Geology and Soils

in

Timor-Leste

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Introduction.

This short report follows on from a request from the 'Seeds of Life' program to research the connection, if any, in Timor-Leste between the geology of the island and the currently known distribution of soil types.

Basic information on Timorese soils is contained in the 'Carta Dos Solos de Timor' published by the 'Junta de Investigações Cientificas do Ultramar' in or around 1961. These maps were subsequently digitized and the information therein re-interpreted and upgraded in 2004 to reflect modern soil classifications, principally that of the United States Department of Agriculture (USDA) Soil Classification for 1990.

The data was then published by the Ministério de Agricultura, Florestas e Pescas (MAP) as their 'Memōrias do Centro de Pesquisa e Extensão No.2' in 2004. The digital data is maintained by the ALGIS division of the Ministry whose assistance is noted here for the provision of soil maps used in this report.

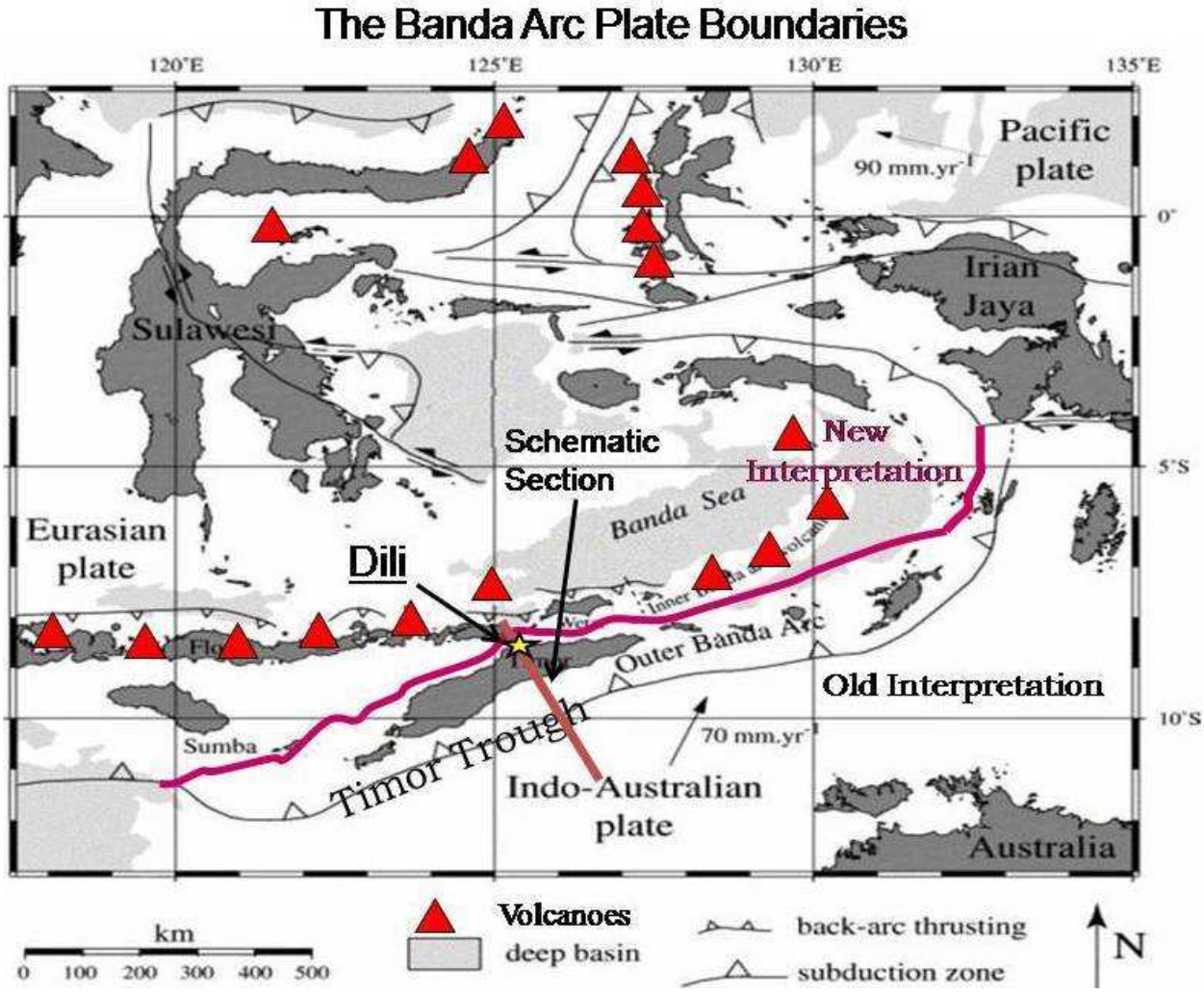
The geology of Timor-Leste has been a major focus of the research into the geology of SE Asia carried out by the SE Asia Research Group at University College, London, the group headed by Professor Audley-Charles since the mid 1960's. His maps remain the main source of geological information relating to the island of Timor. Another member of that research team, Mr. Tim Charlton, undertook significant field, stratigraphic and tectonic studies on Timor through the 1990's and his publications also provide a comprehensive data set on Timorese geology.

These data sets were used as the starting point for a hydrogeological study of Timor-Leste undertaken by Geoscience Australia for the government of Timor-Leste. Geological maps and interpretations sourced from that report and geological database have been used as the main source of geological data within this report. Geological maps presented here are those presented in the recently completed Geoscience Australia report. In this light the assistance and support of Mr. Lindsay Furness, Water Resources Advisor to that project, is greatfully acknowledged and his permission to reproduce this material is noted with thanks.

Timor-Leste, Geology.

The island of Timor sits at the eastern end of and just south of the archipelago of volcanic islands, the Banda Arc, running eastwards from the Indonesian island of Bali. This volcanic arc is the surface expression of lithospheric subduction currently taking place as the Australian crustal plate moves north eastwards towards and underneath the Eurasian plate.

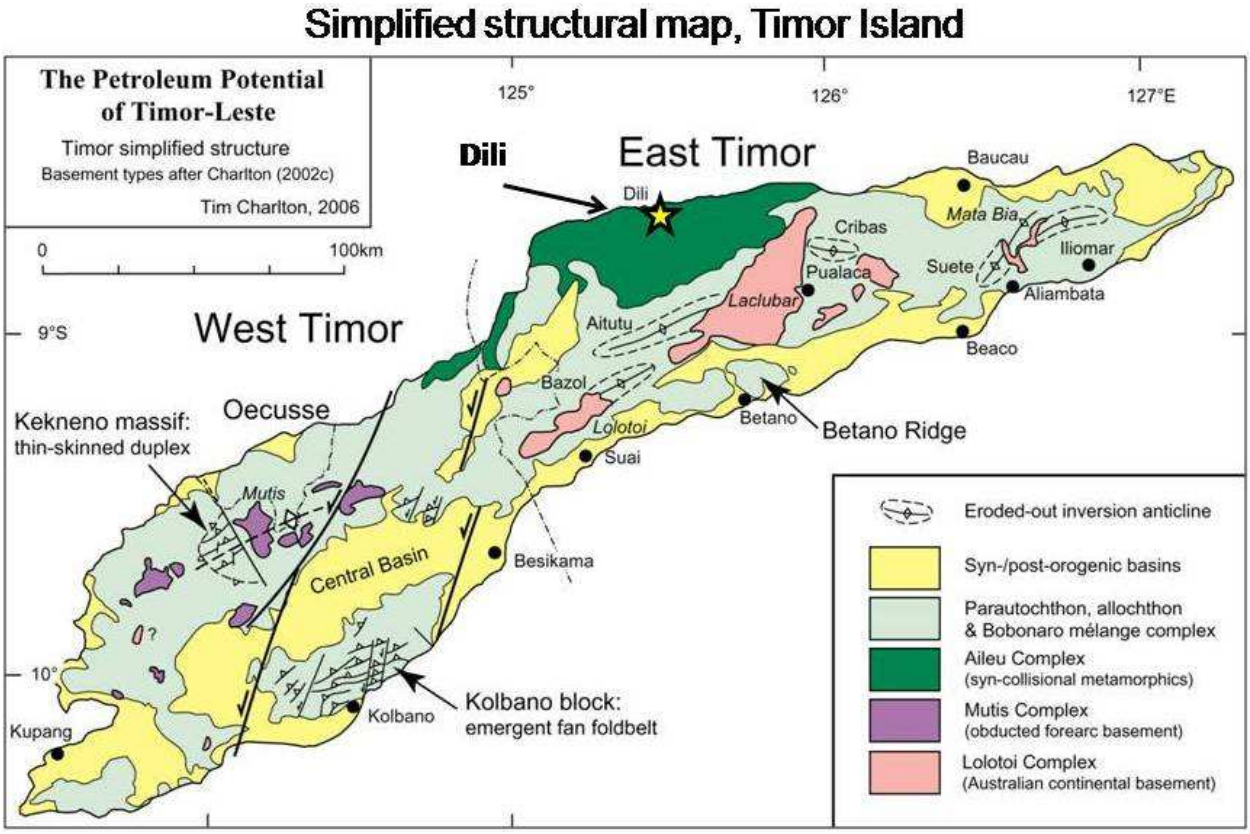
However, for the last 5 million years or so that subduction has become 'locked' in the Timor region thereby causing the island of Timor to be thrust upwards as the only relief mechanism available as the two crustal plates continue to converge. In layman's language, Timor is going up like a 'Geological Cork' at the extreme north eastern edge of continental Australia.



Structurally, the rocks on Timor belong to the Australian plate with basement rocks (Lolotoi Complex) uplifted as the mountainous spine of the island. The results of the continental

collision, leading to immensely deformed, sheared and thrusted lithologies are seen along the north of the island in the syn-collisional metamorphic rocks of the Aileu Complex.

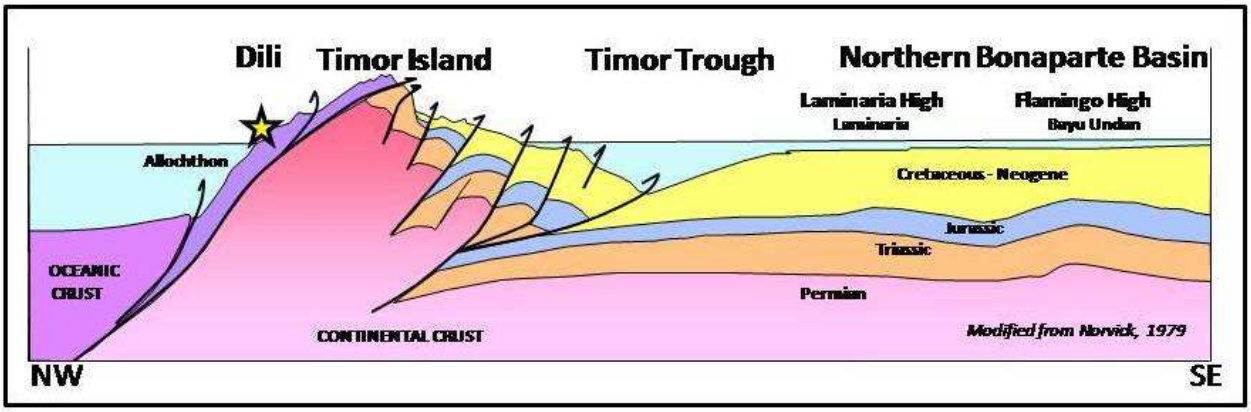
Younger, Mesozoic sediments lie in structurally controlled basins on top of these basement lithologies and Plio-Pleistocene to recent reefal limestones continue to be laid down and uplifted in syn/post orogenic basins on and around the periphery of the island. Tim Charlton's 2006 map serves to illustrate this basic structure.



The overall geological engine behind the creation of Timor is extreme uplift due to the 'locked' continental collision. This is reflected in the mountainous nature of the island and the chaotic geology with the island broken into an immense number of thrust and uplifted structural units. Softer sediments, shales, sandstones and bedded limestones for example are sheared, crushed and folded into complex and contorted lithologies. The more massive reefal and marine limestones however are strong enough to have maintained their integrity and have been literally pushed up through the geological mélange in huge up-thrust slices as seen at Cablac and Matebian for example and elsewhere throughout the central spine of the island.

Norvick's 1979 schematic section neatly illustrates this structural overprint on the geology of Timor.

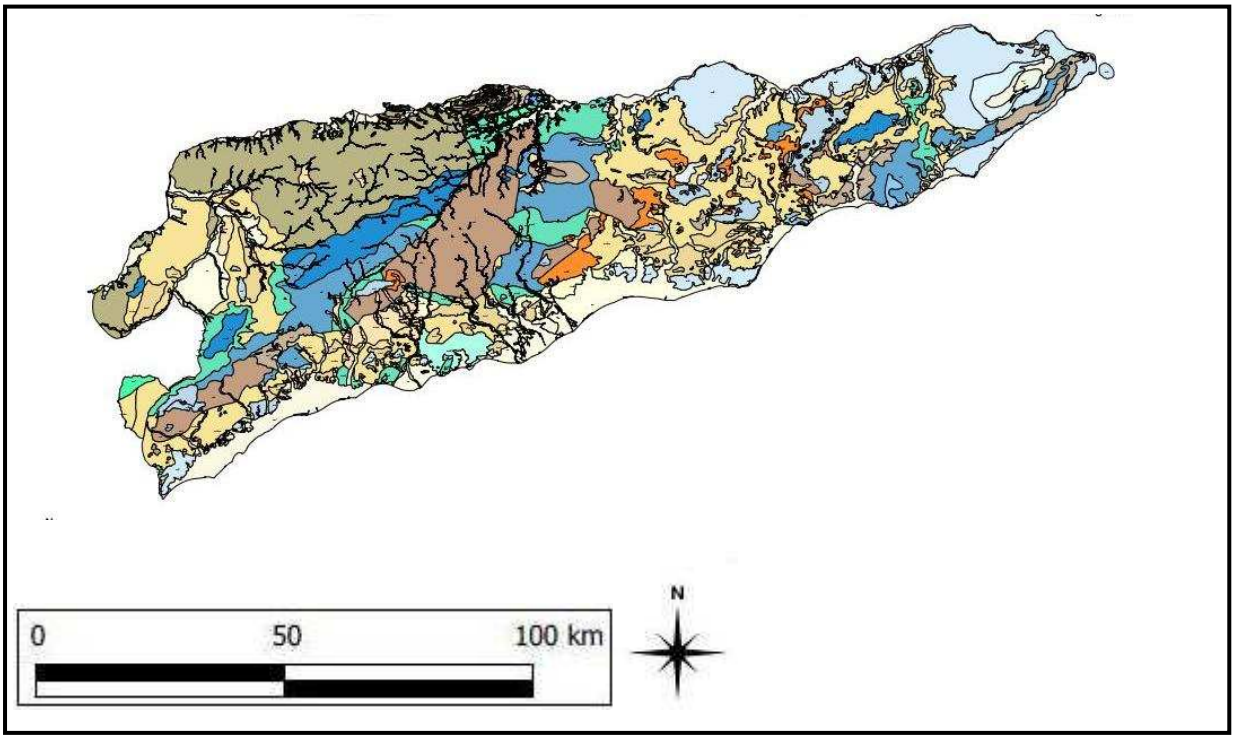
Schematic cross-section across Timor Island and the Timor Trough



The recent work undertaken by Geoscience Australia has focused on the hydrogeological characteristics of Timor-Leste's rocks, that is their ability to act as an aquifer which is directly related to the porosity of the rocks, how fractured and jointed they are and on their physical and chemical make-up, all factors, which in turn, affect the nature of the soils subsequently derived from those rocks.

Removing the structural complexities of the geology, a new geological map of Timor-Leste has been constructed upon the foundation provided by Professor Audley-Charles' earlier mapping.

