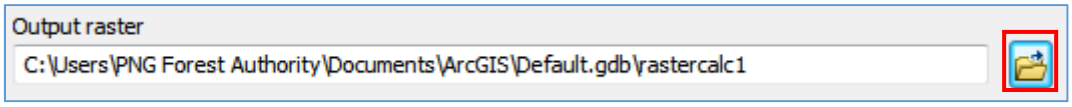
Window opens.

Type in the same equation as in Raster Calculator 1 and 2. This time DN = HH/HV Float (HH)/Float (HV).



2 * 10 * Log10(Float("%S05E149_10_sl_HH.tif%") / Float("%S05E149_10_sl_HV.tif%")) – 83

Under 'Output raster' navigate to your desired folder.



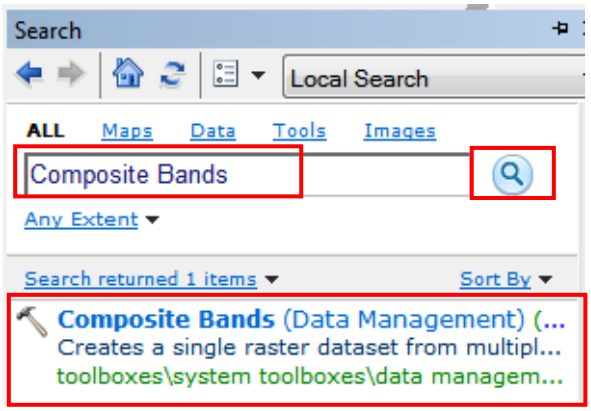
Give a name to your file and add the extension '.tif'.

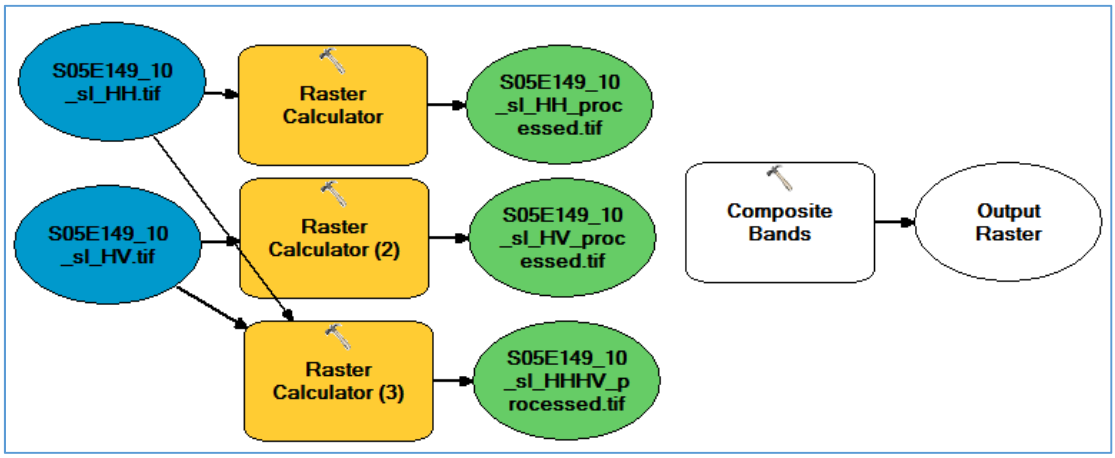
Click 'Save'.

Click 'Ok".

Go to the 'Search' table. Type in 'Composite Bands'. Click search/press enter.

Drag and drop 'Composite Bands (Data Management)' in "Model Builder' window.





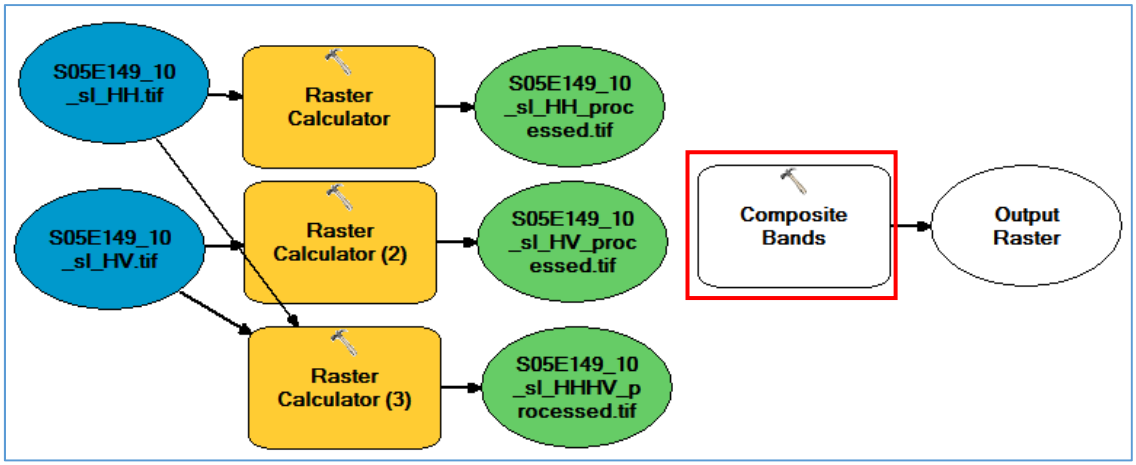
Extra Note:

R=HH

G=HV

B= HH/HV

Double click 'Composite Bands' , window opens.

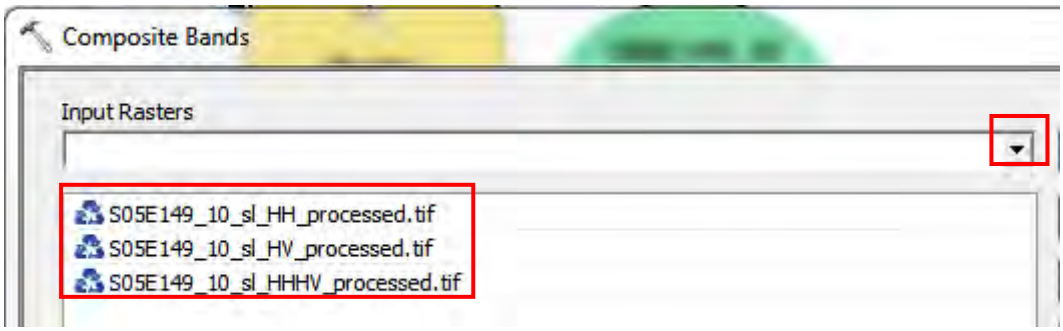


In the 'Input Raster' Click the drop down arrow and select the following in this order:

HH

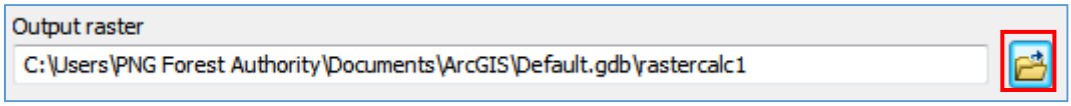
HV

HHHV



These are the files which you have just saved in the Raster Calculator window earlier.

Under 'Output raster' navigate to your desired folder.

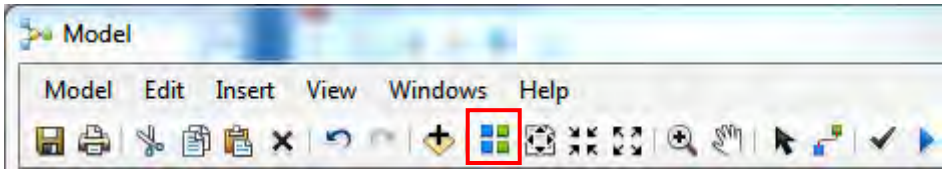


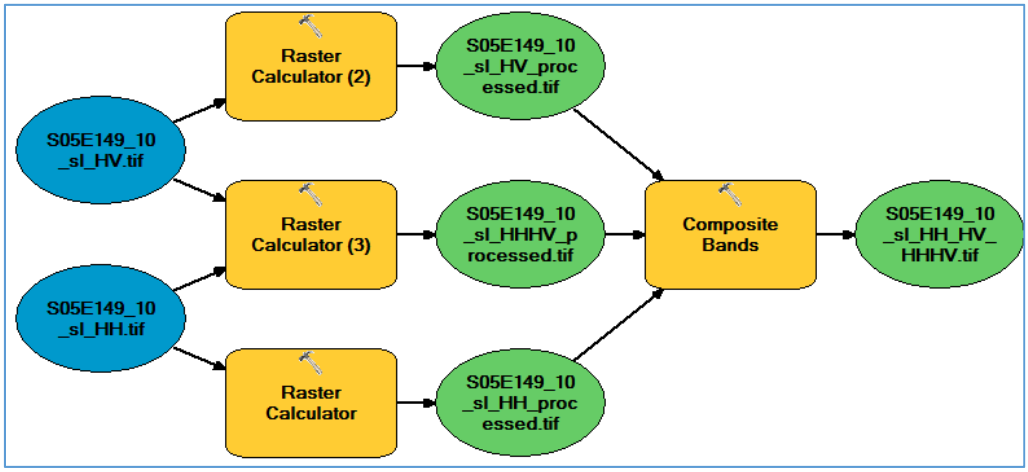
Set the output Raster name: HH_HV_HHHV.tif

Click 'Save'.

Click 'Ok".

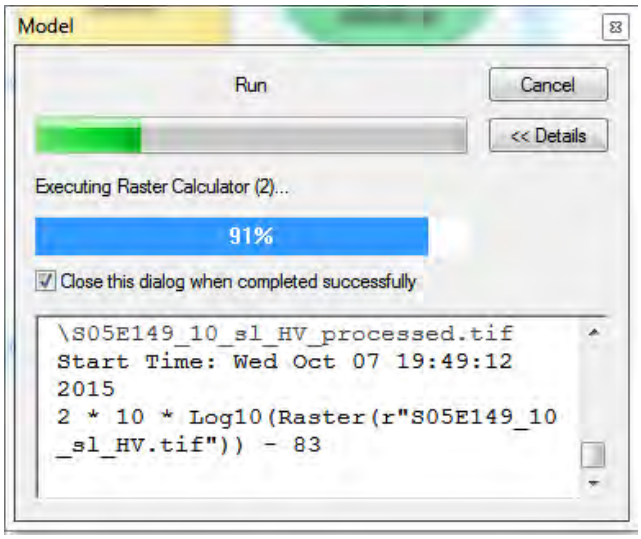
To organize the operations in 'Model Builder' Click on the 'Auto Layout' button to organize the calculators.





Click on the 'Run' button, (the blue play button), window pops up.

Model Builder runs.



When the processing is done, you can save the current working Model and view your processed images.

Create a Toolbox in your desired location.

Give a name for it: 'HH_HV_HHHV.tbx'

Save your current Model in the Toolbox. Give it a name: HH_HV_HHHV

*Names may differ according to your preferences.

Recheck with PALSAR (already calculated image).
Click (…FNF)
Add .tif extension to the file without extension.
Drag and drop that file in ArcMap.

F. Manual to use Google Earth Engine (related to Greenest Pixel)

Manual to Google Earth Engine (related to Greenest Pixel)

Preface

"Greenest Pixel Composite" is mosaicked imagery including all the scenes in each arbitrary period beginning from the first day of the period and continuing to the last day of the period obtained by specified satellite(s) with the greenest pixel on top, where the greenest pixel means the pixel with the greatest value of the Normalized Difference Vegetation Index (NDVI).