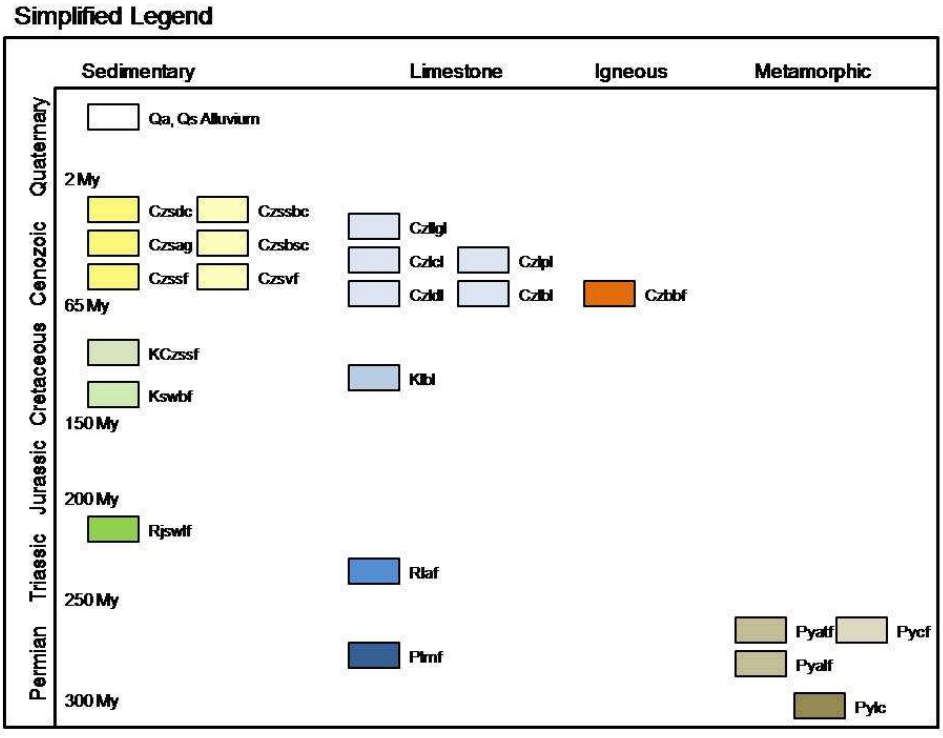
Timor-Leste Lithostratigraphic Map



This map concentrates on lithostratigraphical units, as listed in the simplified table and legend:

Timor-Leste, simplified lithostratigraphic units

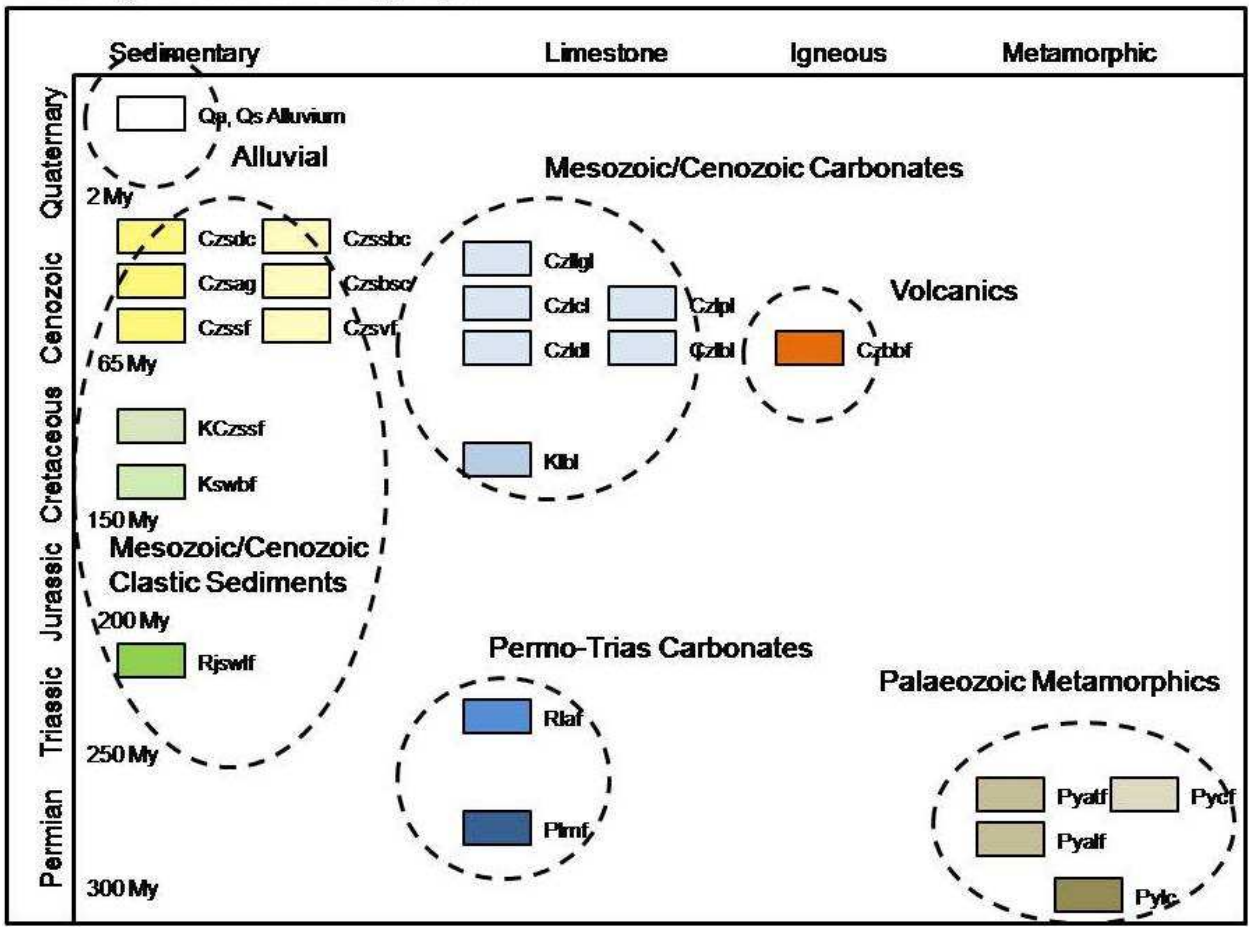
Strat Code	Name	Age	Description
Qa, Qs etc	Alluvium	Quaternary	Unconsolidated alluvium
Czssf	Suai Formation	Quaternary	Coarse marine sands and gravels
Czlbl	Baucau Limestone	Pleistocene	Shallow marime/beach limestone
Czlpl	Poros limestone	Pleistocene	Freshwater lake limestone
Czsag	Ainaro Gravels	Plio-Pleistocene	River gravels
Czssbc	Sekto Block Clay	Pliocene	Marine clays and pebbly mudstones
Czsdc	Dilor Conglomerate	Pliocene	Conglomerate
Czsbsc	Bobonaro Melange	Miocene	Clay rick marine sedimentary unit
Czsvf	Viqueque Formation	Miocene	Fine grained clays and carbonates
Czllcl	Cablac Limestone	Miocene	Shallow marine limestone
Czllgl	Lari Guti Limestone	Miocene	Coastal limestone
Czbbf	Barique Formation	Oligocene	Volcanics
Czldll	Dartollu Limestone	Eocene	Shallow marine limestone
Kczssf	Seical Formation	Cretaceous	Deep marine sediments
Kswbf	Wai Bua Formation	Cretaceous	Thick marine sediments
Klbl	Borolalo Limestone	Cretaceous	Deep marine limestones
Rjswlf	Wai Lili Formation	Triassic-Jurassic	Thick marine sedimentary sequence
Rlaf	Aitutu Formation	Triassic	Marine limestones
Plmf	Maubisse Formation	Permian	Shallow marine limestones
Pyatf	Atahoc Formation	Permian	Deep marine sedimentary sequence
Pycf	Cribas Formation	Permian	Deep marine sedimentary sequence
Pyalf	Aileu Formation	Permian	Hard metamorphosed deep marine sediments
Pylc	Lolotoi Complex	Pre-Permian	Metamorphosed sediments and volcanics



The hydrogeological study subdivided the lithostratigraphic units into 7 groups displaying similar hydrogeological properties. For the purposes of this soil review study the hydrogeological groups 'Intergranular High' and 'Intergranular Low', reflecting modern and ancient alluvial deposits respectively, have been merged into one 'Alluvial' group.

This leaves 6 lithostratigraphic 'Soil Source Groups' which, from review of the Portuguese soil mapping, appear to show some potentially quite strong correlations to several of the main soil units recognized in Timor-Leste.

Lithological 'Soil source groups'

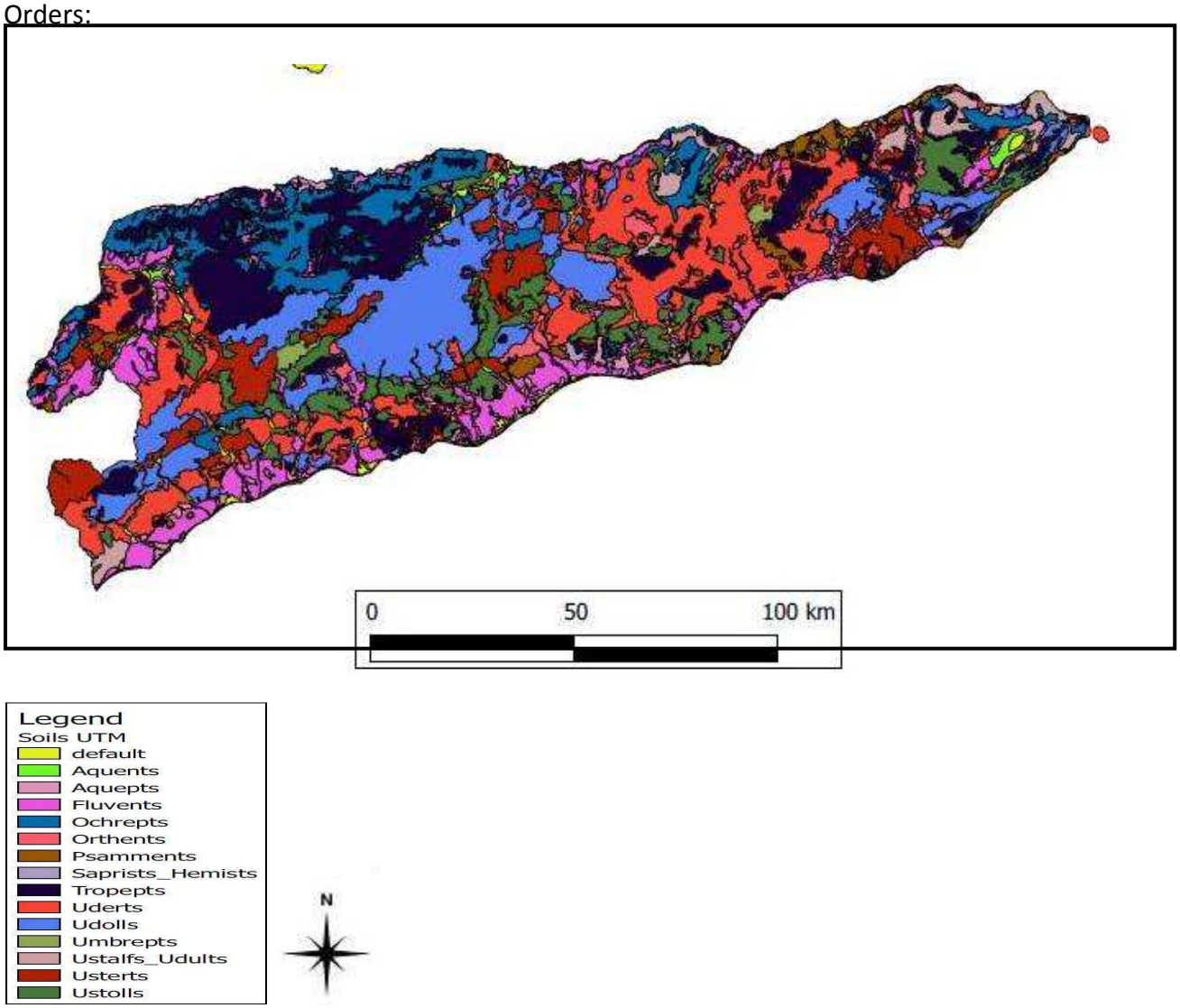


Timor-Leste, Soils.

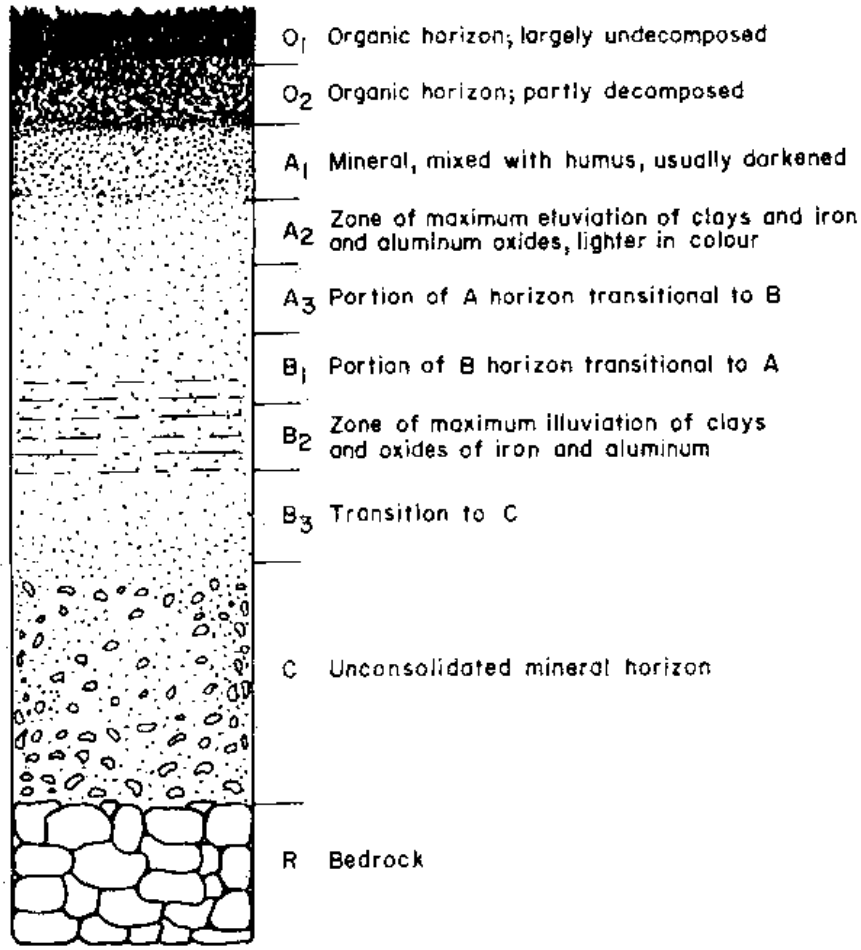
Soils are the thin layer covering the entire earth's surface, except for open water surfaces and rock outcrops. The properties of soil are determined by environmental factors. Five dominant factors are often considered in the development of the various soils: (a) the climate, (b) parent materials (rocks and physical and chemical derivatives of same), (c) relief, (d) organisms (fauna and flora), and (e) the time factor. There are a large number of different soils, reflecting different kinds and degrees of soil forming factors and their combinations.

The soils of Timor-Leste, 'Ultramar', in Portuguese times, were mapped in the early 1960's using aerial photographs at an average scale of 1:40,000, backed up by intensive field mapping. The maps produced are currently available at a scale of 1:100,000 and it was this data which was digitized and updated by ALGIS in 2004.

In 2004 the original Portuguese soil classification was amended to reflect the most widely used USDA (1990) classification. The soil map of Timor-Leste, below, displays soil Sub-Orders:



Well developed soils, in general, display several horizons defined by their organic and mineral content, colour, thickness and texture as in the hypothetical soil profile, below:

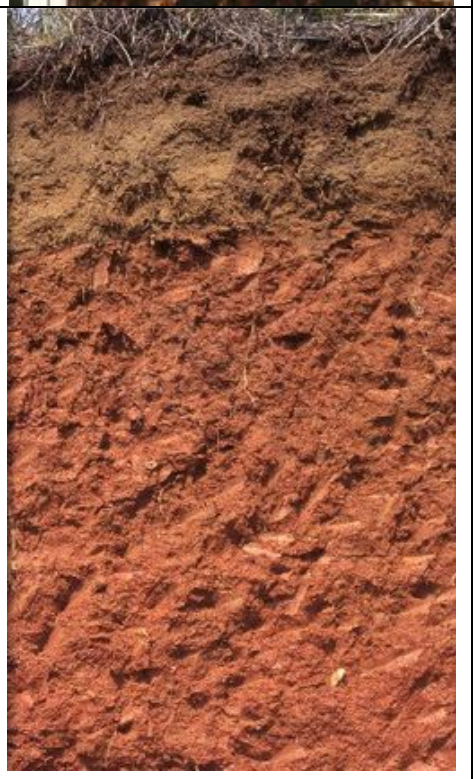


There are six levels in the hierarchy of categories: Orders (the highest category), suborders, great groups, subgroups, families and series (the lowest category) (USDA, 1978).

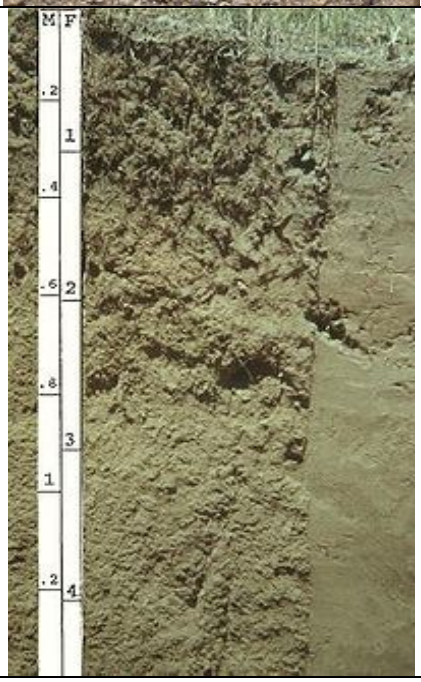
There are ten orders, 7 of which are recognized in Timor-Leste (see Table below), differentiated on gross morphological features by the presence or absence of diagnostic horizons or features which show the dominant set of soil-forming processes that have taken place.

Sub-Orders permit more statements to be made about a given soil. In addition to morphological characteristics other soil properties are used to classify the soil. The suborder focuses on genetic homogeneity like wetness or other climatic factors. There are 47 suborders within the 10 orders. The names of the suborders consist of two syllables. The first connotes the diagnostics properties; the second is the formative element from the soil order name. For example, an Ustalf is an alfisol with an ustic moisture regime (associated with subhumid climates).

Brief descriptions of the ten soil orders according to USDA (United States Department of Agriculture) 1990 Soil Taxonomy. *(√ Recognized in T-L)*

SOIL ORDERS	DESCRIPTION	Typical Profile
ALFISOLS √	Soils with a clayey B horizon and exchangeable cation (Ca + Mg + K + Na) saturation greater than 50% calculated from NH_4OAc-CEC at p^H7. Alfisols form in semiarid to humid areas, typically under a hardwood forest cover. They have a clay-enriched subsoil and relatively high native fertility. "Alf" refers to aluminium (Al) and iron (Fe). By definition, they have at least 35% base saturation, meaning calcium, magnesium, and potassium are relatively abundant.	
ULTISOLS √	Soils with a clayey B horizon and base saturation less than 50%. They are acidic, leached soils from humid areas of the tropics and subtropics. highly leached forest soils having less than 35% base (meaning calcium, magnesium, and potassium) saturation, commonly known as **red clay soils**. They are defined as mineral soils which contain no calcareous material anywhere within the soil, have less than 10% weatherable minerals in the extreme top layer of soil, and have less than 35% base saturation throughout the soil.	

SOIL ORDERS	DESCRIPTION	Typical Profile
OXISOLS	Oxisols are strongly weathered soils but have very little variation in texture with depth. Some strongly weathered, red, deep, porous oxisols contain large amounts of clay-sized Fe and Al oxides.	
VERTISOLS √	Dark clay soils containing large amounts of swelling clay minerals (smectite). The soils crack widely during the dry season and become very sticky in the wet season. Vertisols typically form from highly basic rocks, such as basalt, in climates that are seasonally humid or subject to erratic droughts and floods, or to impeded drainage	
MOLLISOLS √	Prairie soils formed from colluvial materials with dark surface horizon and base saturation greater than 50%, dominating in exchangeable Ca. Mollisols form in semi-arid to semi-humid areas, typically under a grassland cover. Their parent material is typically base-rich and calcareous and include limestone, loess, or wind-blown sand.	

SOIL ORDERS	DESCRIPTION	Typical Profile
INCEPTISOLS √	Young soils with limited profile development. They are mostly formed from colluvial and alluvial materials. Soils derived from volcanic ash are considered a special group of Inceptisols, presently classified under the Andept suborder (also known as Andosols).	
ENTISOLS √	Soils with little or no horizon development in the profile. They are mostly derived from alluvial materials. An Entisol has no diagnostic horizons, and most are basically unaltered from their parent material, which can be unconsolidated sediment or rock.	
ARIDISOLS	Soils of arid region, such as desert soils. Some are saline.	
SPODOSOLS	Soils with a bleached surface layer (A2 horizon) and an alluvial accumulation of sesquioxides and organic matter in the B horizon. These soils are mostly formed under humid conditions and coniferous forest in the temperate region.	

SOIL ORDERS	DESCRIPTION	Typical Profile
HISTOSOLS √	Soils consisting primarily of organic materials which are rich in organic matter such as peat and muck.	

16 USDA soil Sub-Orders have been recognized in Timor-Leste (see table below):

Soil Orders and Sub-Orders in Timor-Leste

ORDER	SUB-ORDER	ORDER	SUB-ORDER
ALFISOLS	Ustalfs	**INCEPTISOLS**	Umbrepts Aquepts Ochrepts Tropepts
ULTISOLS	Udults	**ENTISOLS**	Aquents Fluvents Orthents Psamments
VERTISOLS	Usterts Uderts	**HISTOSOLS**	Saprists Hemists
MOLLISOLS	Udolls Ustolls		

It is at the level of Sub-Orders that soil distributions have been mapped using the 2004 digital data. The complete set of 14 soil Sub-Order distribution maps (Saprists/Hemists and Ustalfs/Udults maps having been combined) is presented in Appendix-1.

Also in Appendix-1 a detailed table is presented in which USDA Order and Sub-Order soil definitions are taken down to the level of individual soil codes and example soil descriptions from the original Portuguese soil survey. As soil study in Timor-Leste progresses this information may provide a useful tool for field descriptions of Timorese soils linked directly back to the standardized USDA soil classification system.

Timor-Leste, Geology and Soils.

Comparative review of each series of maps, lithostratigraphical and soil, clearly reveals that there are, on a regional scale, several clear correlations existing between soil types and soil source rocks as listed below:

Soils – Lithology Correlation Timor-Leste

Lithology	Associated Soil Sub-Order
1 - Alluvial	*Fluvents *Aquents/Aquepts/Psamments*
2 – Mesozoic & Cainozoic Clastic Sediments	*Uderts *Tropepts/Ustols/Usterts*
3 – Mesozoic & Cainozoic Carbonates	*Ochrepts *Tropepts/Ustolls*
4 - Volcanics	*Orthents/Umbrepts
5 – Permo-Trias Carbonates	*Udolls/Usterts *Tropepts/Ustalfs-Udults*
6 – Palaeozoic Metamorphics	*Ochrepts/Tropepts Psamments/Uderts/Ustolls

(*Stronger correlation)

These correlations are visually evident but far from 100%, except possibly for Fluvents soils developed on the alluvial fans along the south coast of the island.

In many cases a single lithostratigraphic group can be straddled by two or more soil Sub-Orders.

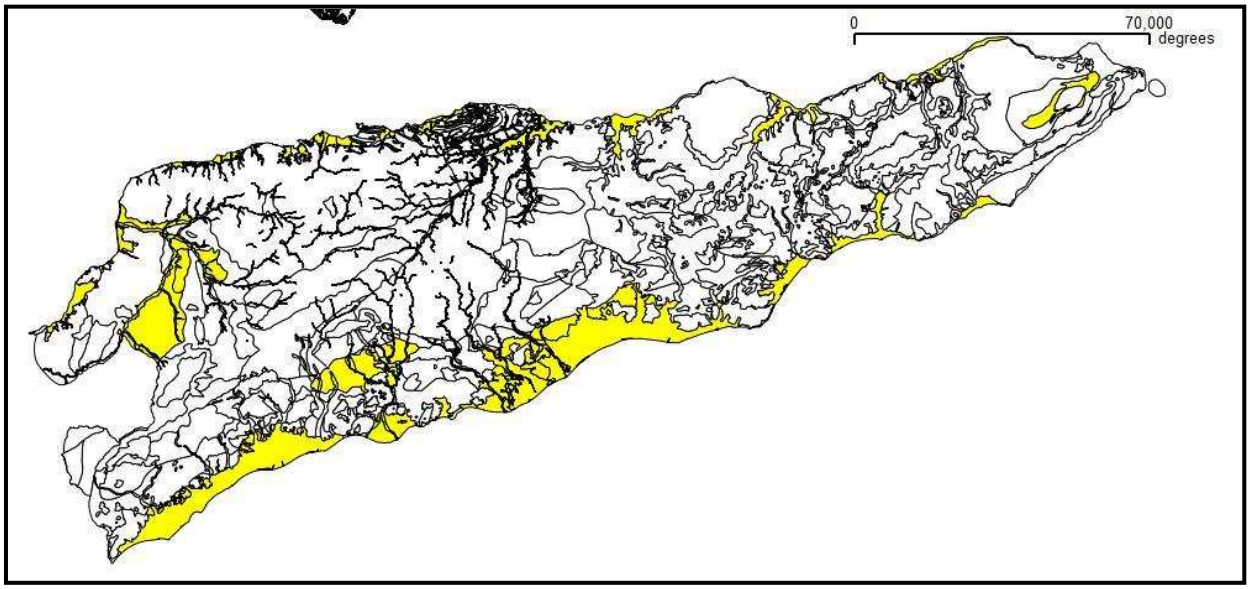
Ochtrepts and Troptepts soils together appear to closely match the mapped areas of Palaeozoic metamorphic rocks and the two carbonate suites, the younger Baucau Limestones and equivalents and the older Permian Maubisse Limestones and equivalents, displaying not quite as strong a correlation to particular soil Sub-Orders.

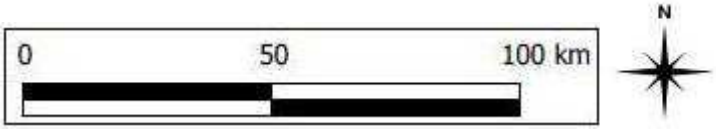
The ‘Soil Source Groups’ other than the alluviums and carbonates are lithologically diverse and hence soil types can be expected to be more variable reflecting their bed rock variation.

In reality in Timor-Leste, climate and, more importantly, the relief of the land and therefore excessive soil erosion and movement, will be amongst the most important factors controlling soil development.

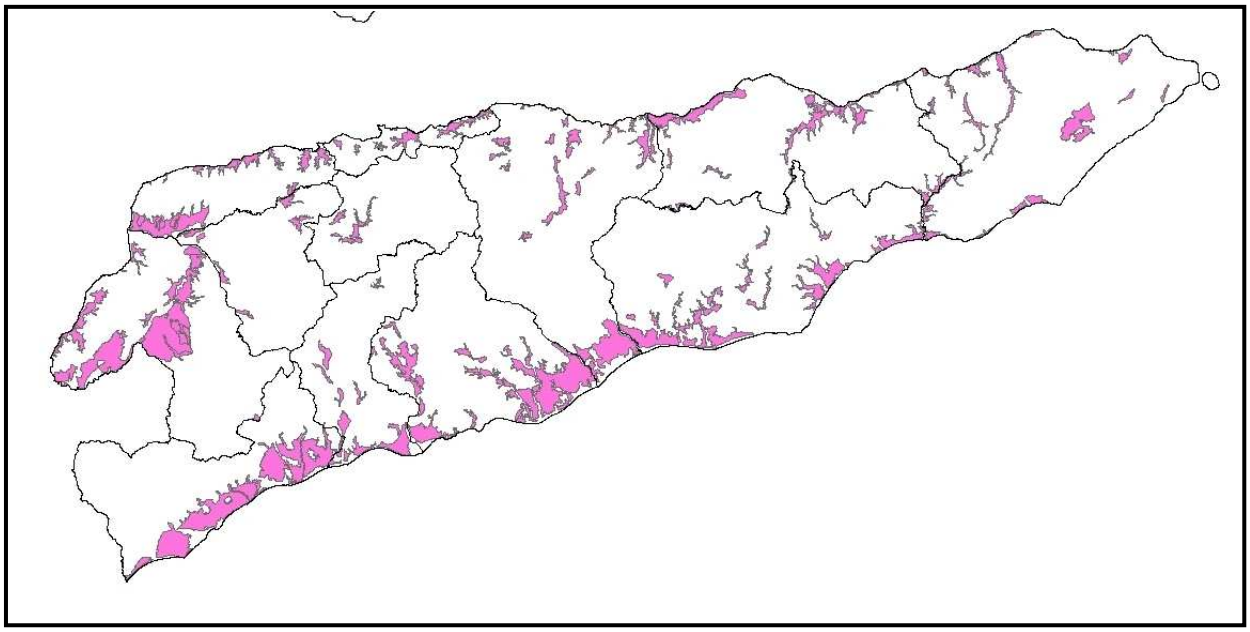
The following series of comparative maps serve to illustrate the main soil/rock associations observed.