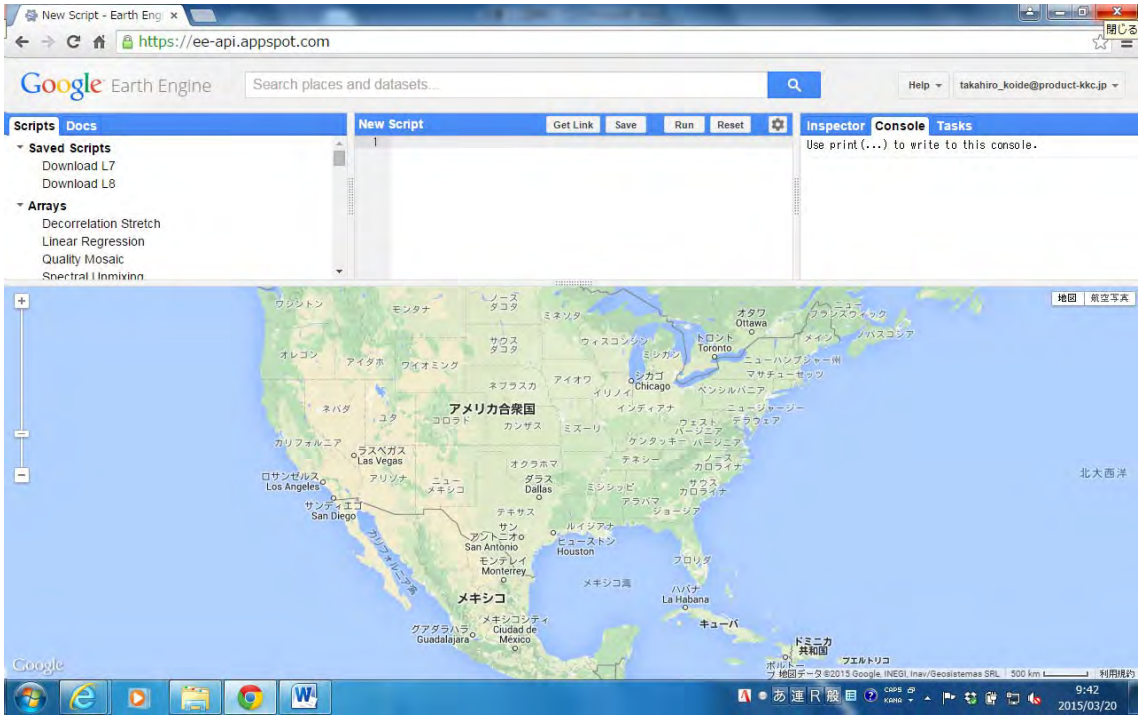
This composite allow to show mosaic of the imagery which has less cloud in some period and facilitate to monitor ground condition during the period. In this document, procedure to make Greenest Pixel Composite with both LANDSAT and Sentinel-2 and to download the composites are described.

I. Showing and downloading LANDSAT Greenest Pixel Composite for an arbitrary period

1. Obtain the tester account of Google Earth Engine Code Editor.

2. Access on https://code.earthengine.google.com/ using Google Chrome or Firefox and log in with the tester account.

3. The main page of Google Earth Engine Code Editor appears.



4. To show LANDSAT Greenest Pixel Composite for an arbitrary period on the browser and download it in GeoTIFF format, code as the following (example for Landsat 8) should be input in the box located at the top center of the page and click “Run”:

```
// ---The following is an example of the code.
//
// Select an image collection and filter by date.

var dateStart = '2015-01-01';
var dateEnd = '2015-12-31';
```

Arbitrary period to calculate Greenest Pixel.

Declare the area for download, resolution, projection system and filename,

```
var region = [[142, -9], [141, -9], [141, -10], [142, -10]];
var scale = 30;
var crs = 'EPSG:4326';
var filename = 'S09E141_2015_L8_greenest ';
```

Declare “gain” which affects on the brightness of the image.

```
var gain = 0.1;
```

Choose name of Satellite, data processing level and data type (with “_TOA”: Top-of-Atmosphere (TOA) reflectance, without “_TOA”: Digital Number (DN)).
Landsat 8 -> LC8、Landsat 7 -> LE7、Landsat 5 -> LT5、Landsat 4 -> LT4

```
var collection = ee.ImageCollection('LC8_L1T_TOA')
    .filterDate(dateStart, dateEnd);
```

Define a function to calculate the NDVI for each image obtained during the period.

```
var ndviCollection = collection.map(
function(image) {
    var ndvi = image.normalizedDifference(['B5', 'B4']);
    return image.addBands(ndvi.select([0], ['ndvi']));
}
);
```

Declare bands to calculate NDVI. This should be “['B4', 'B3']” for Landsat 4, 5, 7.

Calculated NDVI will be stored in a band named as “ndvi”.

Mosaic Pixels with highest NDVI stored in “nd” in each location.

```
var greenestPixel = ndviCollection.qualityMosaic('ndvi');
```

The data in the imagery is multiplied by 10,000 and converted to 16 bit to reduce the file size.

```
greenestPixel = greenestPixel.multiply(10000).toUint16();
```

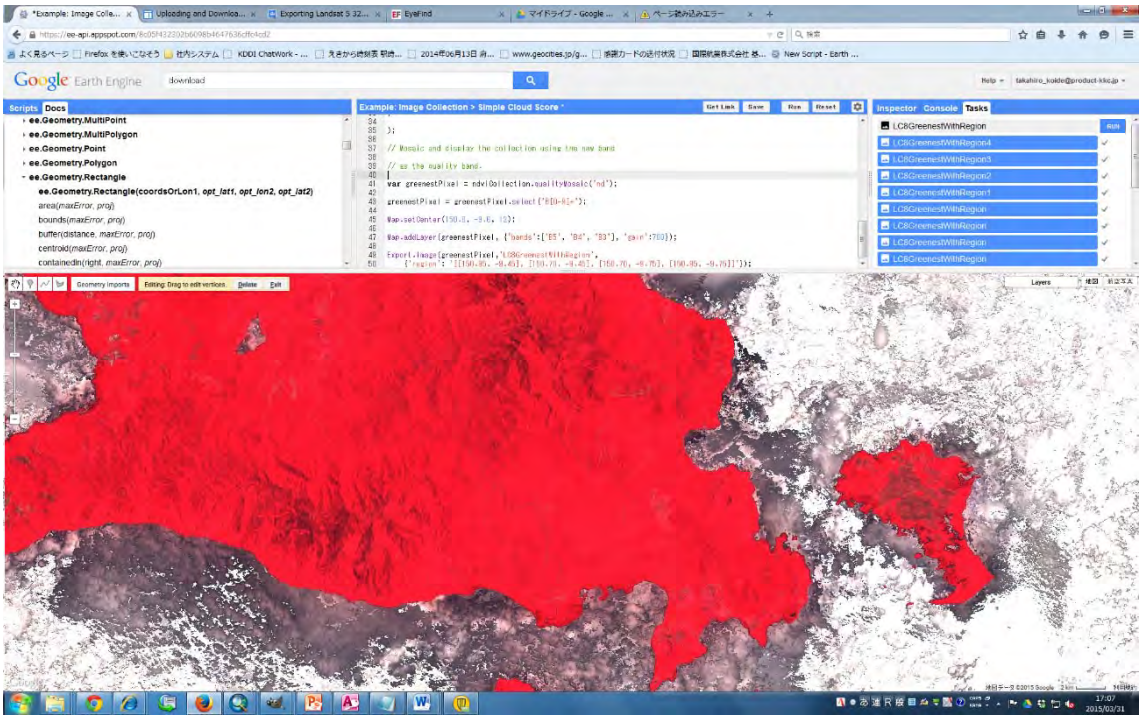
Declare bands for downloading. In this case, every band is selected.

```
greenestPixel = greenestPixel.select('B[0-9]');
```

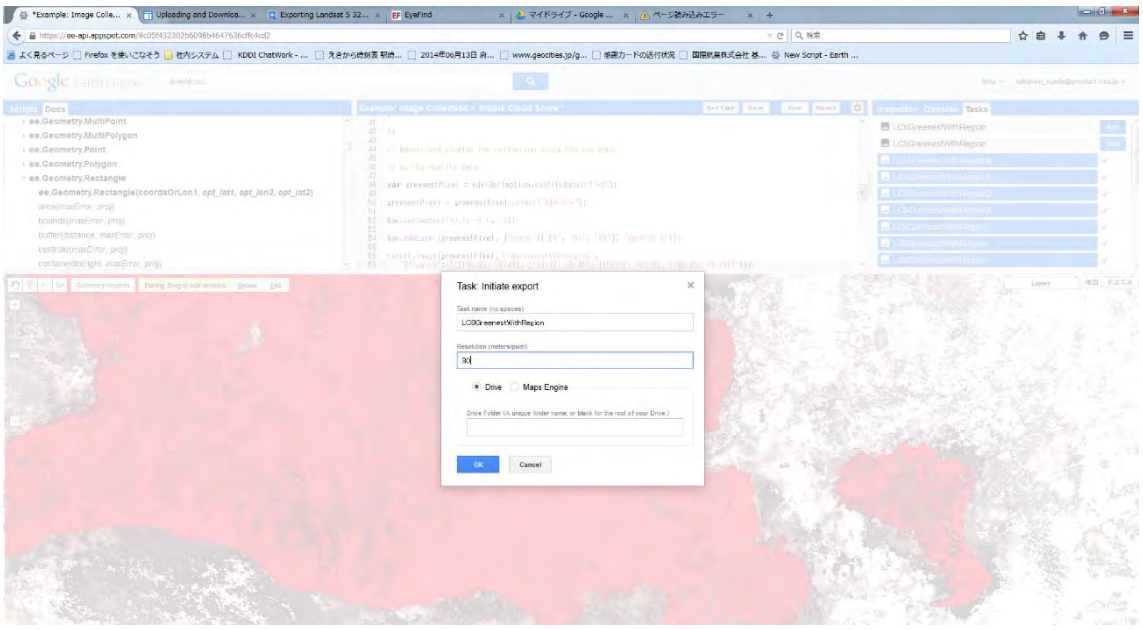
Declare the bands ([R, G, B]) to be shown on the browser.

```
Map.addLayer(greenestPixel, {'bands':['B4','B3','B2'], 'gain':gain});


Export.image(greenestPixel,filename, {'region': region, 'scale': scale, 'crs': crs}
    );


// ---The code ends here.
```

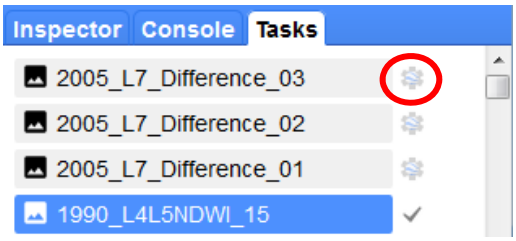
7. The Greenest Pixel for the declared period will be shown on the bottom side of the browser and “RUN” button will appear on the console located at the right center of the page.



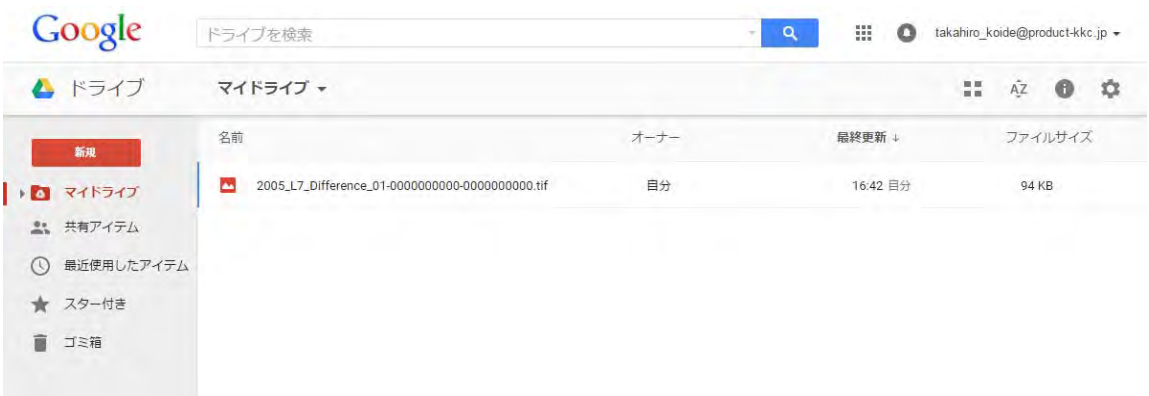
8. Click the “RUN” button to get a picture as the following picture. Confirm the resolution. Select “Drive” and click “OK”.



9. Icons as following picture will appear during processing. Multiple processing is accepted at once.



10. The data will be found on the Google drive folder of the account after the processing. It is able to download the file into a local computer.



Miscellaneous information

- Greenest Pixel Composite for an arbitrary period can be downloaded. All layers of Landsat 4, 5, 7 and 8 are available.
- The default projection system is WPS84. The availability of the other system is not confirmed.
- Very large area can be set for download (at least whole PNG territory). However, the total number of pixel cannot exceed 100,000,000. Besides, the maximum file size for download from Google Drive is 2 GB. Practically, it is better to download 1˚× 1˚at a time (in case of downloading Landsat 8 imagery keeping 30-m resolution and whole bands).
- Obtaining only necessary layers reduces the size of each download.

  If a imagery is downloaded with float numbers, the no data values in it will be “1.#QNAN”, which is difficult to handle.

G. Arrangement of Global Forest Change data published by Hansen et al.

Arrangement of Global Forest Change data published by Hansen et al.

GFC data, which has forest loss year information, is updated by Hansen et al. annually. This data was used in the Project activities in order to capture forest loss and gain location and loss year.

Procedures of preparing GFC data are illustrated here. The procedures are divided into three steps: (1) Data procurement, (2) Data adjustment, and (3) Data reflection to the Forest Base Map.

For more information of GFC data, please refer to the "Global Forest Change" website (http://earthenginepartners.appspot.com/science-2013-global-forest).