1) Lithostratigraphic 'Soil Source Group' - Alluvium

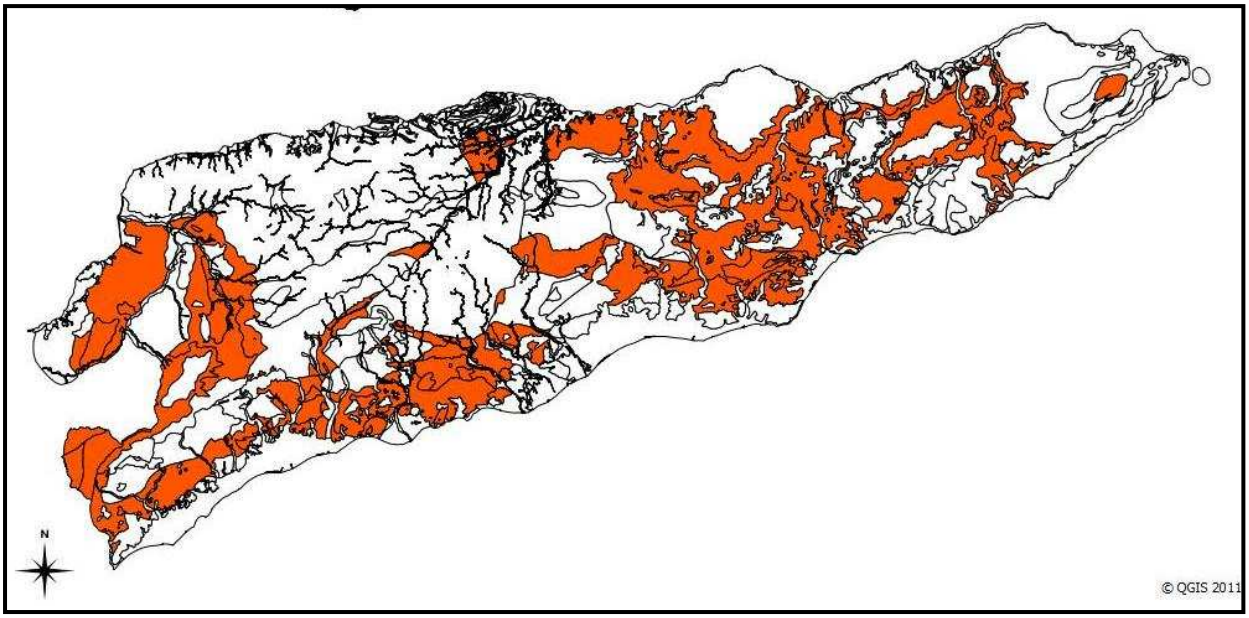


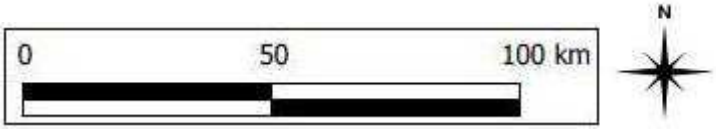


Fluvents Soils

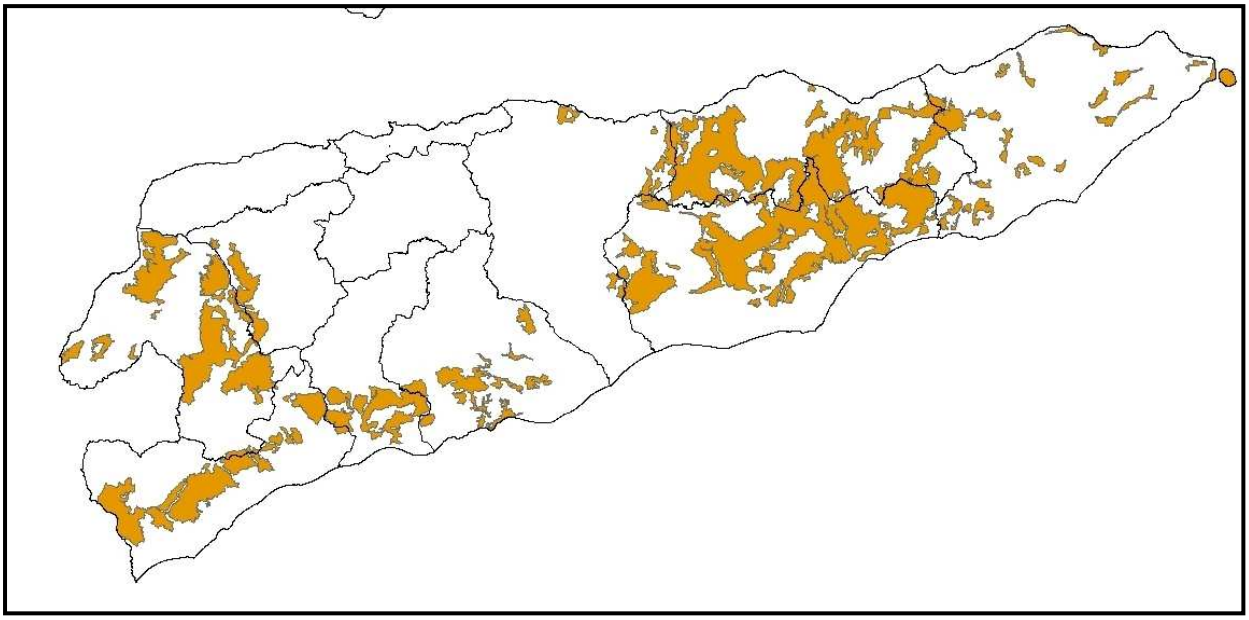


Lithostratigraphic 'Soil Source Group' – **Mesozoic & Cainozoic Clastic Sediments**

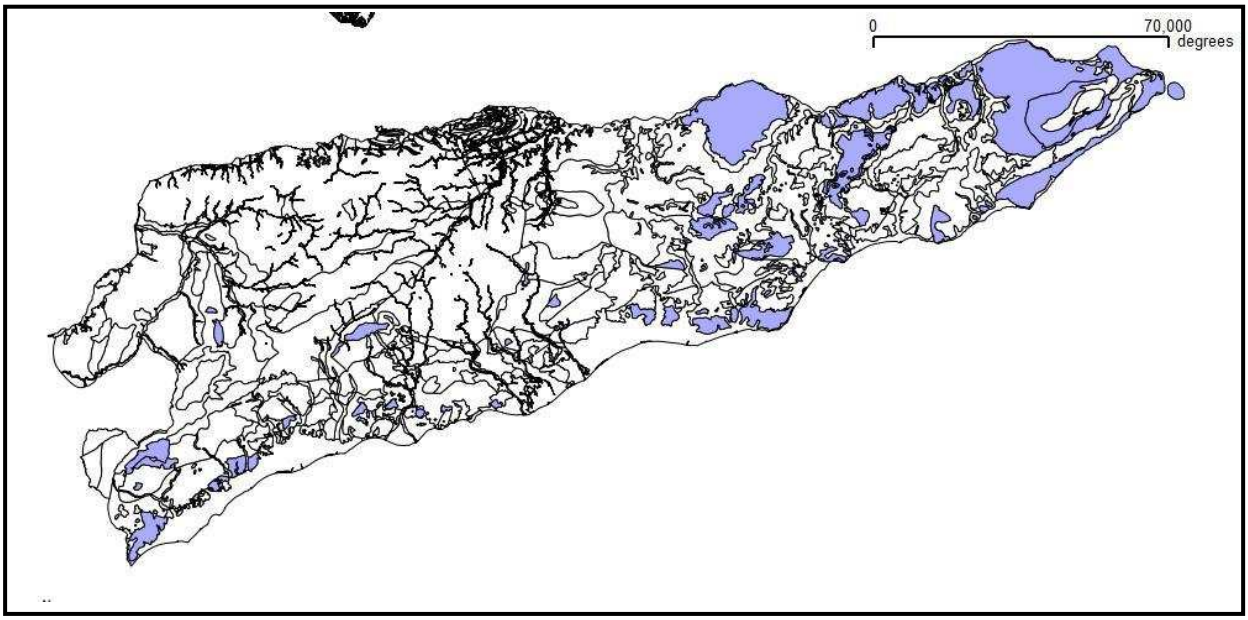


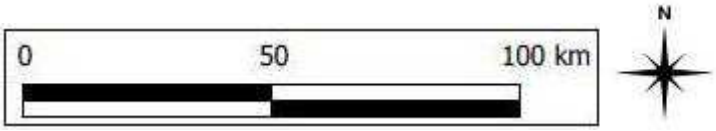


Uderts soils

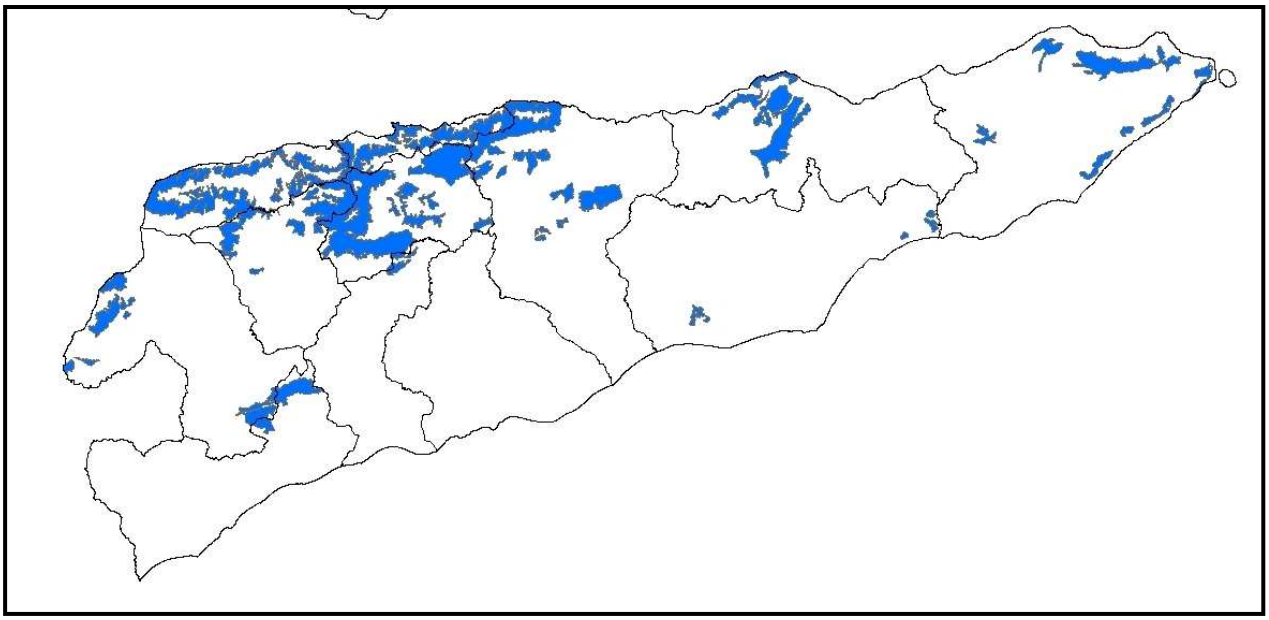


3) Lithostratigraphic 'Soil Source Group' – Mesozoic & Cainozoic Carbonates

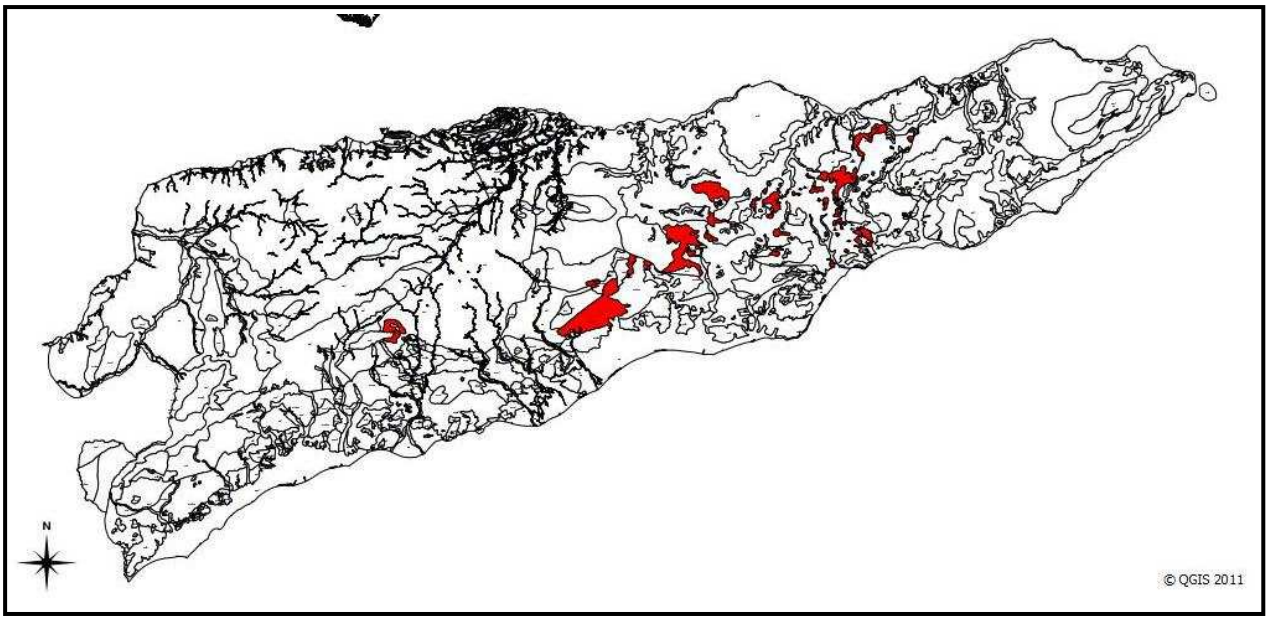




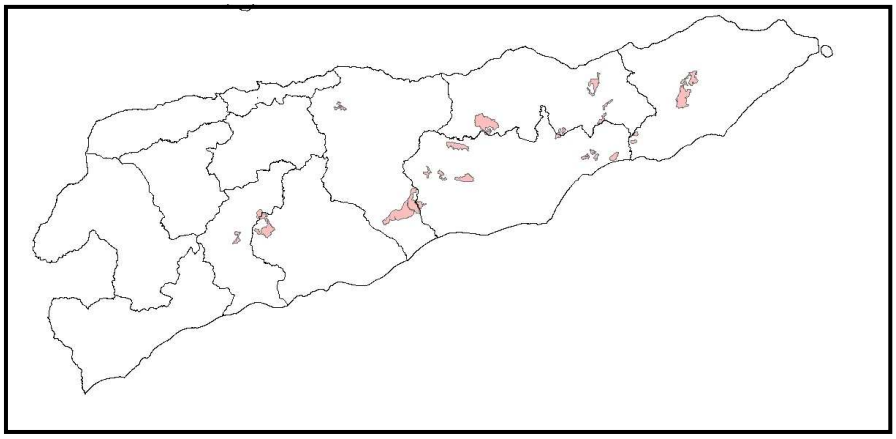
Ochrepts soils



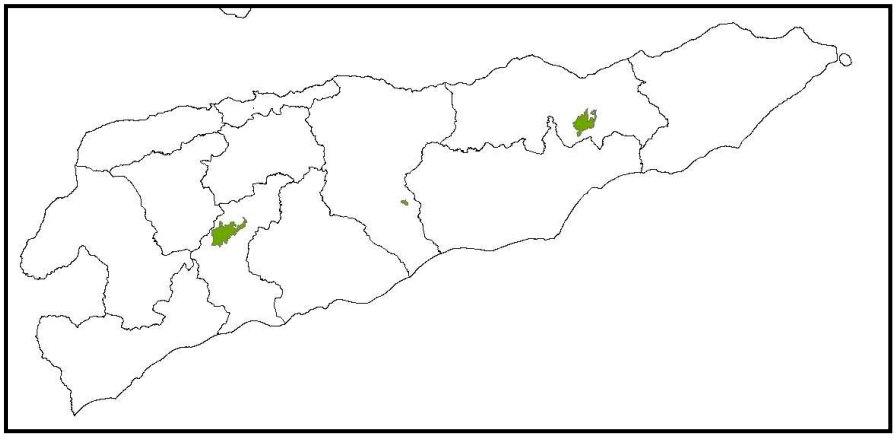
4) Lithostratigraphic 'Soil Source Group' - Volcanics



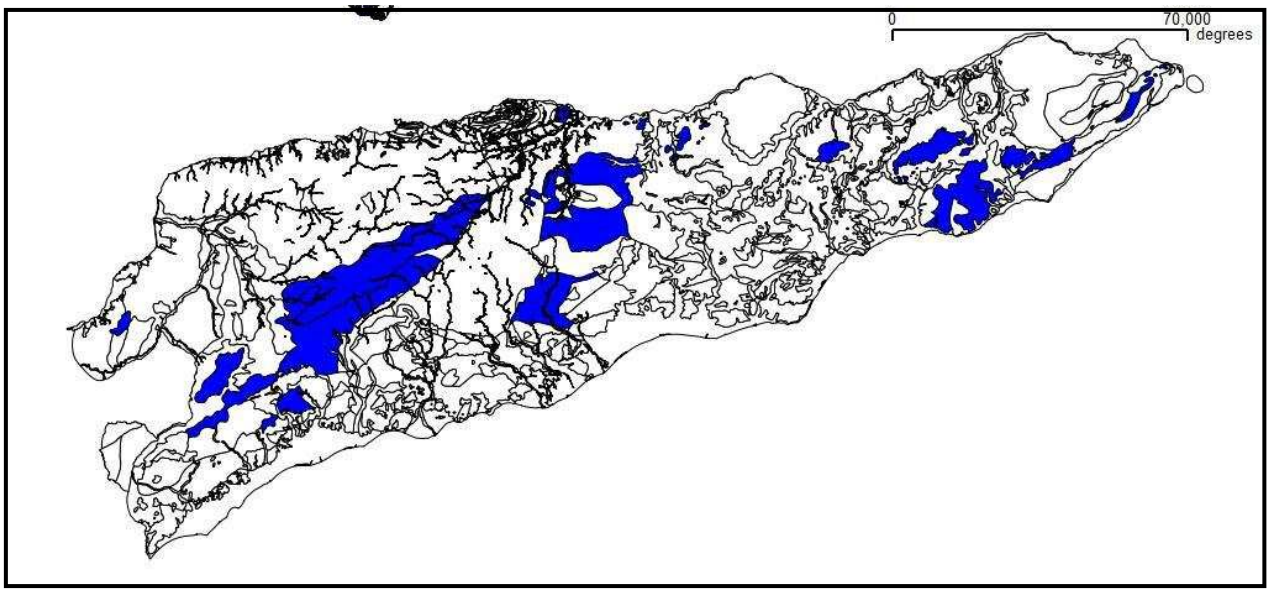
Orthents soils



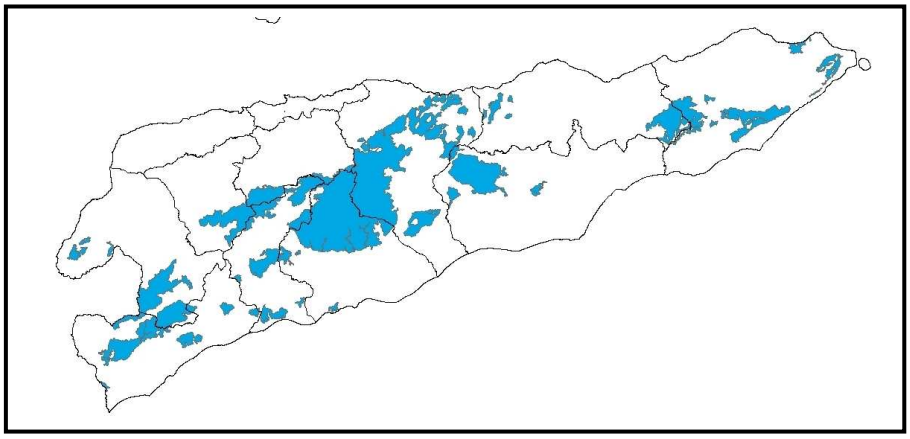
Umbrepts soils



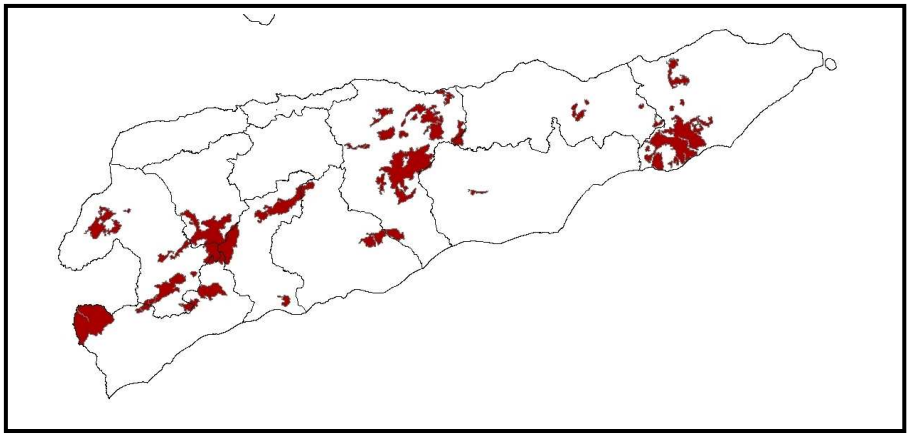
5) Lithostratigraphic 'Soil Source Group' – Permo-Trias Carbonates



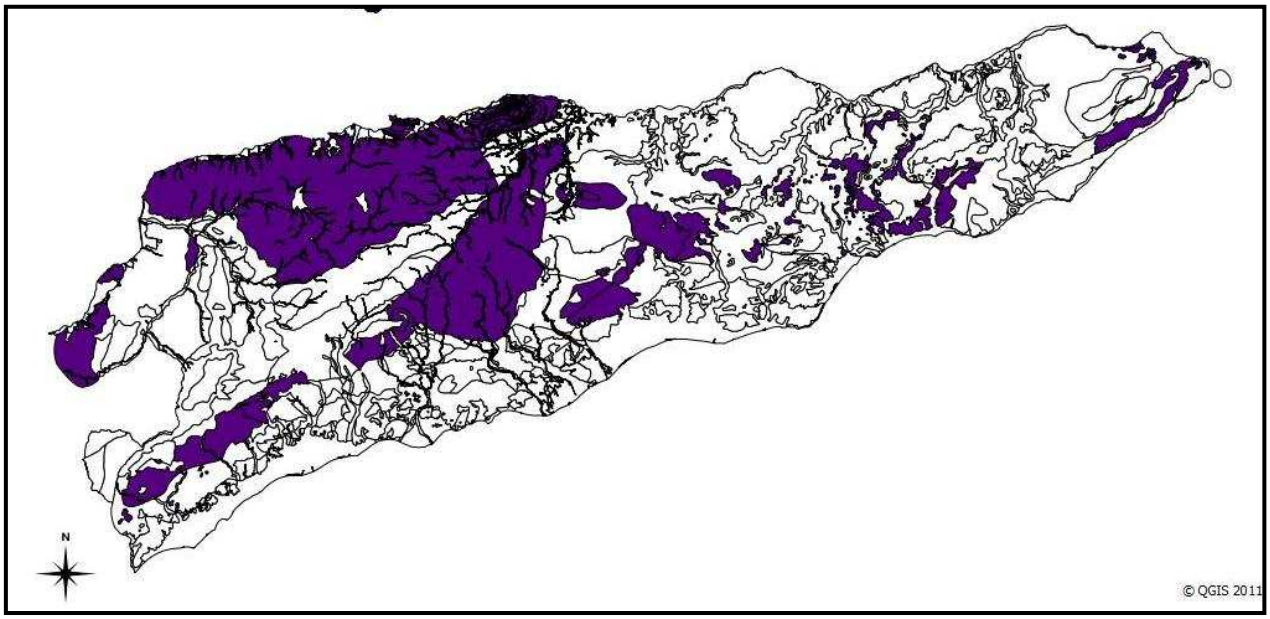
Udolls soils



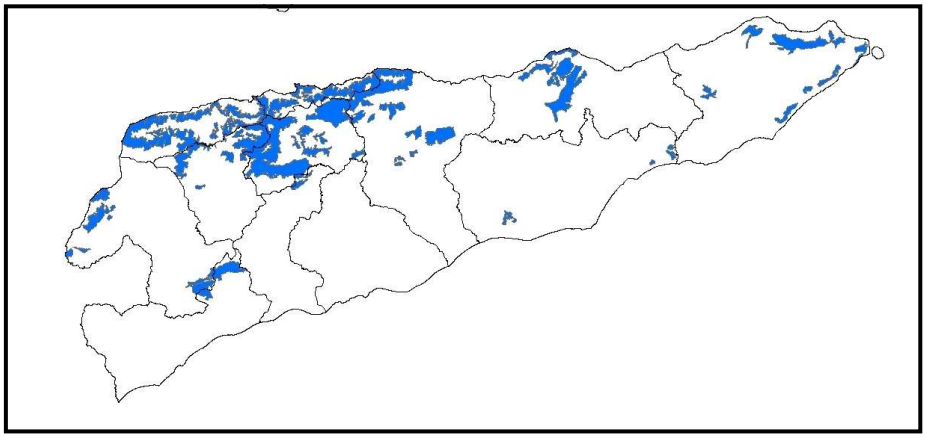
Usterts soils



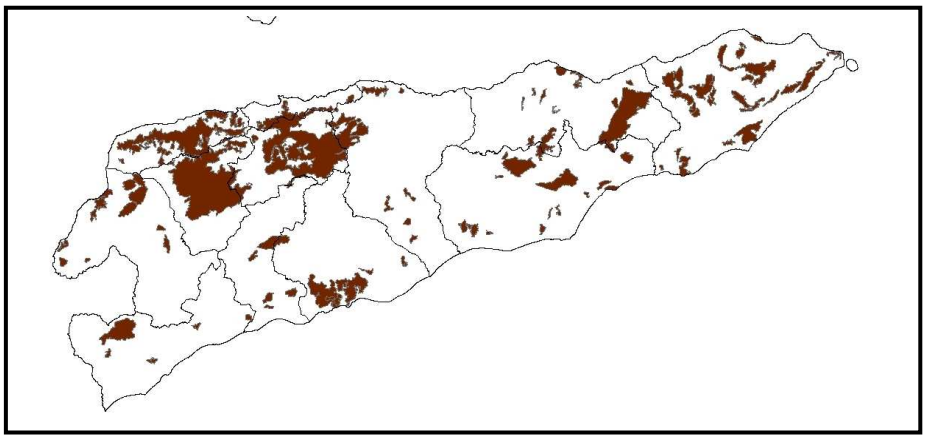
6 Lithostratigraphic 'Soil Source Group' – Palaeozoic Metamorphics



Ochrepts soils



Tropepts soils

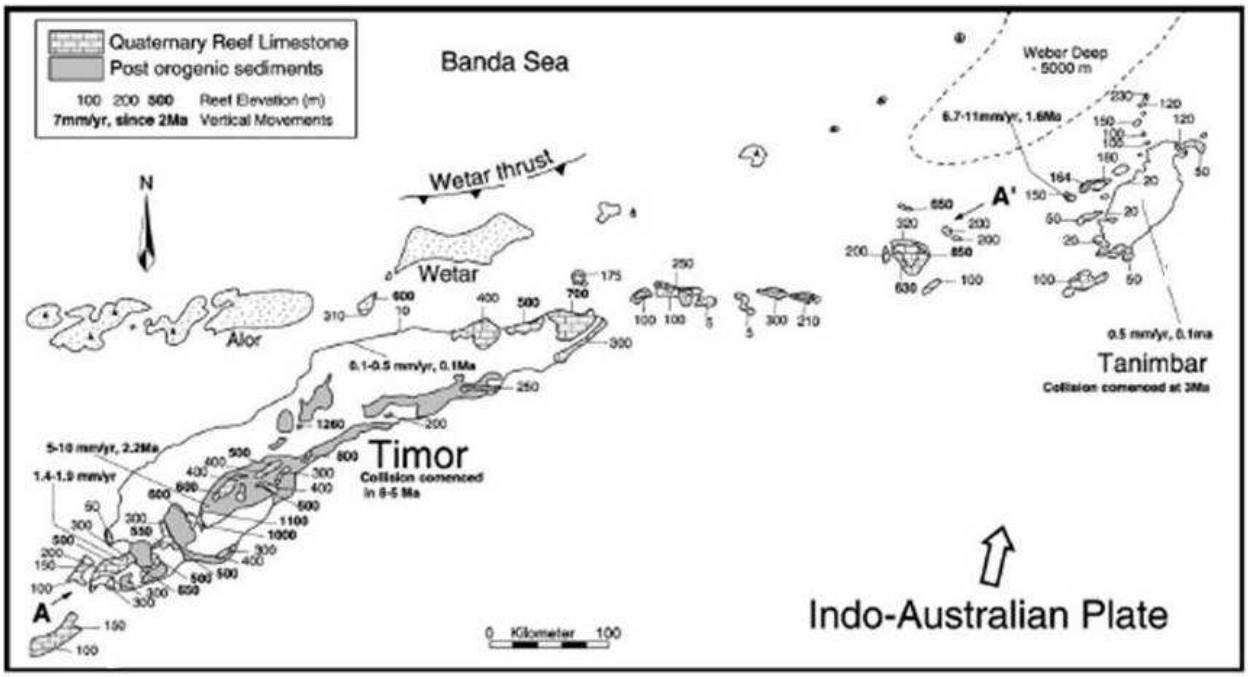


Timor-Leste, Geology and Soils – Discussion

The rock to soil correlations displayed in the previous section of this report, although real, cannot currently be given a very high significance as many other factors especially relief, climate and time affect soil generation and longevity.

As has been discussed the island of Timor is going up like a 'Geological Cork'. This, geomorphologically, results in very steep slopes representing the equilibrium between geological uplift and erosion and also in exceptionally high sediment loads in the rivers leading to extensive and thick alluvial fans and flood plains along river courses and across the coastal plains.

Studies involving height variations and measurements of uplifted Quaternary reefs and post orogenic sediments undertaken by Kaneko et al (2007) reveal that Timor is rising at anywhere between 5 and 10 mm per year as illustrated in the map below:.



As almost half of Timor's land has a slope of 40° or more reflecting this steep equilibrium, classic soil profiles as illustrated earlier have not developed across much of the central spine of the island.

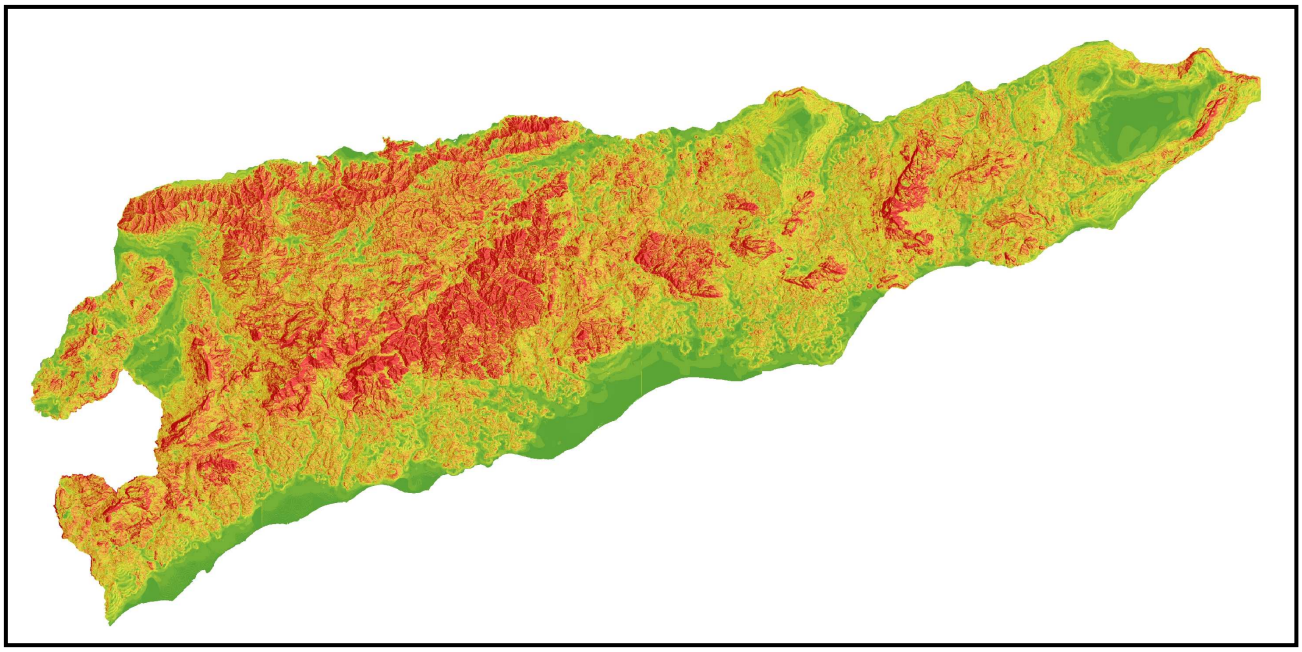
In detail the original Portuguese soil maps display the immense variation in soils across even small areas as the topography can quickly change from river valley to steep slopes to elongate and flat mountain ridges, all of which will display different soil developments.

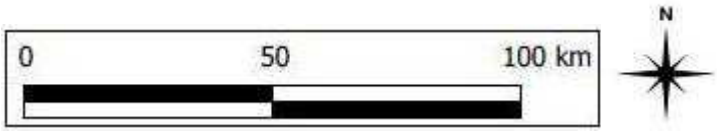
Extensive steep slopes and high rainfall lead directly to extensive soil creep and downhill slumping and soil erosion which in severe cases often gives rise to major landslips which are also abetted by the highly sheared and therefore weak nature of the bedrock.