Dataset Details

This global dataset is divided into 10x10 degree tiles, consisting of seven files per tile. All files contain unsigned 8-bit values and have a spatial resolution of 1 arc-second per pixel, or approximately 30 meters per pixel at the equator.

Tree canopy cover for year 2000 *(treecover2000)*

Tree cover in the year 2000, defined as canopy closure for all vegetation taller than 5m in height. Encoded as a percentage per output grid cell, in the range 0–100.

Global forest cover loss 2000–2013 *(loss)*

Forest loss during the period 2000–2013, defined as a stand-replacement disturbance, or a change from a forest to non-forest state. Encoded as either 1 (loss) or 0 (no loss).

Global forest cover gain 2000–2012 *(gain)*

Forest gain during the period 2000–2012, defined as the inverse of loss, or a non-forest to forest change entirely within the study period. Encoded as either 1 (gain) or 0 (no gain).

Year of gross forest cover loss event *(lossyear)*

A disaggregation of total forest loss to annual time scales. Encoded as either 0 (no loss) or else a value in the range 1–13, representing loss detected primarily in the year 2001–2013, respectively.

Data mask *(datamask)*

Three values representing areas of no data (0), mapped land surface (1), and permanent water bodies (2).

Circa year 2000 Landsat 7 cloud-free image composite *(first)*

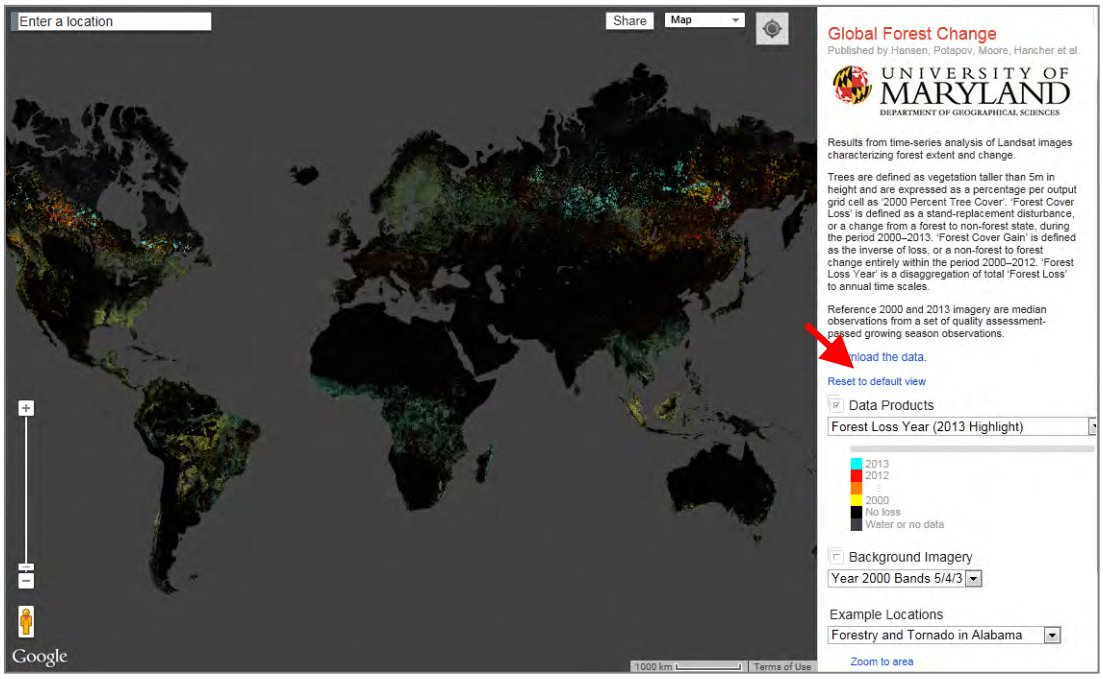
Reference multispectral imagery from the first available year, typically 2000. If no cloud-free observations were available for year 2000, imagery was taken from the closest year with cloud-free data, within the range 1999–2012.

Circa year 2013 Landsat cloud-free image composite *(last)*

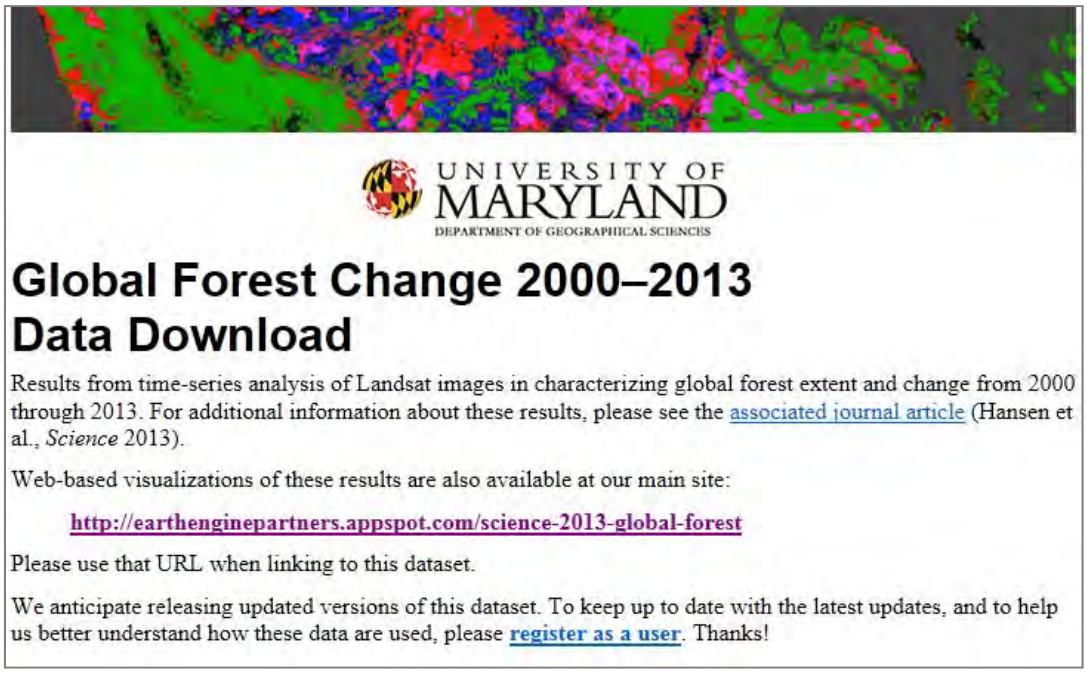
Reference multispectral imagery from the last available year, typically 2013. If no cloud-free observations were available for year 2013, imagery was taken from the closest year with cloud-free data, within the range 2010–2012.

(1) Data procurement

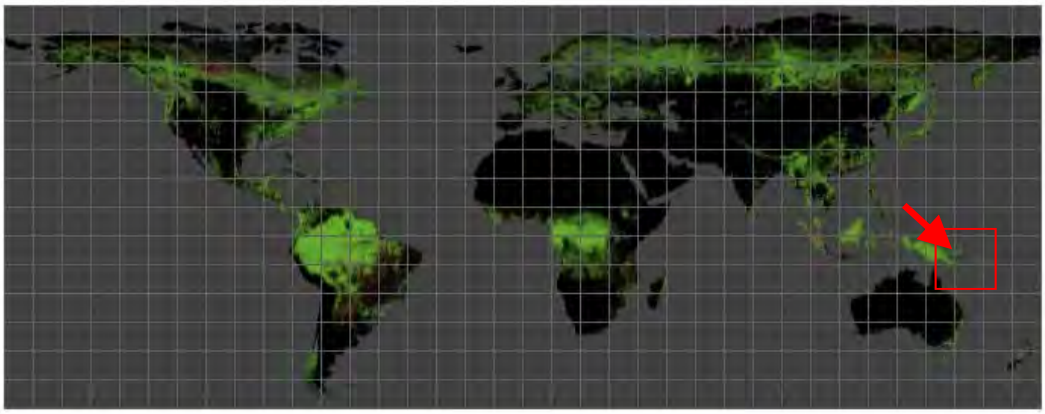
1. Open the “Global Forest Change” website and then click “Download the data” in the page.



Data Download page will open.



2. To download individual 10x10 degree granules, click on the PNG area (0N x 140E, 0N x 150E, 10S x 140E, and 10S x 140E) on the map in the web site then click on URLs underneath it.



Granule with top-left corner at 0N, 140E:

https://storage.googleapis.com/earthenginepartners-hansen/GFC2015/Hansen_GFC2015_treecover2000_00N_140E.tif
https://storage.googleapis.com/earthenginepartners-hansen/GFC2015/Hansen_GFC2015_loss_00N_140E.tif
https://storage.googleapis.com/earthenginepartners-hansen/GFC2015/Hansen_GFC2015_gain_00N_140E.tif
https://storage.googleapis.com/earthenginepartners-hansen/GFC2015/Hansen_GFC2015_lossyear_00N_140E.tif
https://storage.googleapis.com/earthenginepartners-hansen/GFC2015/Hansen_GFC2015_datamask_00N_140E.tif
https://storage.googleapis.com/earthenginepartners-hansen/GFC2015/Hansen_GFC2015_first_00N_140E.tif
https://storage.googleapis.com/earthenginepartners-hansen/GFC2015/Hansen_GFC2015_last_00N_140E.tif

DL folder: **Z:¥99_FreeData¥HansenData¥GFC_2015_00_14¥01DL**

DL tile: **0N x 140E**, **0N x 150E**, **10S x 140E**, and **10S x 140E**

DL data: loss, **gain**, **lossyear**, last

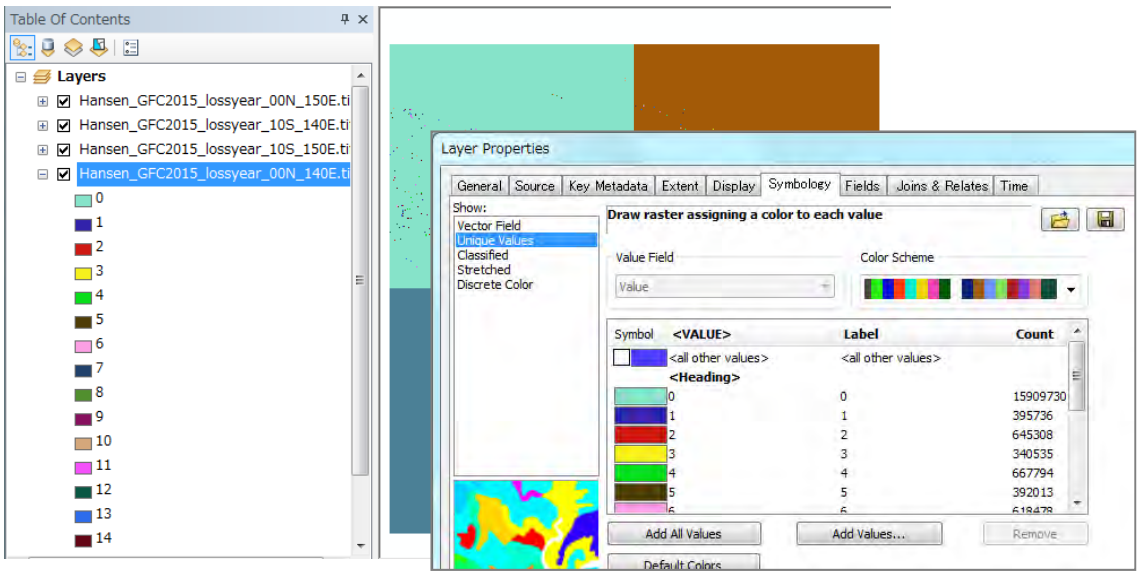
* Treecover and first data are the same data as previous year.

* Gain and lossyear data will be used the following steps.

(2) Data adjustment

PNG covers four tiles, so you will mosaic data split into four tiles, and then clip mosaiced data only within PNG area to have data to be handled easily.

1. Open ArcMap and add data which you have downloaded.



You can find forest loss year location to show data by unique values. For example, “0” in Value field indicates “2000”, and “14” indicates “2014”.