On and across steep slopes soil profiles are chaotic and rock strewn without obvious profile development as in the soil section below, above Aria Branca in Dili. In reality, such soils are better called 'Regolith', defined in the 'Dictionary of Geological Terms' as:

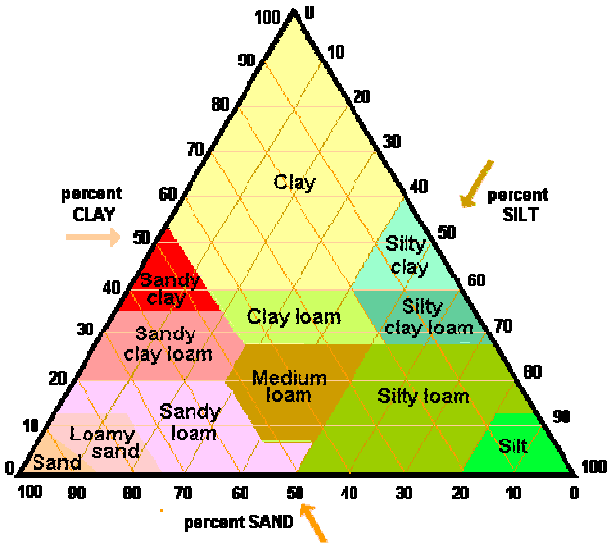
'The layer or mantle of loose, incoherent rock material, of whatever origin, that nearly everywhere forms the surface of the land and rests on the hard or 'bed' rocks. It comprises rock waste of all sorts, volcanic ash, glacial drift, alluvium, windblown deposits, vegetal accumulations and soils.'

A useful tool in defining the extent of such 'Regolith' soils would be the digital study of slopes, landform and topography across Timor-Leste. Slope maps and digital topographic images (as below) should be of high priority in helping to define the areas displaying the best soil types for agricultural development.





The Portuguese soil maps are a good starting point for further study. Soil definitions using the USDA taxonomy are highly academic and probably not suited to the realities of soil study in rural Timor-Leste. Original Portuguese soil descriptions are excellent and could be used as a basis to develop local soil classification which could be based on the relative proportions of silt, sand and clay as displayed in the classic soil Textural Triangle:



It would seem sensible to move forward from the current desk study to build such a simplified soil classification with reference to local soils and conditions and soil fertility across the country.

Certainly it is recommended to further define 'type' soil sections for each soil Sub Order in each district and to dig and record such 'type' sections as 'anchor' points to future study of soils in Timor-Leste.

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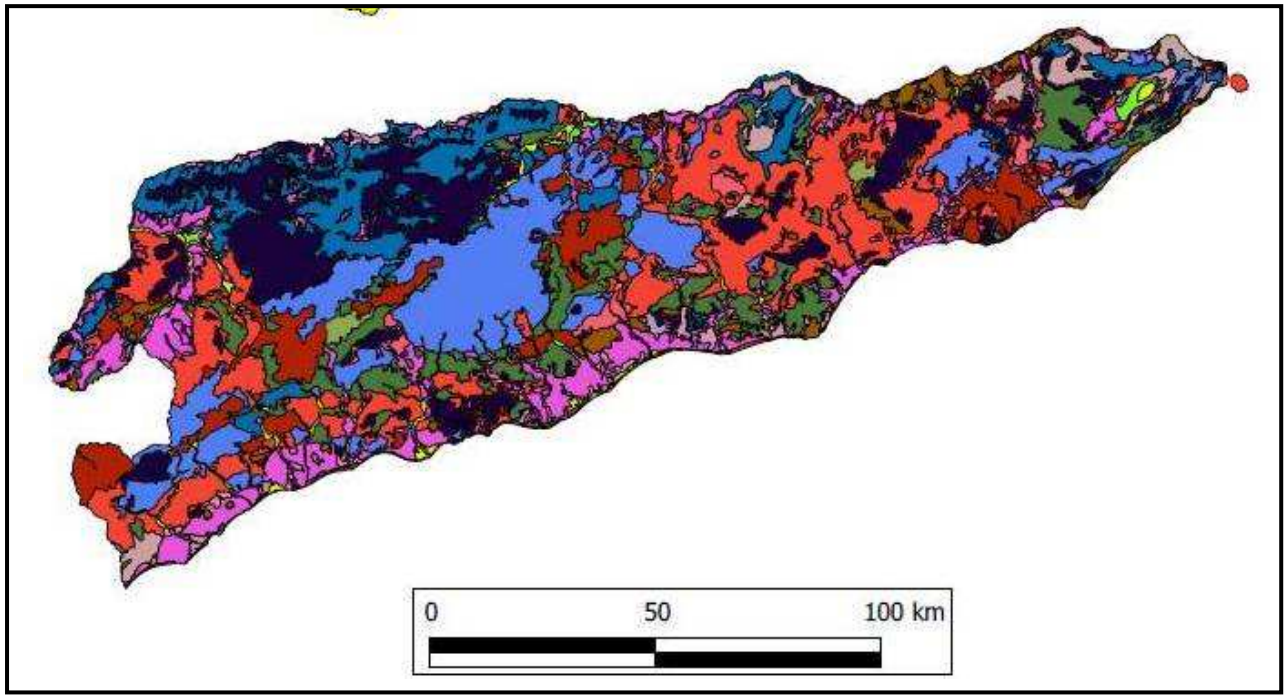
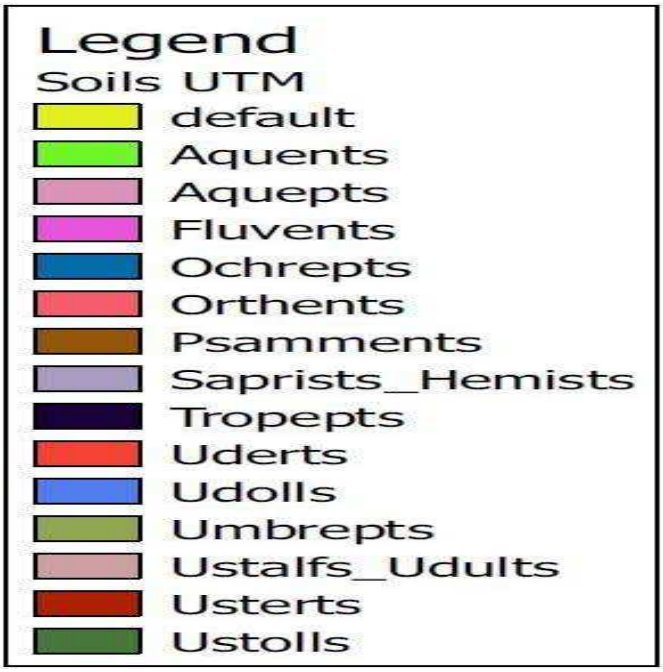
United States Department of Agriculture (USDA). Soil Taxonomy webpage:

http://soils.usda.gov/technical/classification/taxonomy/

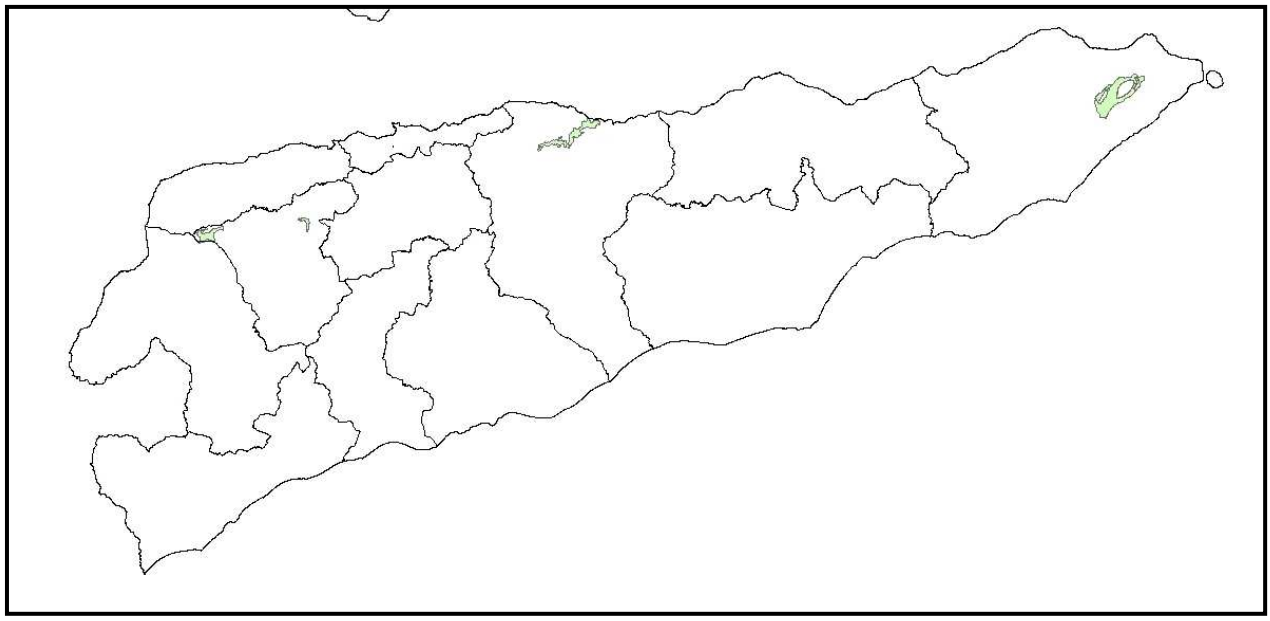
Appendix-1: Soil Maps and Soil Classification, Timor-Leste