2. Mosaic layers by using Mosaic to New Raster tool.

   Tool: Data Management tools > Raster > Raster Dataset > Mosaic to New Raster

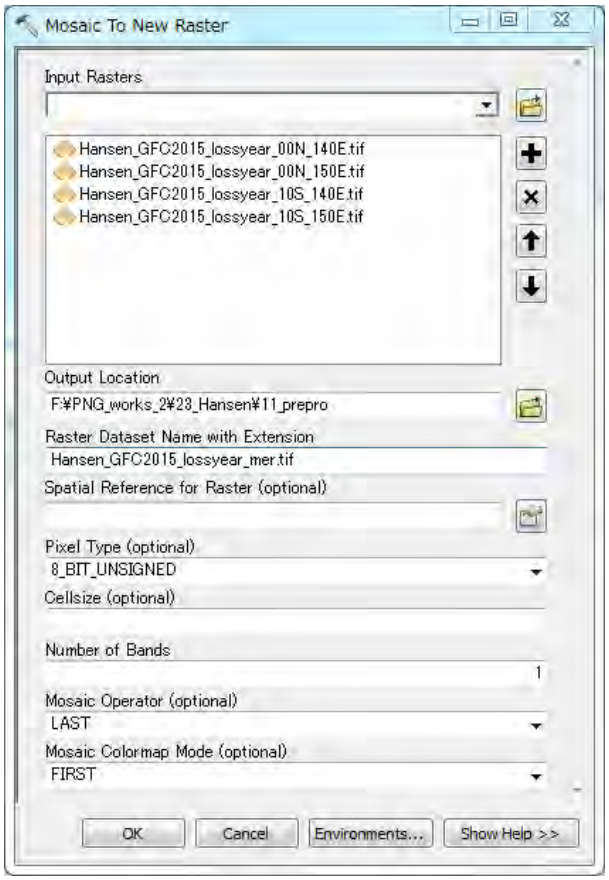
   Output folder:

   Z:¥ 99_FreeData¥HansenData ¥GFC_2015_00_14¥02_prepro

   Output file name:

   Hansen_GFC2015_ lossyear_mer.tif

3. Add **Hansen_GFC2014_lossyear.tif** which is the GFC data prepared in only PNG area in previous year.



4. Clip **Hansen_GFC2015_lossyear_mer.tif** with Hansen_GFC2014_lossyear.tif.

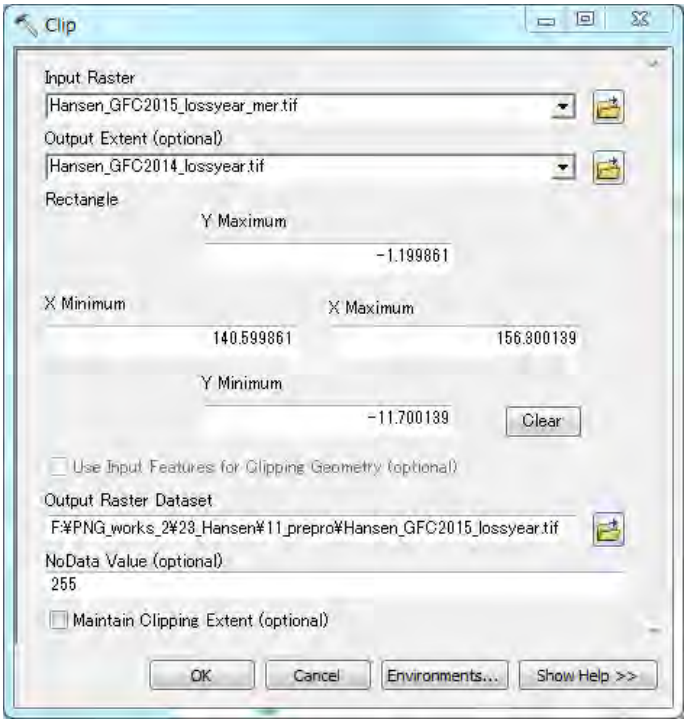
Tool: Data Management tools > Raster > Raster Processing > Clip

Output folder:

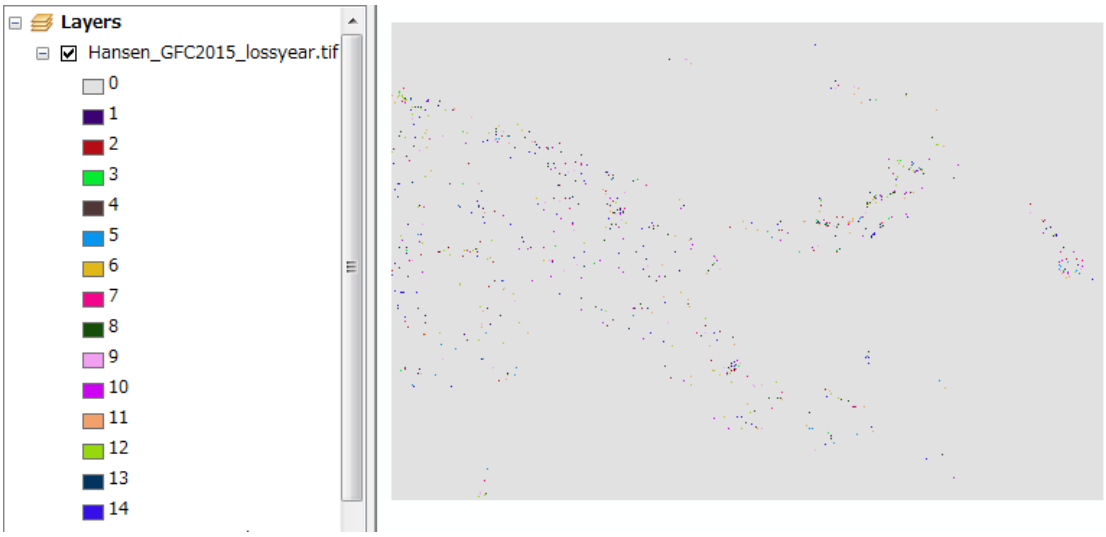
Z:¥ 99_FreeData¥HansenData ¥GFC_2015_00_14 ¥02_prepro

Output file name:

Hansen_GFC2015_lossyear.tif



Data cliped within PNG area is created.



5. Also, create gain data cliped within PNG area in the same way (step (2) 1 - 4).

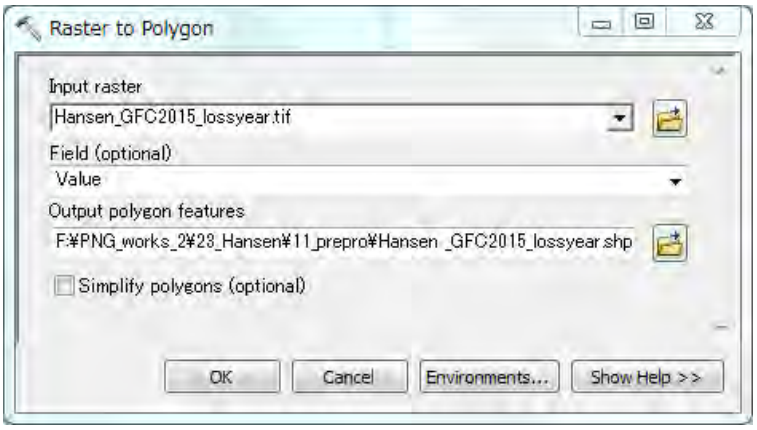
(3) Data reflection to the Forest Base Map

You will confirm how much loss area is in each FMU of the Forest Base Map in new year, and then add loss area in new year into the Hansen loss relational database table (XXX_RD_hansen) in the Forest Base Map.

1. Convert the lossyear raster of GFC data to vector by using Raster to Polygon tool.

Tool: Conversion Tools > From Raster > Raster to Plygon

*If you select only target year in the lossyear raster table, only the lossyear data in target year will be converted.



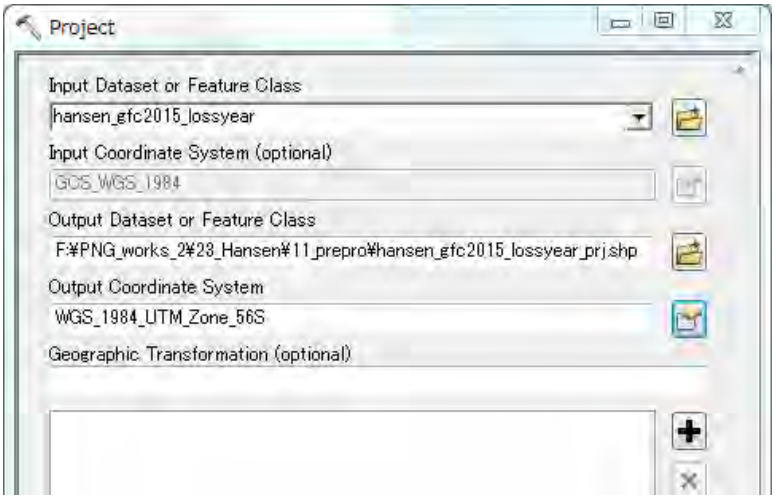
Output folder:

Z:¥ 99_FreeData¥HansenData¥GFC_2015_00_14¥02_prepro

Output file name: **Hansen_GFC2015_lossyear.shp**

2. Convert a projection of the converted lossyear polygon to the one of target area.

Tool: Data Management Tools > Projections and Transformations > Project



Output folder:

Z:¥ 99_FreeData ¥HansenData ¥GFC_2015_00_14 ¥02_prepro

Output file name:

Hansen_GFC2015_lossyear_z56.shp

3. Intersect the lossyear polygon with the target Forest Base Map.

Tool: Analysis Tools >

Overlay > Intersect

Output folder:

Z:¥ 99_FreeData

¥HansenData

¥GFC_2015_00_14

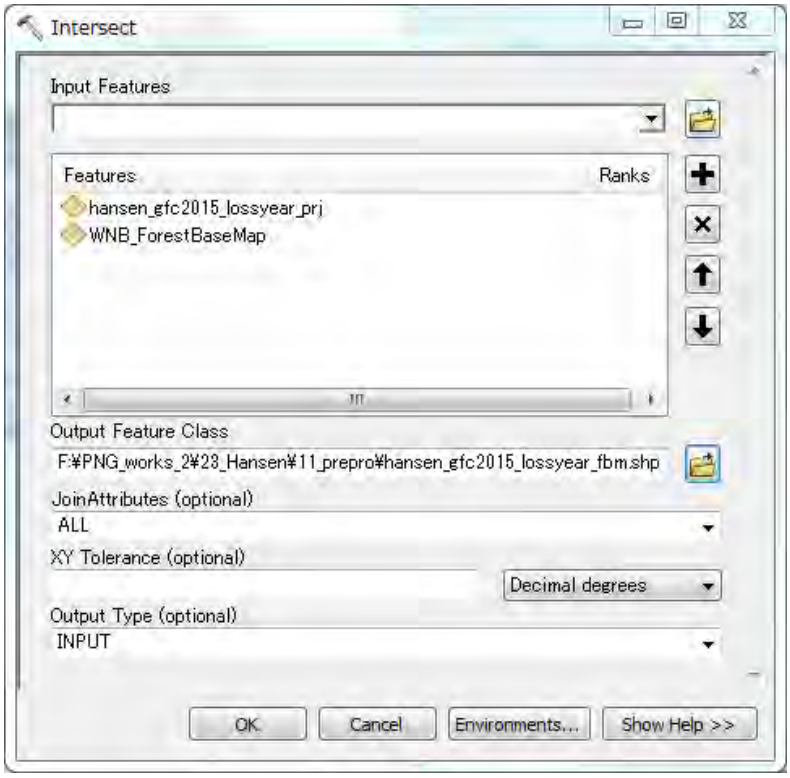
¥03_add_pro

¥21_WNB

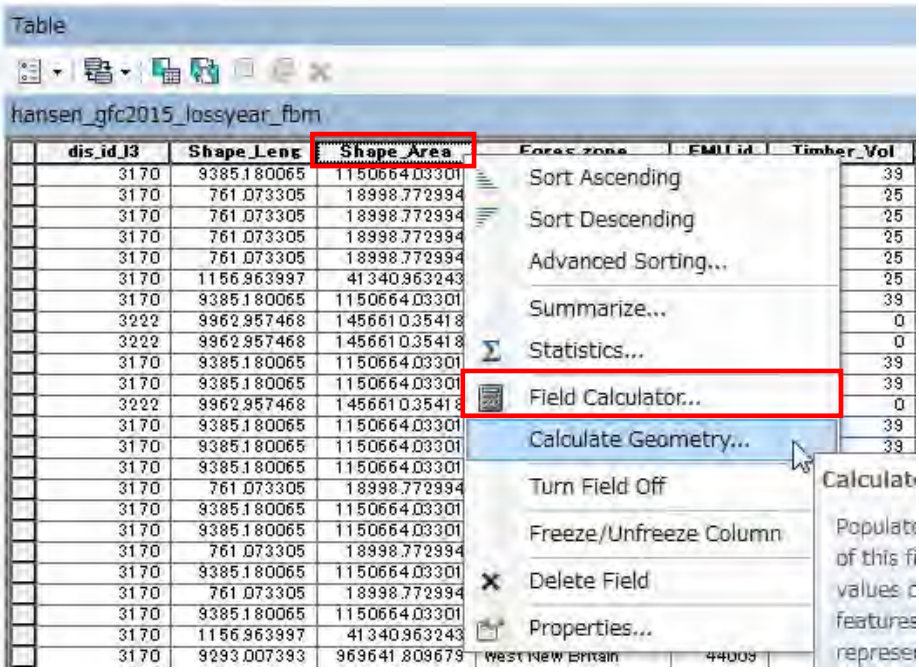
Output file name:

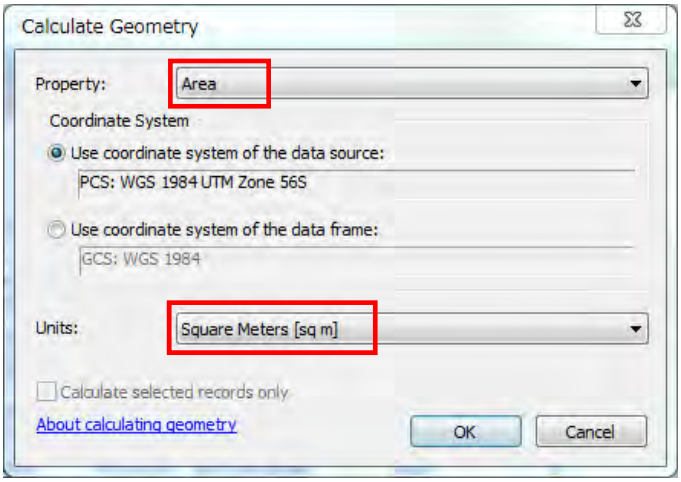
hansen_gfc2015

_lossyear_fbm.shp

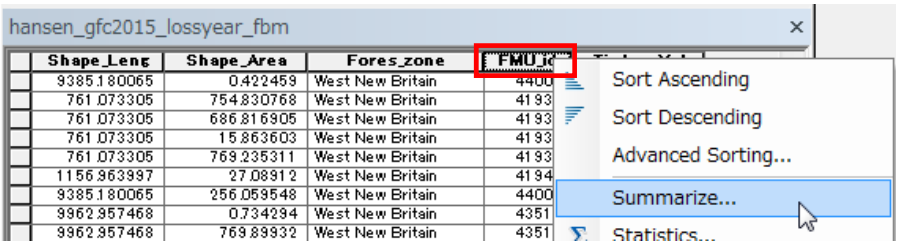


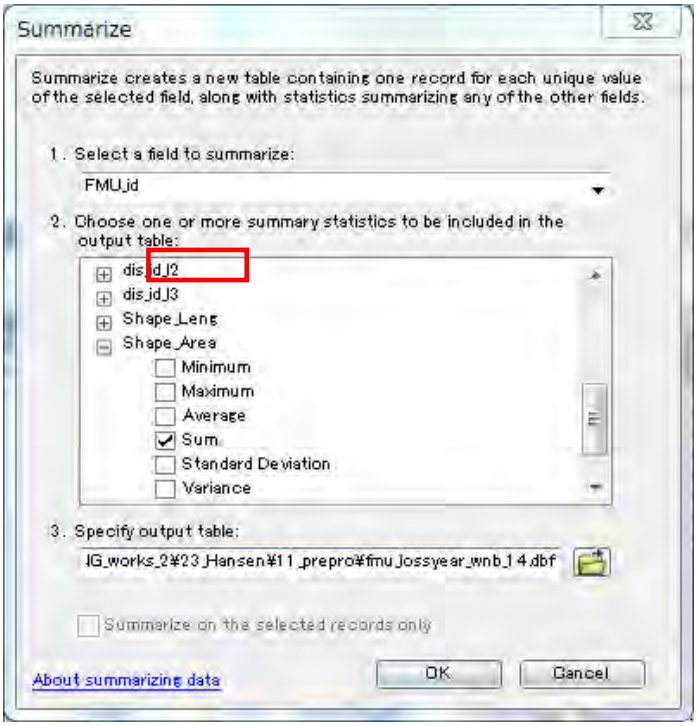
4. Open the attribute table of the intersected data, and calculate area in Shape_Area field.





5. Right-click on FMU_id field, select Summarize…, and set parameters in the Summarize dialog to calculate sum of area in each FMU and then export the summary dbf table.





*If your target year is multiple like 2013 and 2014, you should calculate sum in each year one by one.

Select target year records before Summarize.

Year field: GRIDCODE

Output file name:

fmu_lossyear_wnb_14.dbf

6. Also, create area summary table for gain data in the same way (Step (3) 1- 5).

Output file name: **fmu_gain_wnb.dbf**

* This fairy green rectangle denote work for "gain".

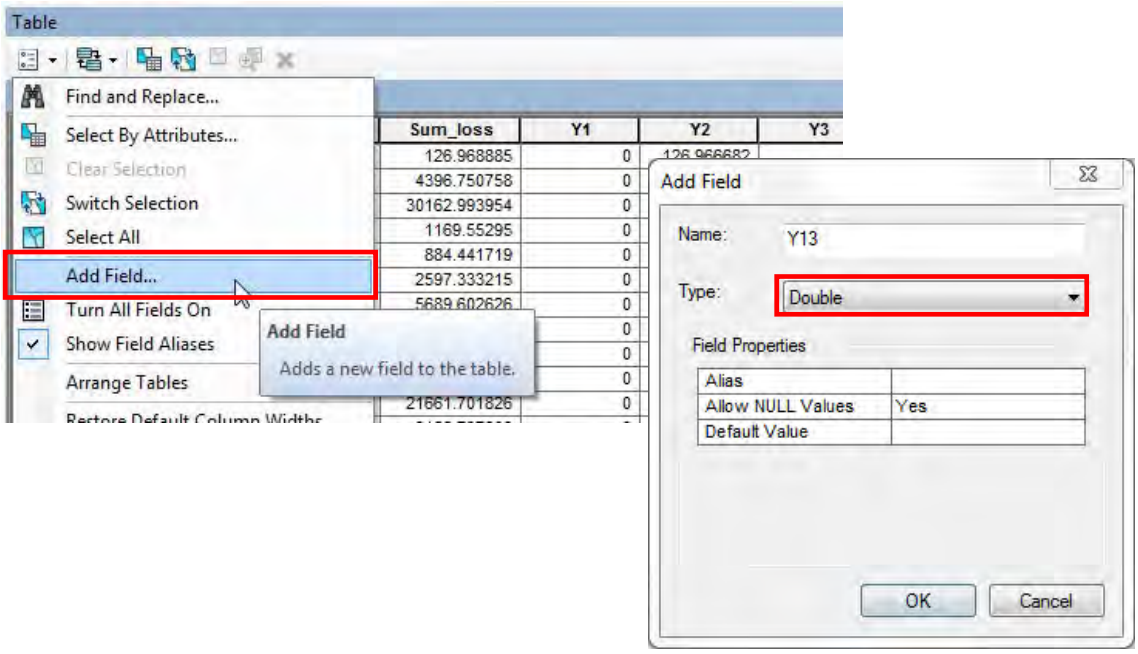
There are some ways to update Hansen relational database (RD) table (XXX_RD_hansen). Here, the way to update the RD table in ArcGIS is illustrated.

7. In ArcCatalog, create the copy of the Hansen loss relational database table (XXX_RD_hansen) in the Forest Base Map filegeodatabase, and name "XXX_RD_hansen_2015" not to update the RD table directly just in case.

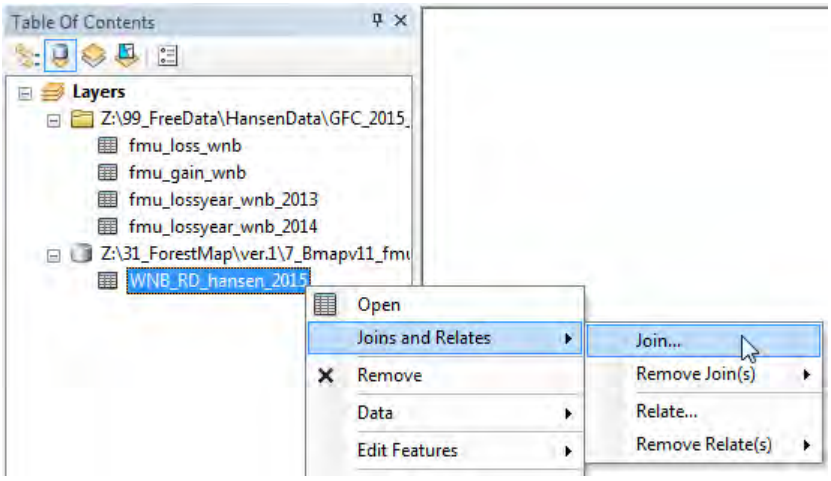
8. In ArcMap, add the XXX_RD_hansen_2015 table and the dbf tables created in previous steps (fmu_lossyear_wnb_13.dbf, fmu_lossyear_wnb_14.dbf, fmu_gain_wnb.dbf).

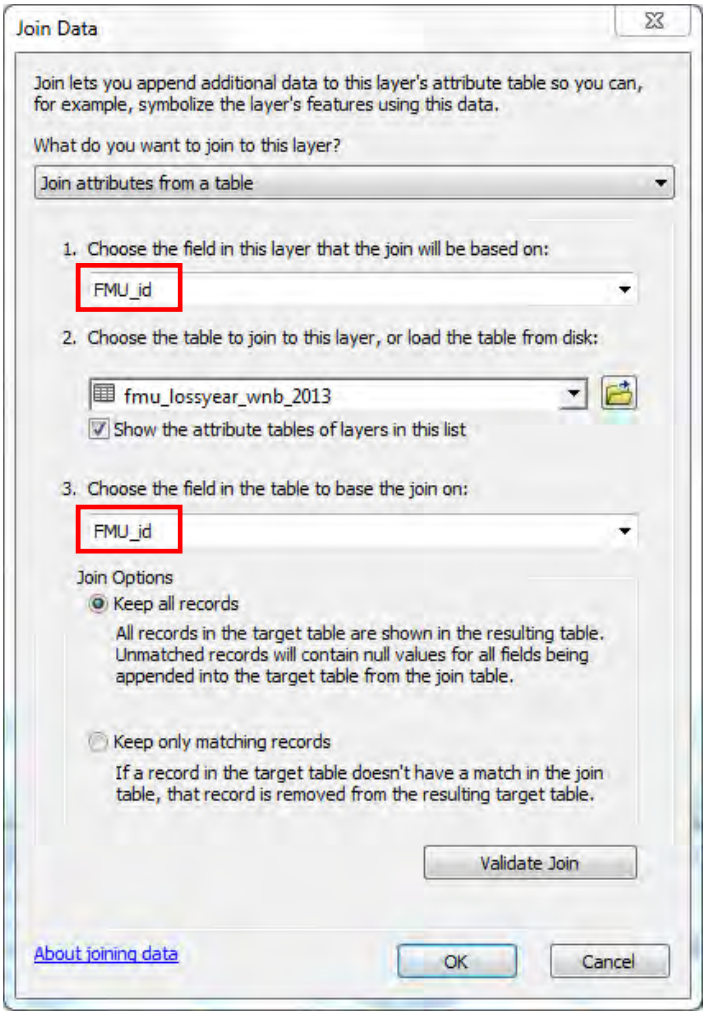
9. Open the XXX_RD_hansen_2015 table

10. Add new Field(s) for loss area in new year.

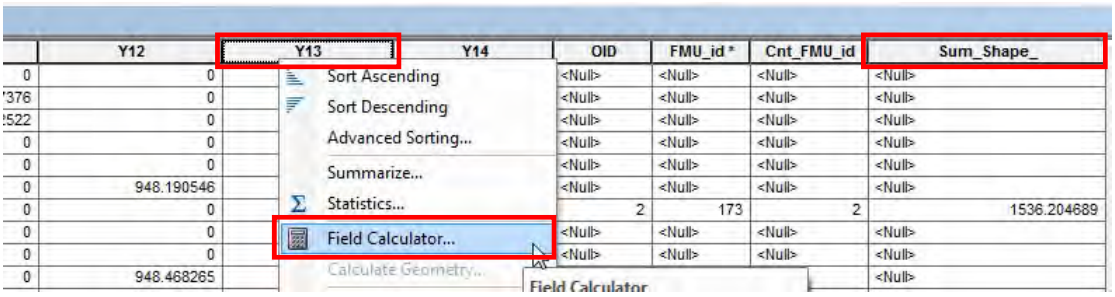


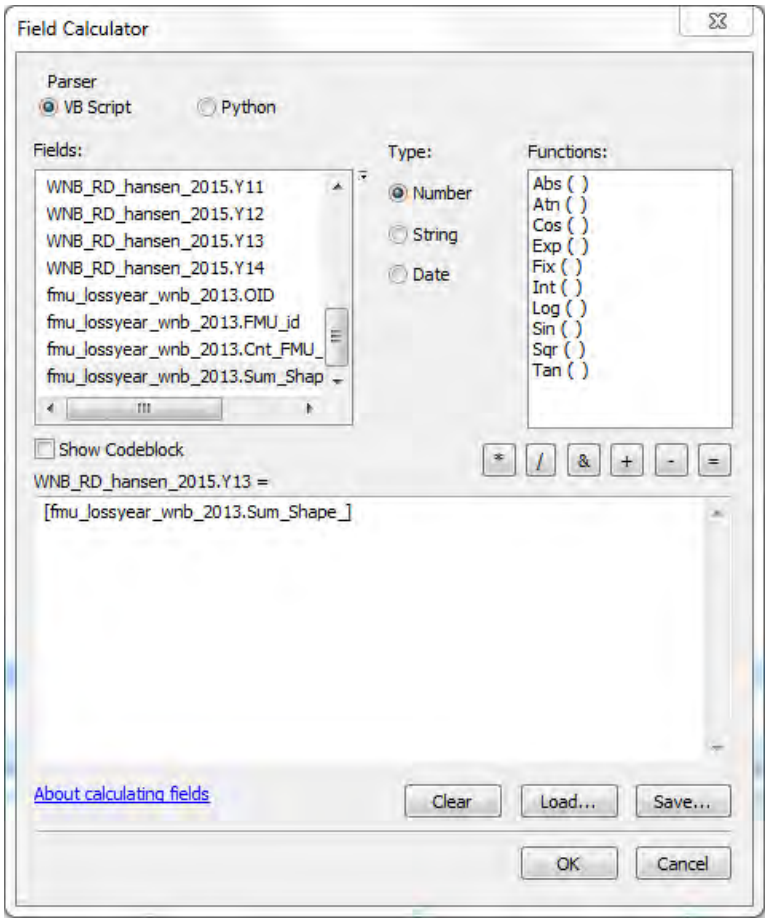
11. To update the records of the field(s), join the **lossyear** table (fmu_lossyear_wnb_13.dbf, fmu_lossyear_wnb_14.dbf) being based on “FMU_id” field.