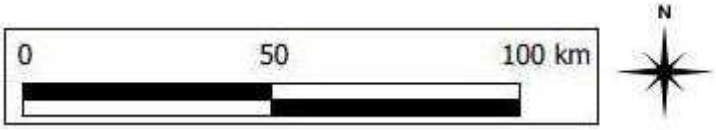
Timor-Leste soils – Sub Orders

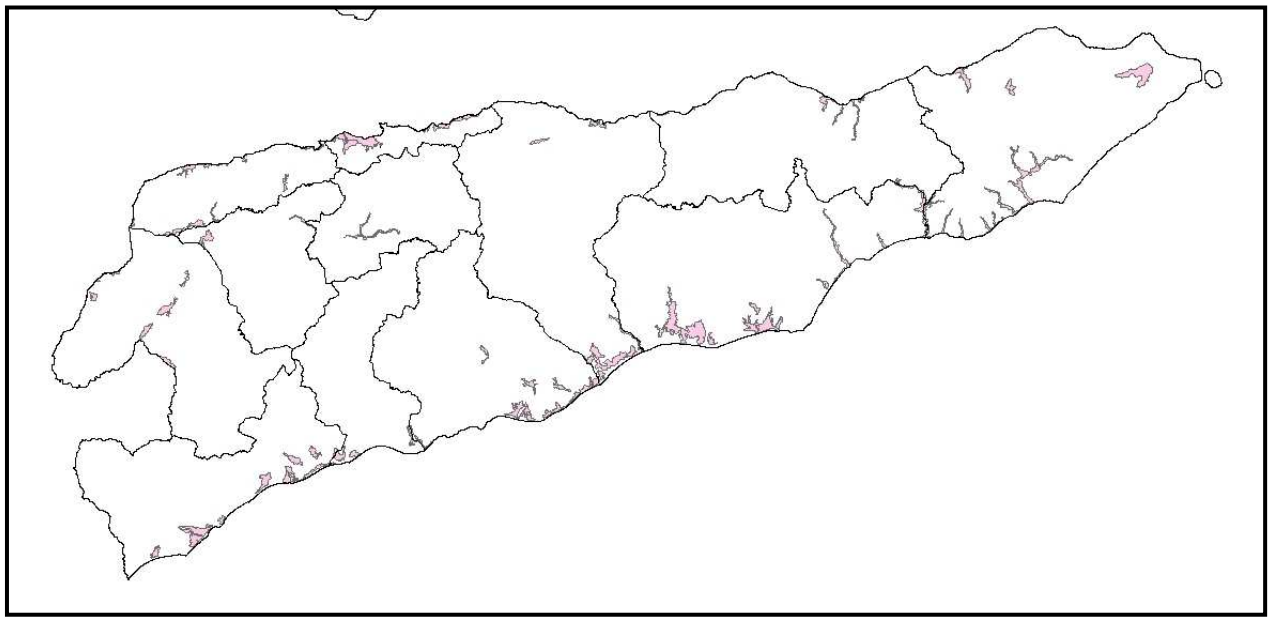




Aquents

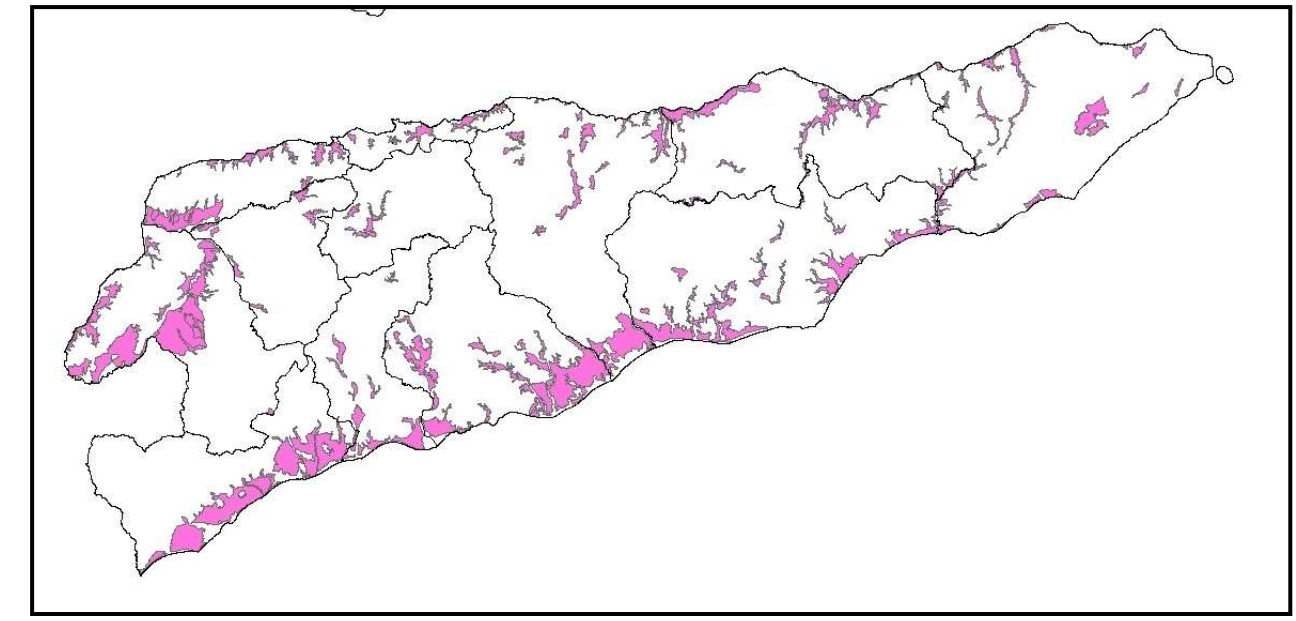


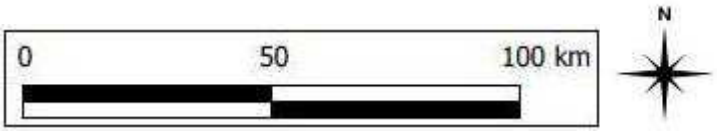


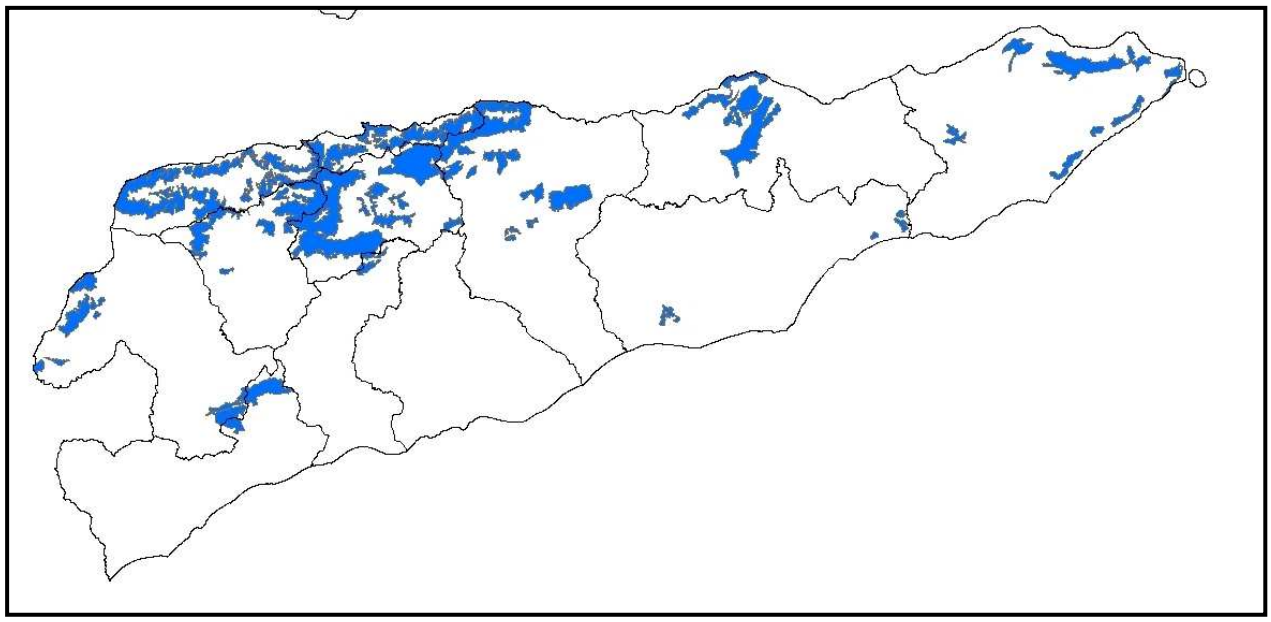


Aquepts

Fluvents

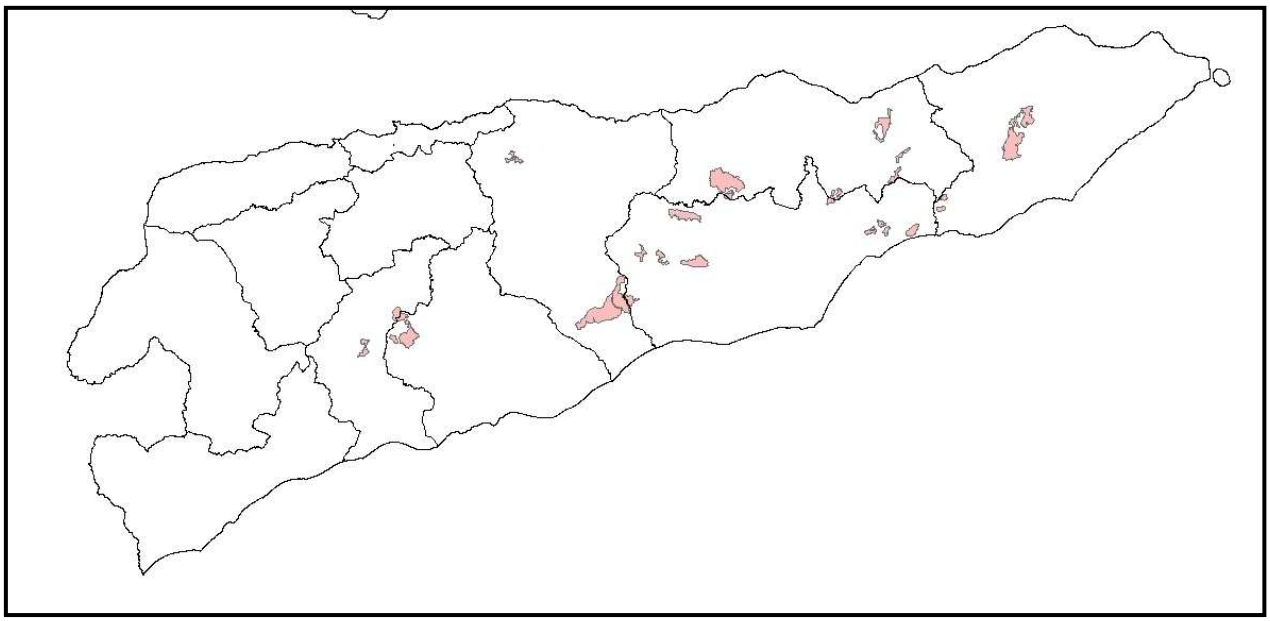


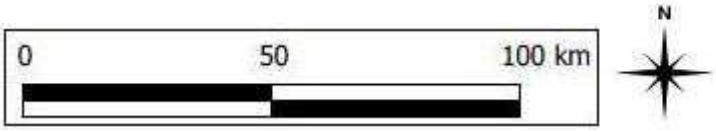


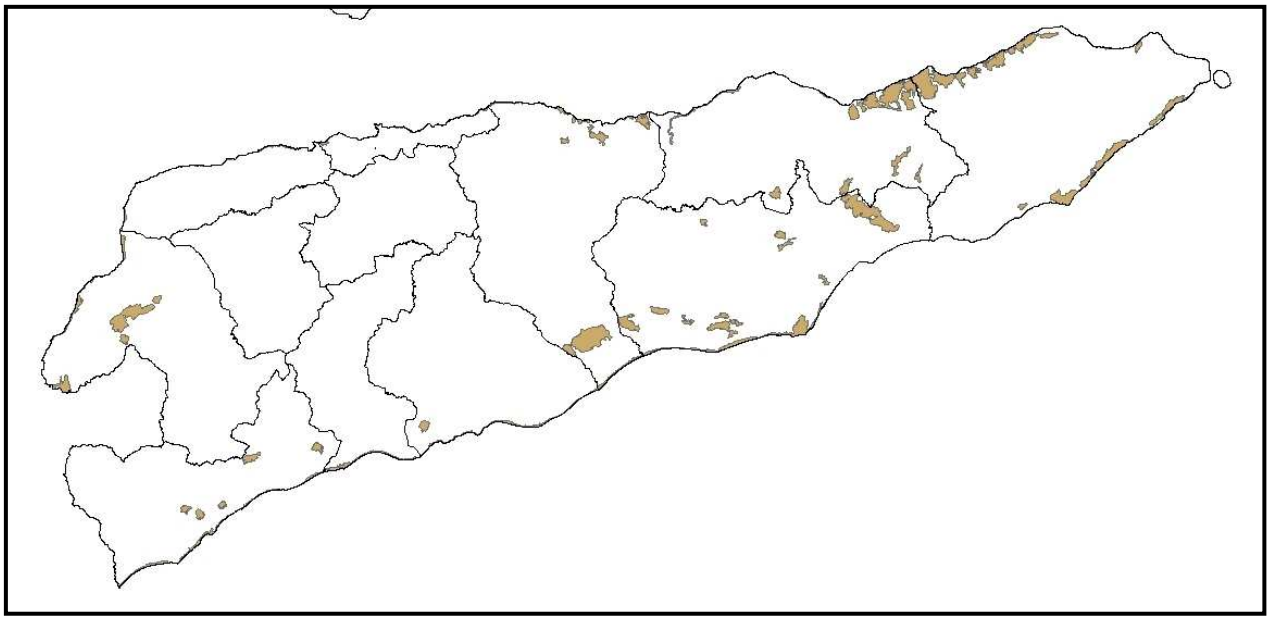


Ochrepts

Orthents

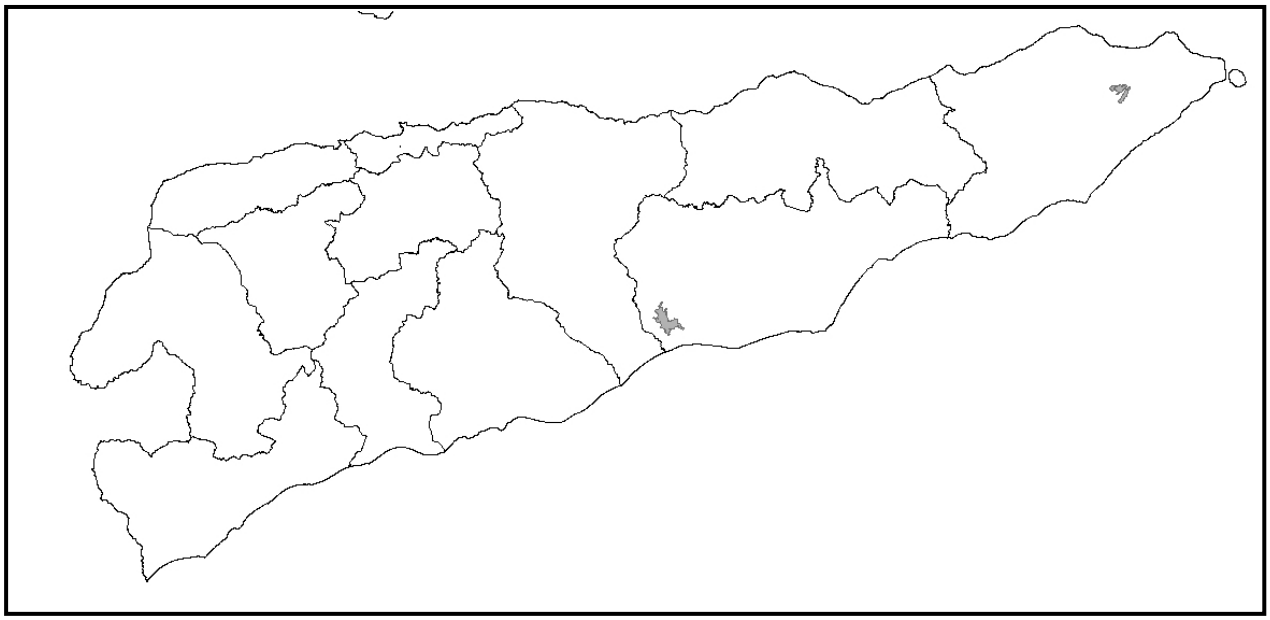


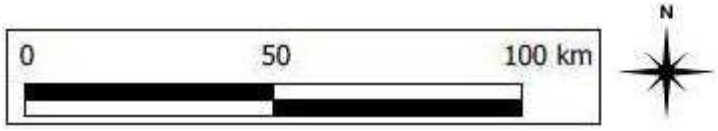


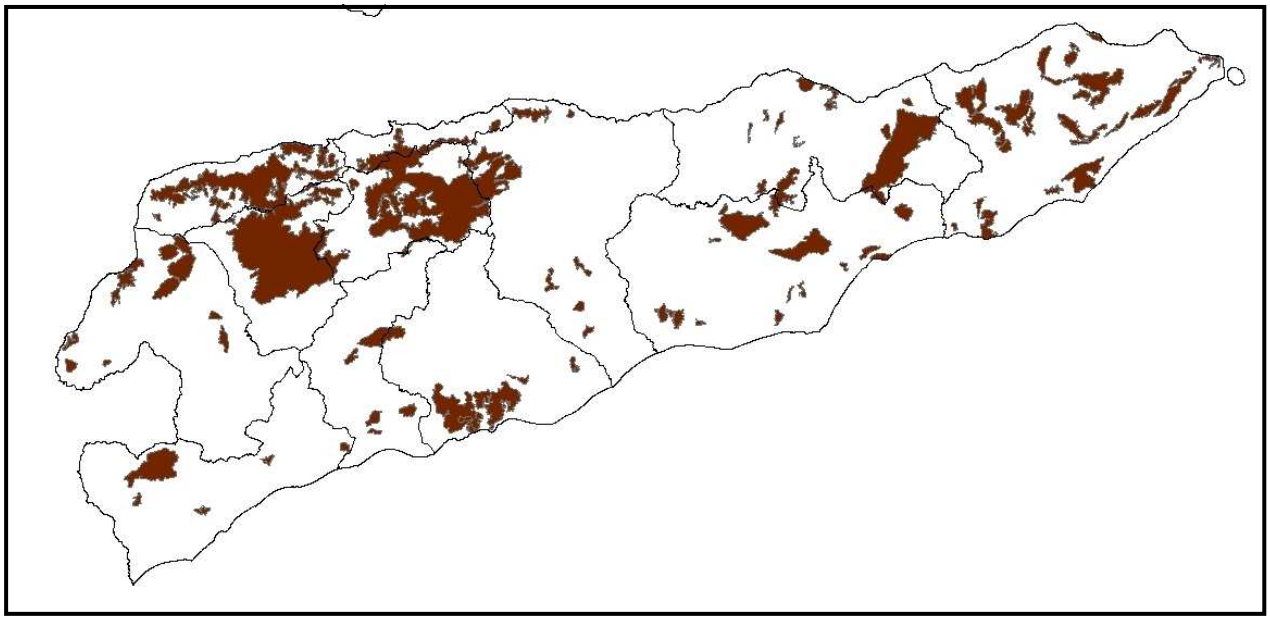


Psamments

Saprists-Hemists

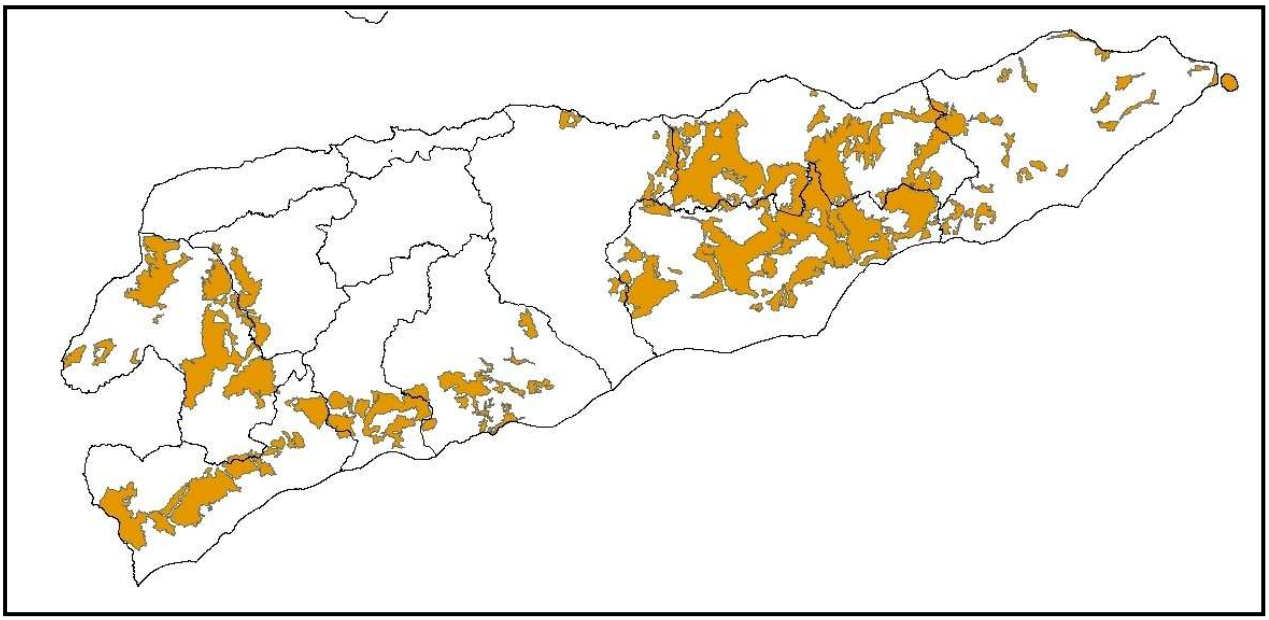


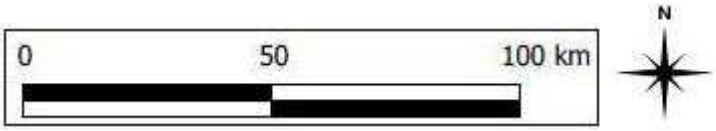


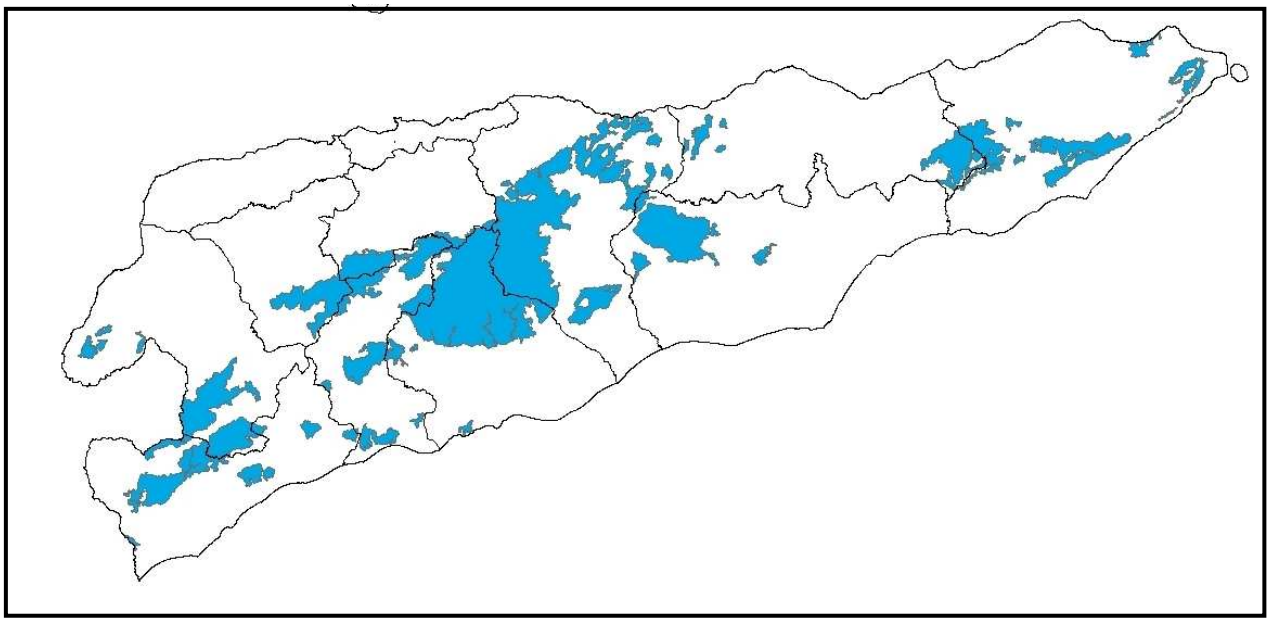


Tropepts

Uderts

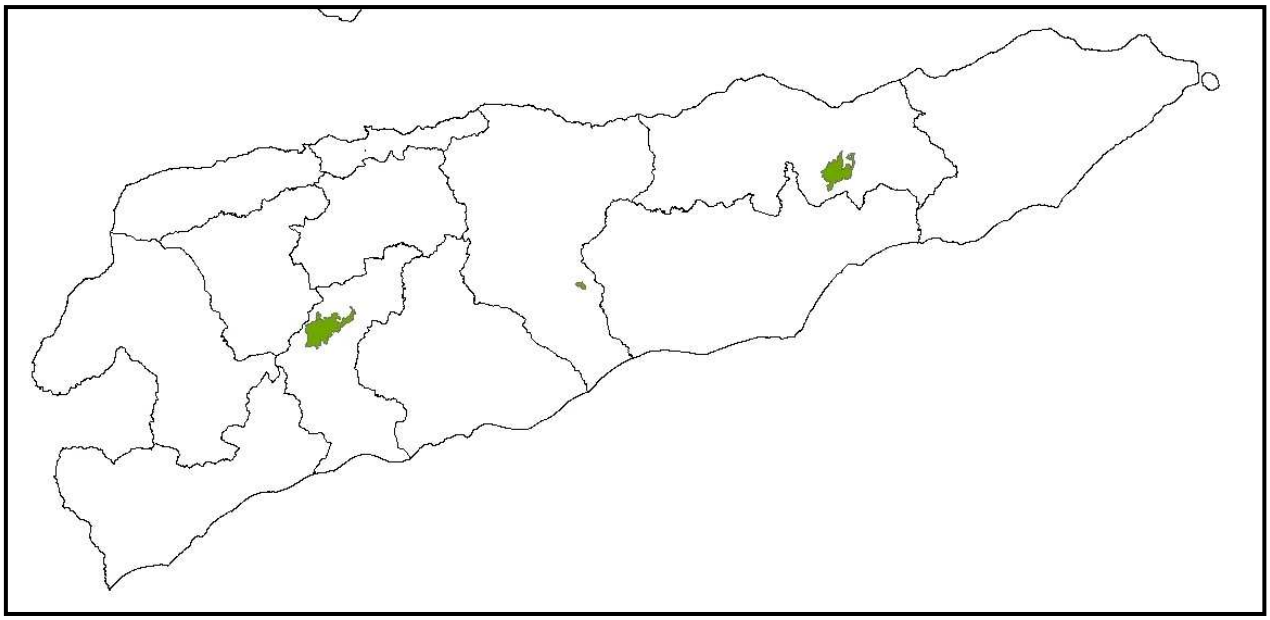


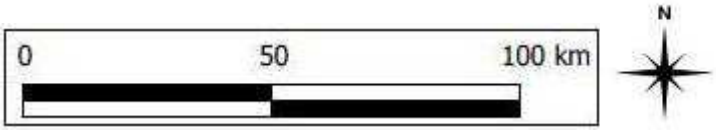


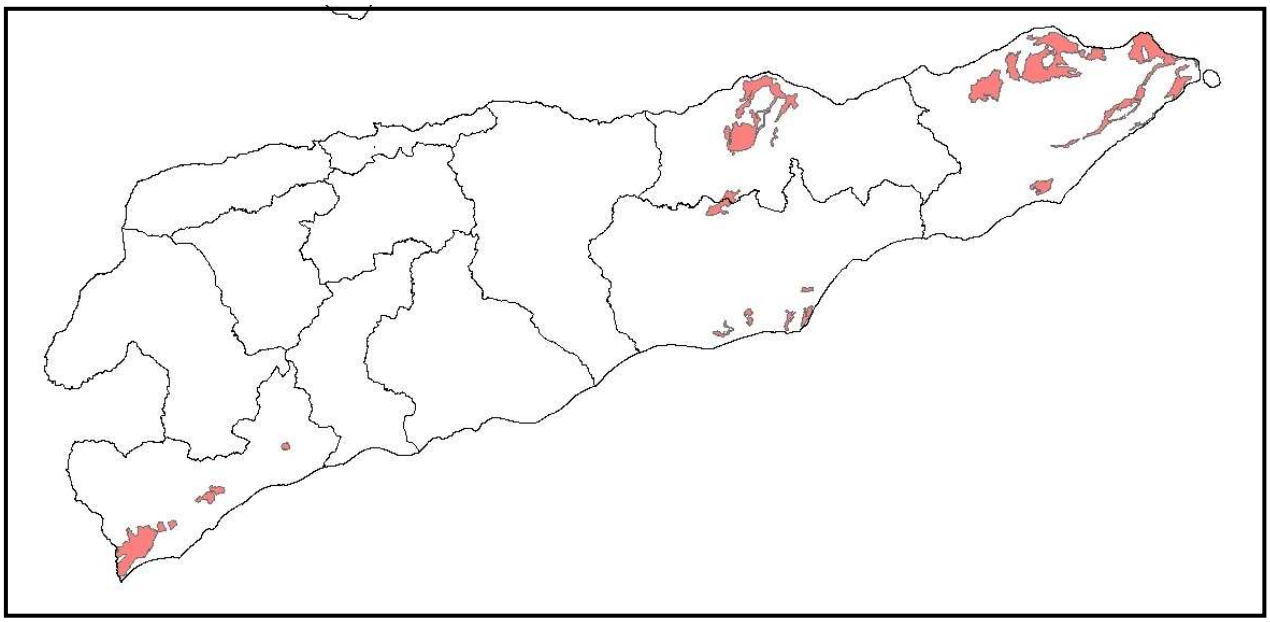


Udolls

Umbrepts

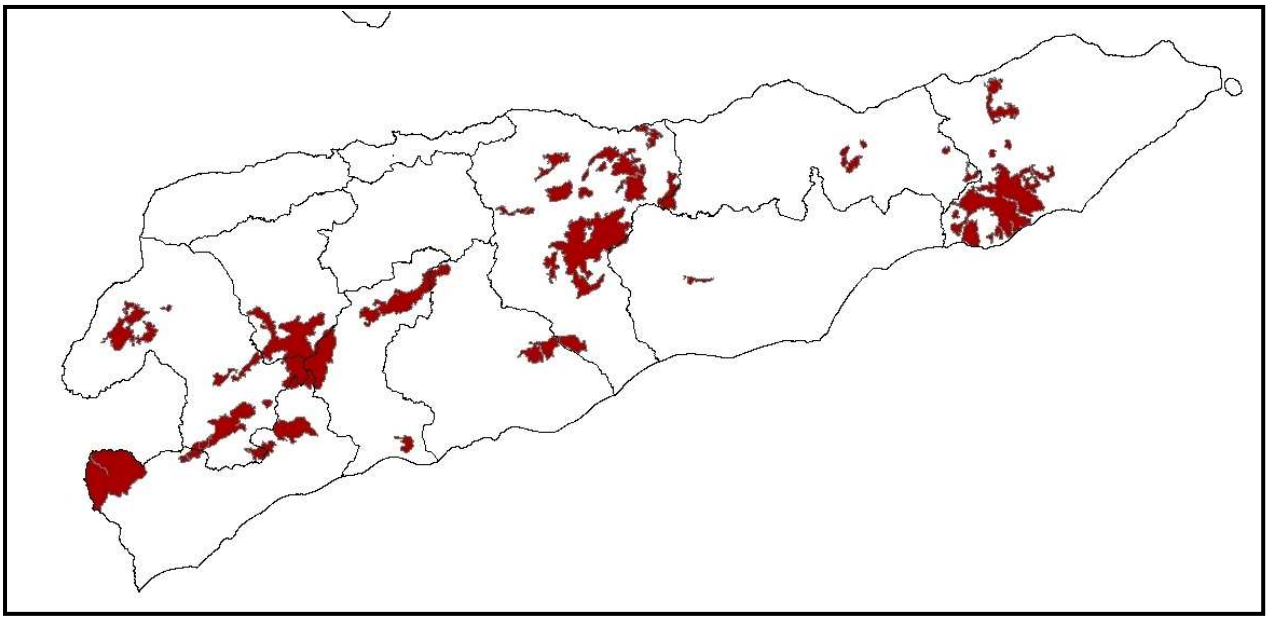


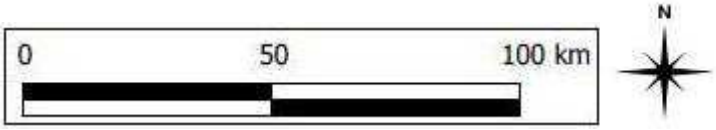


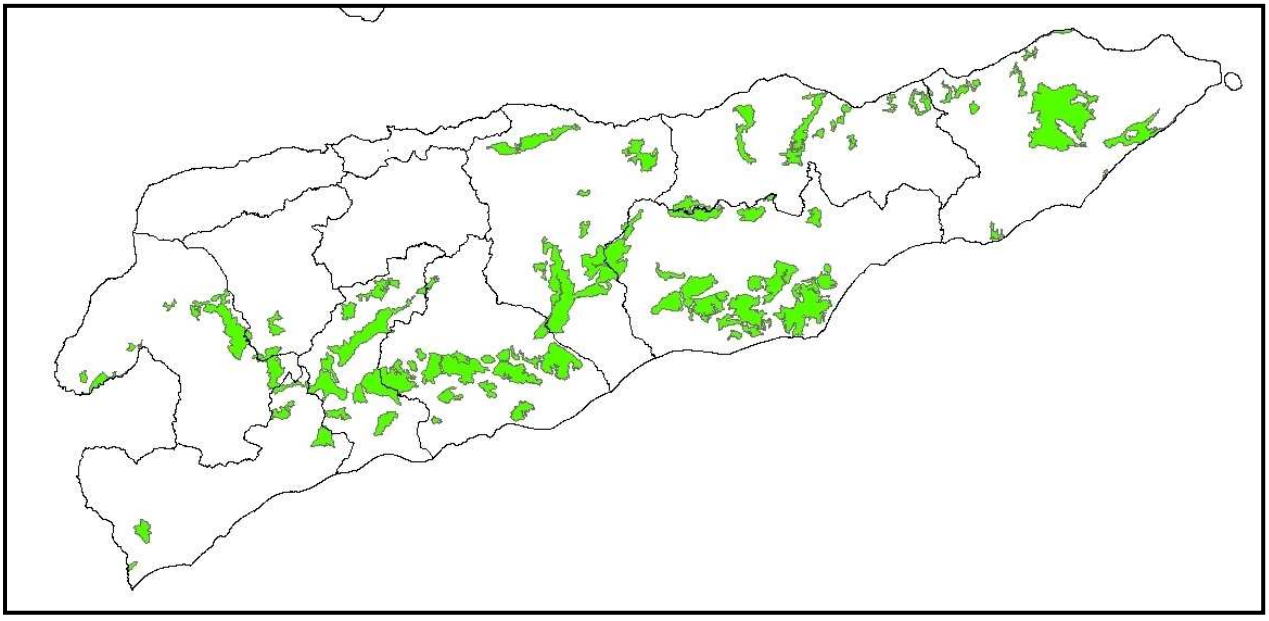


Ustalfs-Udults

Usterts







Ustolls

Appendix – 1 Soil Orders and Sub-Orders in Timor-Leste

USDA ORDER	USDA SUB-ORDER	USDA Sub-Order description	Portuguese Soil Survey example soil description	Portuguese Soil Survey soil Codes* cross reference
ALFISOLS An order of soils with gray to brown surface horizons, a medium-to-high base supply, and horizons of clay accumulation.	Ustalfs	**Ustalfs** - subhumid climate; **ustic*** moisture regime, an order of soils with gray to brown surface horizons, a medium-to-high base supply, and horizons of clay accumulation.	Brown sometimes red soil, of variable thickness with concretions. (VRd)	VRd