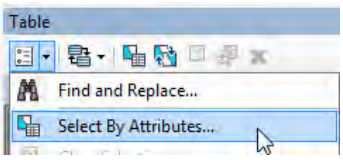
12. Copy the records of lossyear area (Sum_Shape_) to Y13 field.

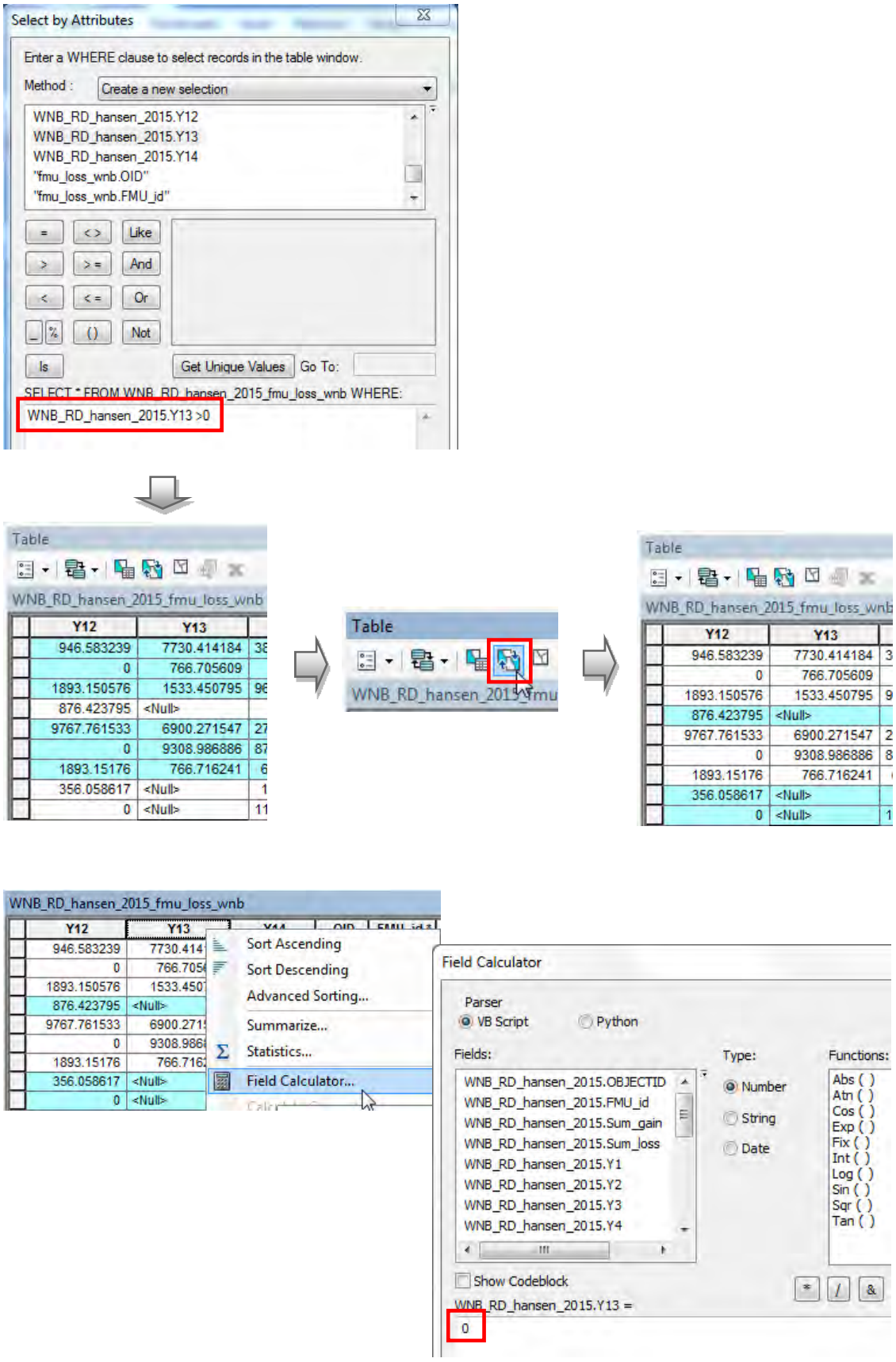


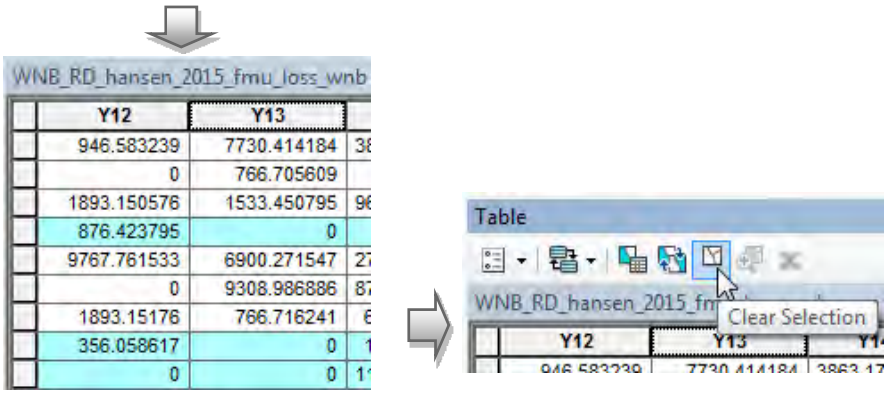


13. Change <Null> records in Y13 field into 0.

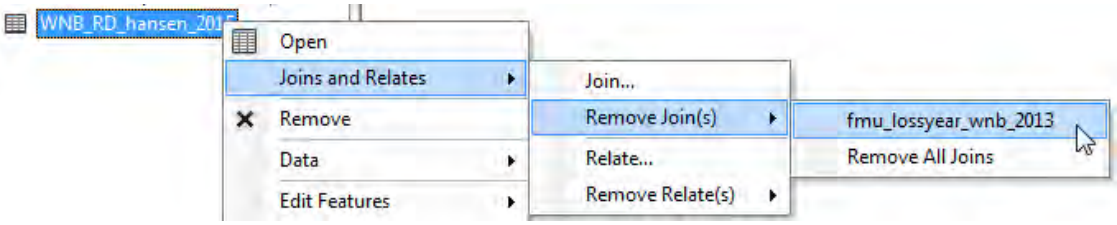
Tips:





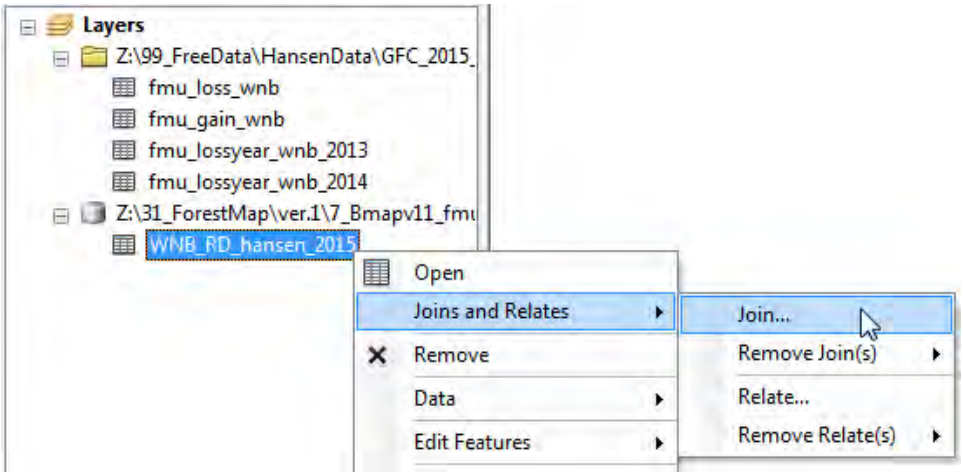


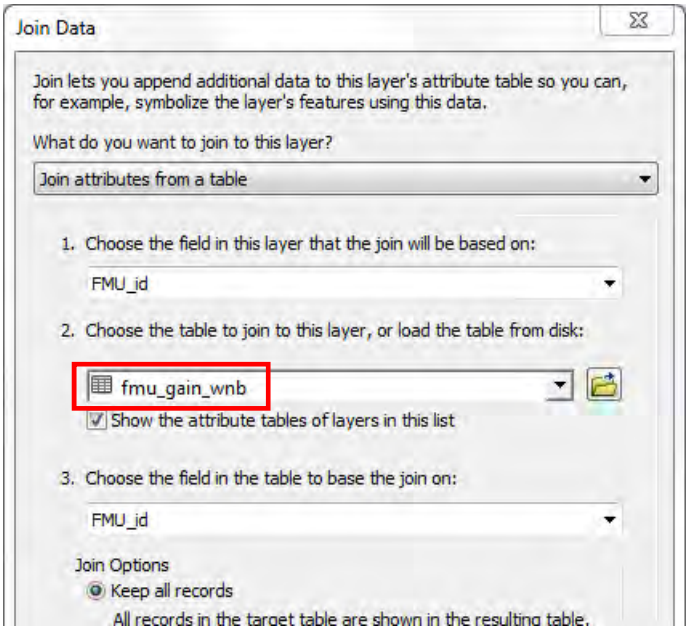
14. Remove the joined table.



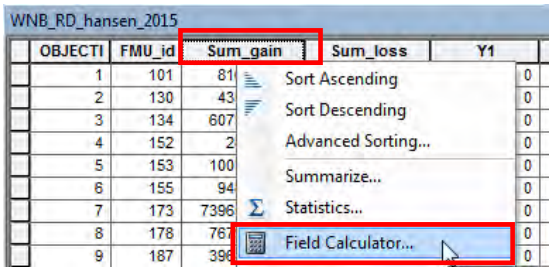
* If you have multiple lossyear tables, update their year area in the same way.

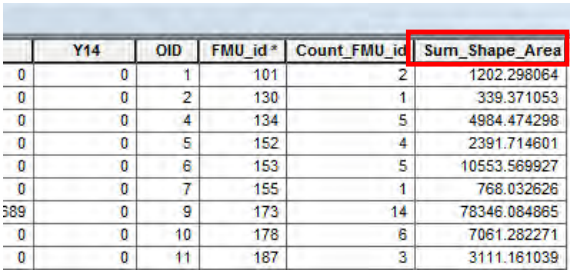
15. To update the records of the **Sum_gain** field, join the **gain** table (fmu_gain_wnb.dbf) being based on "FMU_id" field.

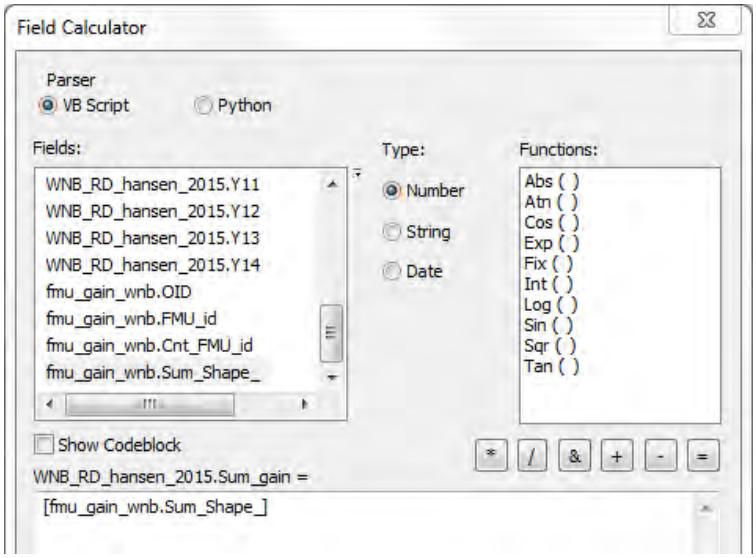




16. Copy the records of gain area (Sum_Shape_Area) to Sum_gain field.



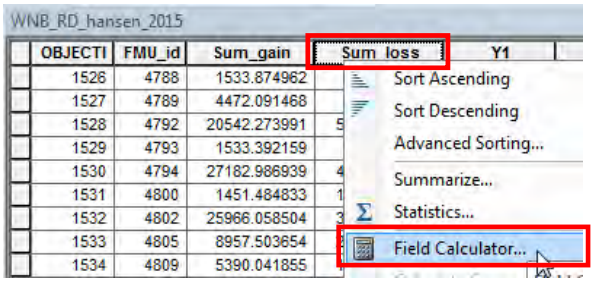


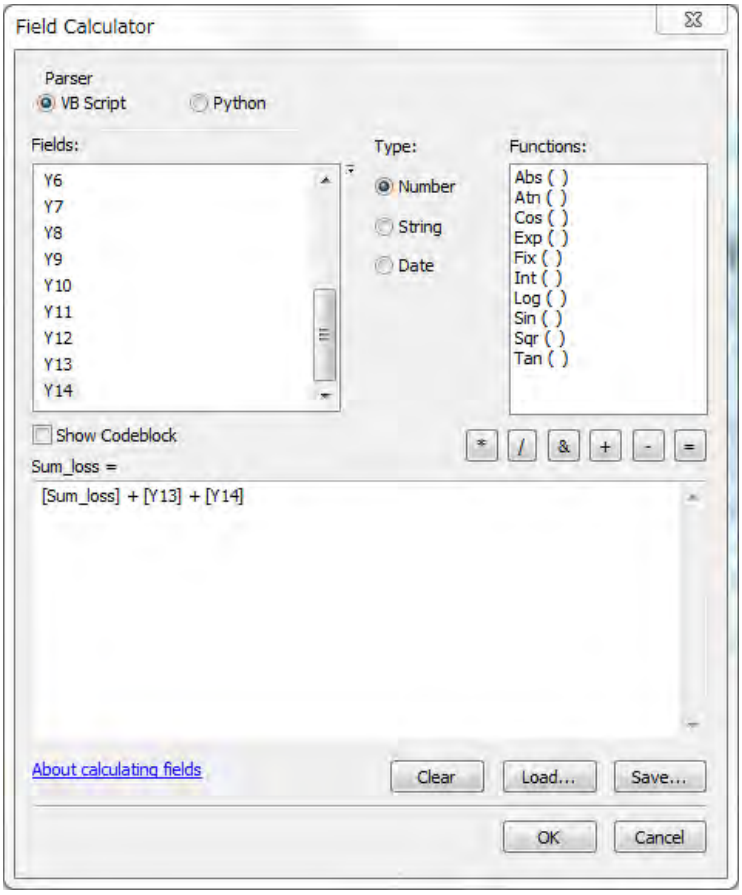


17. Change <Null> records in Sum_gain field into 0.

18. Remove the joined table.

19. To update the records of the **Sum_loss** field, add new lossyear values to the current sum_loss values.



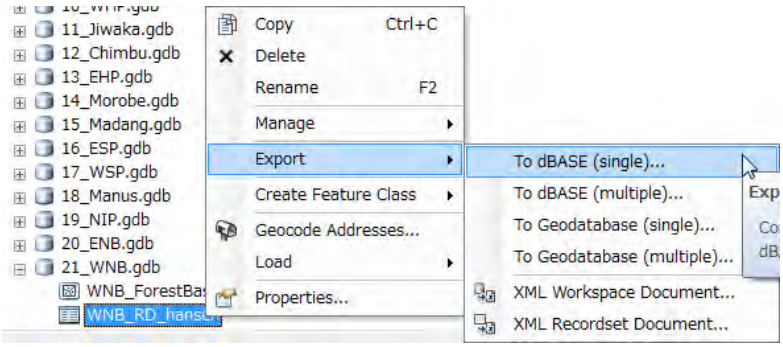


Now, lossyear area, gain area and loss area in the Hansen relational database table (XXX_RD_hansen_2015) are updated.

Optional way:

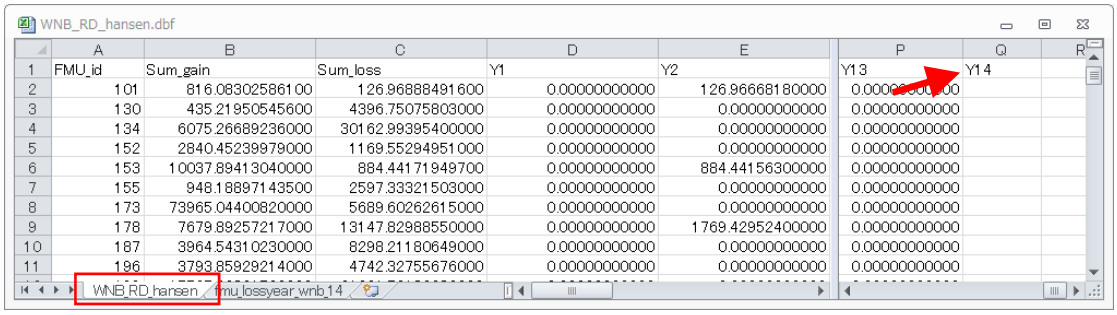
Here, another way to update the RD table is illustrated instead the way from step 7.

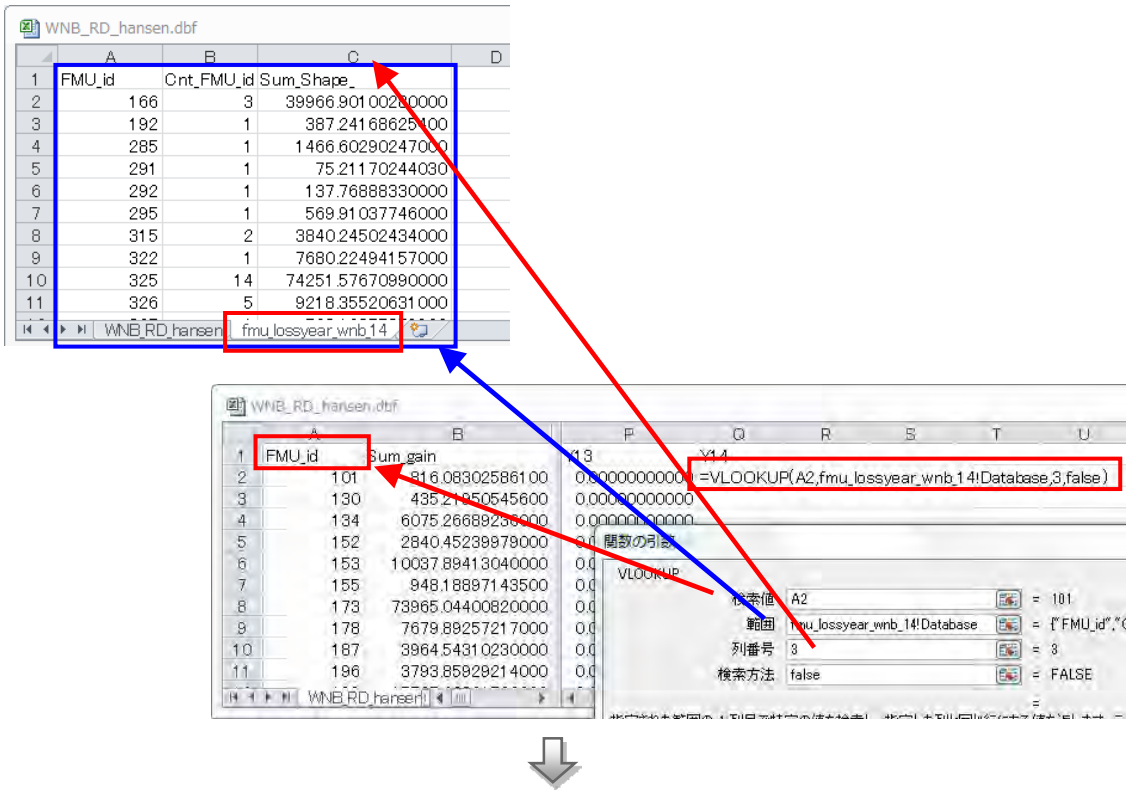
7'. In ArcCatalog, right-click the Hansen loss relational database table (XXX_RD_hansen) in the Forest Base Map filegeodatabase, select Export > To dBASE (single)…, and set parameters in the Table to Table dialog to convert filegeodatabase table into dbf file.

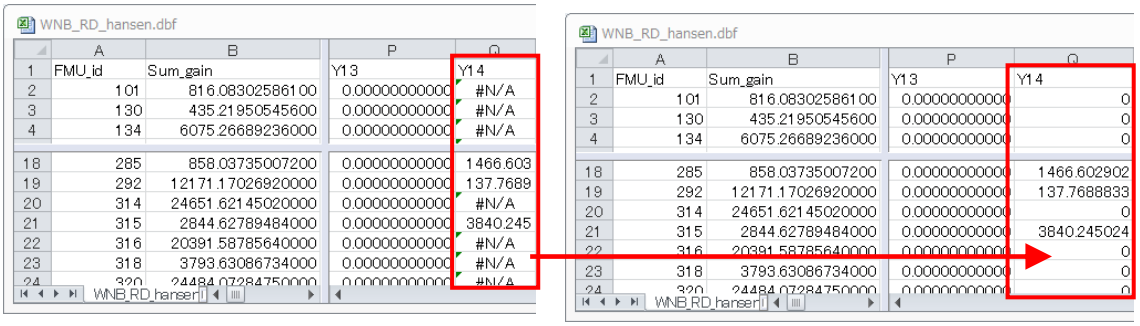


8'. In Excel, open the exported Hansen loss relational database table (XXX_RD_hansen.dbf) and the exported lossyear area table (fmu_lossyear_XXX_YY.dbf).

9’. In the Hansen loss relational database table, type new column name (Y14), and add lossyear area in the new column by using VLOOKUP[14] function.

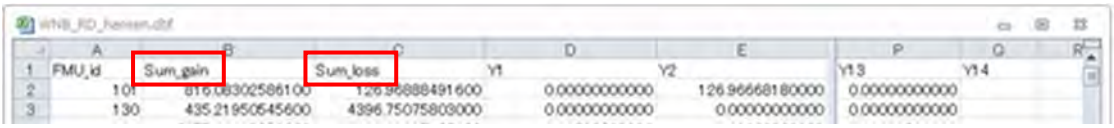






[14] See **Annex K** for more information of VLOOKUP.

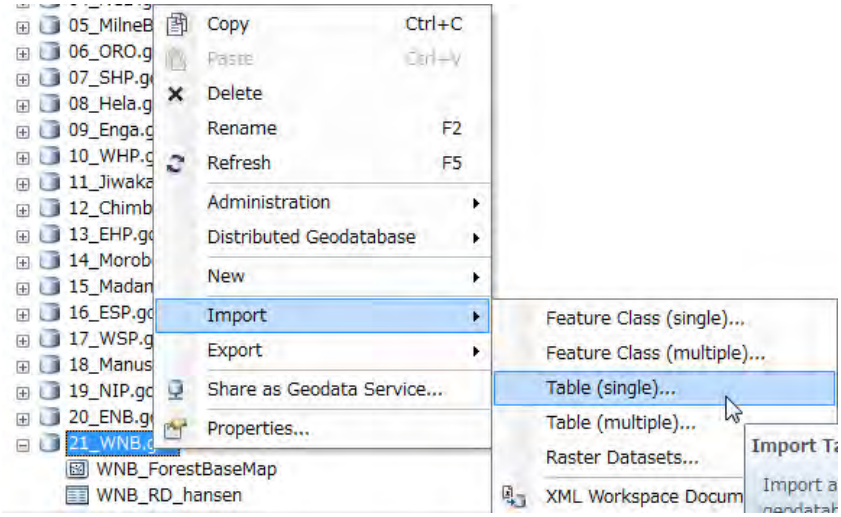
10’. In the same way above, create gain and loss data, calculate total gain area and total loss area, and then update Sum_gain field and Sum_loss field in the dbf file.

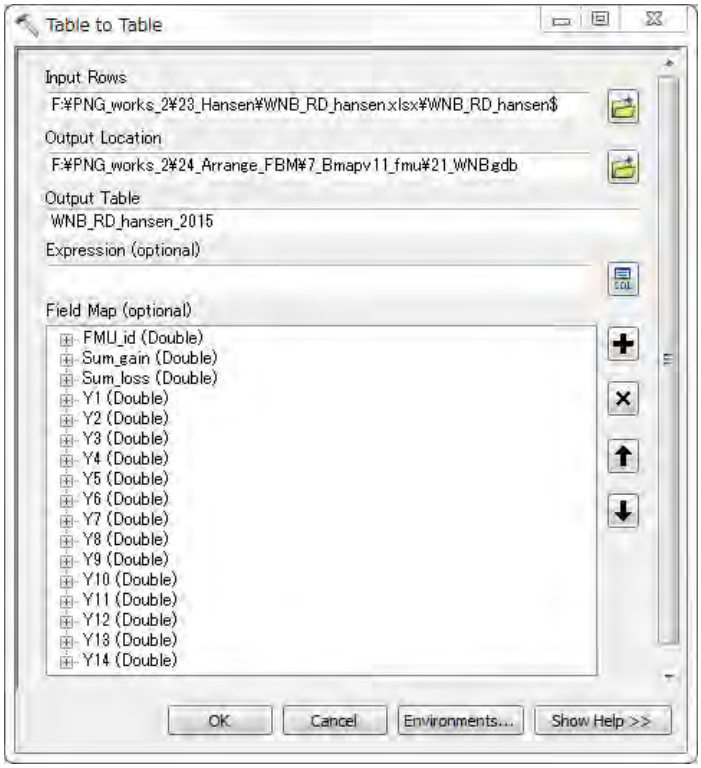


	A	B	C	D	E	P	Q
1	FMU_id	Sum_gain	Sum_loss	Y1	Y2	Y13	Y14
2	101	816.0830258610	126.96888491600	0.00000000000	126.96668180000	0.00000000000	
3	130	435.21950545600	4396.75075803000	0.00000000000	0.00000000000	0.00000000000	

11’. After adding new year loss area and updating Sum_gain and Sum_loss column, save the dable in Excel format such as *xls or *xlsx.

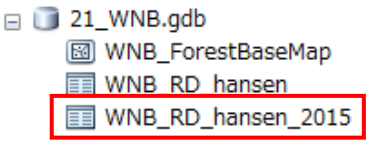
12’. In ArcCatalog, right-click the Forest Base Map filegeodatabase, select Import > Table (single)…, and set parameters in the Table to Table dialog to import the created excel file into the Forest Base Map filegeodatabase.

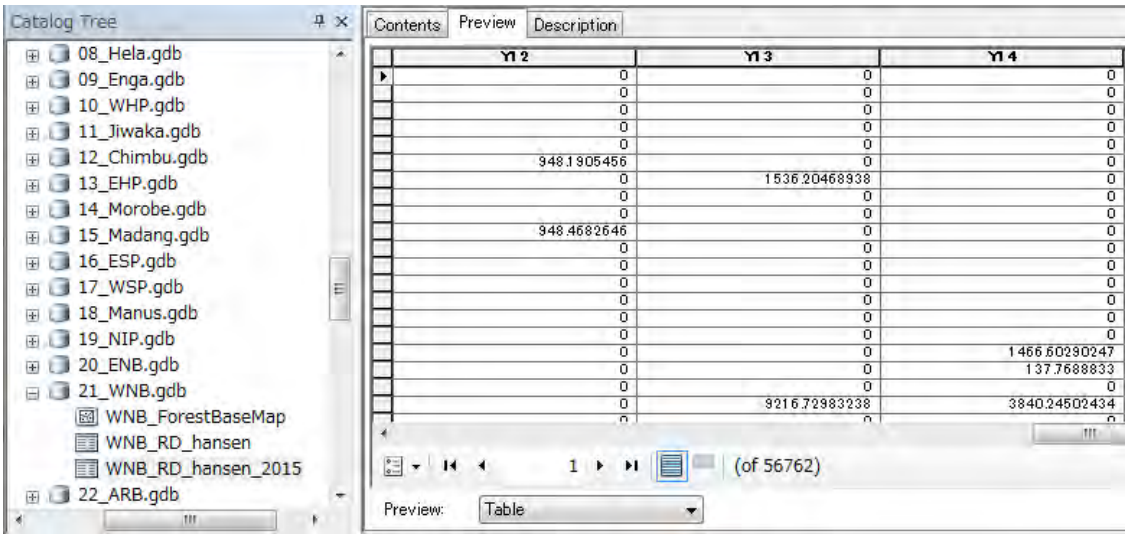




Output table name:

WNB_RD_hansen_2015





The new Hansen loss relational database (XXX_RD_hansen_YYYY) is created in the Forest Base Map file geodatabase.

Note

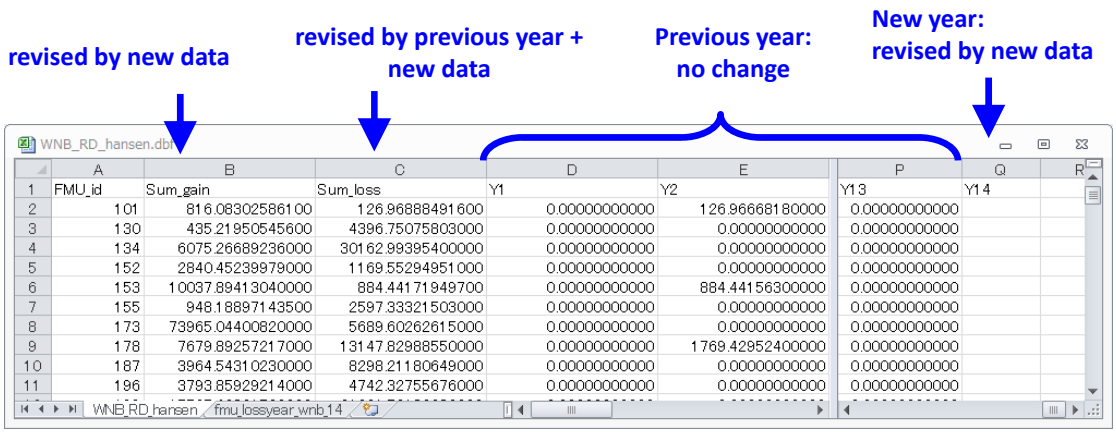
There could be some options to update Hansen data.

✧ Option A

- Update [Sum of Gain] area by using new published data
- Update only new [Lossyear] area by using new published data, no change for the previous [Lossyear] area
- Update [Sum of Loss] area by adding new [Lossyear] area to the previous [Sum of Loss area]

* The previous [Lossyear] figures do not change.

* The previous [Lossyear] and [Sum of Loss] figures do not match the figures derived from the new published data.



	A	B	C	D	E	P	Q
1	FMU_id	Sum_gain	Sum_loss	Y1	Y2	Y13	Y14
2	101	816.08302586100	126.96888491600	0.00000000000	126.96668180000	0.00000000000	
3	130	435.21950545600	4396.75075803000	0.00000000000	0.00000000000	0.00000000000	
4	134	6075.26689236000	30162.99395400000	0.00000000000	0.00000000000	0.00000000000	
5	152	2840.45239979000	1169.55294951000	0.00000000000	0.00000000000	0.00000000000	
6	153	10037.89413040000	884.44171949700	0.00000000000	884.44156300000	0.00000000000	
7	155	948.18897143500	2597.33321503000	0.00000000000	0.00000000000	0.00000000000	
8	173	73965.04400820000	5689.60262615000	0.00000000000	0.00000000000	0.00000000000	
9	178	7679.89257217000	13147.82988550000	0.00000000000	1769.42952400000	0.00000000000	
10	187	3964.54310230000	8298.21180649000	0.00000000000	0.00000000000	0.00000000000	
11	196	3793.85929214000	4742.32755676000	0.00000000000	0.00000000000	0.00000000000	

✧ Option B

- Update all data: [Sum of Gain] area, [Sum of Loss] area, each [Lossyear] area, by using new published data

* All data figures match the figures derived from the latest data.

* The previous [Lossyear] figures change.

* It takes time to revise all [Lossyear] figures because of data-intensive task

revised by new data

WNB_RD_hansen.xlsx

	A	B	C	D	E	P	Q
1	FMU_id	Sum_gain	Sum_loss	Y1	Y2	Y13	Y14
2	101	816.08302586100	126.96888491600	0.00000000000	126.96668180000	0.00000000000	
3	130	435.21950545600	4396.75075803000	0.00000000000	0.00000000000	0.00000000000	
4	134	6075.26689236000	30162.99395400000	0.00000000000	0.00000000000	0.00000000000	
5	152	2840.45239979000	1169.55294951000	0.00000000000	0.00000000000	0.00000000000	
6	153	10037.89413040000	884.44171949700	0.00000000000	884.44156300000	0.00000000000	
7	155	948.18897143500	2597.33321503000	0.00000000000	0.00000000000	0.00000000000	
8	173	73965.04400820000	5689.60262615000	0.00000000000	0.00000000000	0.00000000000	
9	178	7679.89257217000	13147.82988550000	0.00000000000	1769.42952400000	0.00000000000	
10	187	3964.54310230000	8298.21180649000	0.00000000000	0.00000000000	0.00000000000	
11	196	3793.85929214000	4742.32755676000	0.00000000000	0.00000000000	0.00000000000	

WNB_RD_hansen / fmu_lossyear_wnb_14

We choose Option A because updating previous year every time is meaningless.

Points of remember

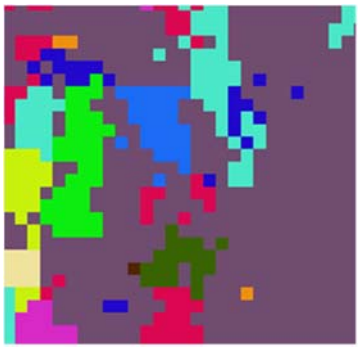
Hansen data has several versions, which were published in 2013, 2014, 2015 (two times), and 2016. The “Loss year” covered by each version are shown in the table below. The Project team checked the differences of spatial distribution (position) and area among these versions. In the case of the 2016 version is selected to collect information, the 2013 version had position gaps of less than one pixel. Also, there are gaps of areas in 2014 Loss year in 2015 version 1, 2012 and 2013 Loss year in 2014 version, and 2011 and 2012 Loss year in 2013 version. The reason for this may be that LANDSAT 8 was included in the satellite image used for data analysis, and analysis accuracy was improved or the analysis method was adjusted. In the Project activities, Loss year and Gain data of 2013 version and 2015 version 1 have been developed as a relational database of FMU in the Forest Base Map. And then, Loss year and Gain data of 2016 version have been newly developed. The difference between the versions of Hansen data and the Hansen data versions used for data development will be noted in a metadata file.

Table: Comparison between versions of Hansen data

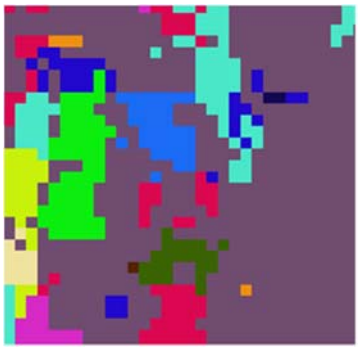
Version	2001	...	2008	2009	2010	2011	2012	2013	2014	2015	2016
2016 ver.	○	○	○	○	○	○	○	○	○	○	○
2015 ver.2	○	○	○	○	○	○	○	○	○	○	—
2015 ver.1	○	○	○	○	○	○	○	○	×	—	—
2014 ver.	○	○	○	○	○	○	×	×	—	—	—
2013 ver.	△	△	△	△	△	×	×	—	—	—	—

○: Presence of data. △: Presence of data, with position gap. ×: Presence of data, but with area gap.

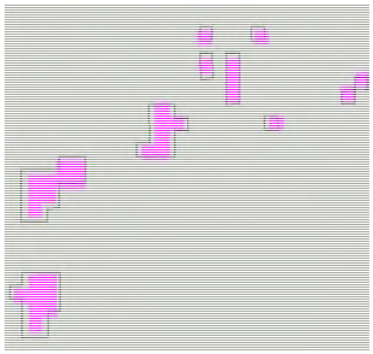
—: Absence of data.



2013 ver.



2015 ver.1



* Overlaying two Hansen data

* Color shows each year. Same color cells between two images should be the same size and location.