ULTISOLS Commonly known as red clay soils.	Udults	**Udults** – Ultisols of humid climates	Brown or red soil of variable depth, slender, and sometimes with stony concretions. (VRdp)	VRdp
VERTISOLS Soils in which there is a high content of expansive clay, montmorillonite, that forms deep cracks in drier seasons or years. Alternate shrinking and swelling causes *self-mulching*, where the soil material consistently mixes itself, causing vertisols to have an extremely deep A horizon and no B horizon.	Usterts Uderts	**Usterts** – have faint horizons and are dry for an appreciable period or more than one period of the year, and have cracks that are open for at least 90 cumulative days per year, tropical and monsoonal climates. **Uderts** - They have cracks that are open less than 90 cumulative days per year and less than 60 consecutive days during the summer.	Brown calcareous soils derived from Triasic limestones and shales. (PCX). Soils brownish with high carbonate content. ABC profile type. Generally covered by large and small limestone fragments, bare rock showing up in places. Grayish calcareous soils (from the clay complex) (CN). Marked heterogeneity associated to the nature of the parent material. Dark brown, reddish brown or grayish; clay; subangular and angular blocky structure. Variable carbonate content along the profile.	PCX, PCXp, PCXd, PCXdp CN, CNp, CNd, CNdp

USDA ORDER	USDA SUB-ORDER	USDA Sub-Order description	Portuguese Soil Survey example soil description	Portuguese Soil Survey soil Codes* cross reference
MOLLISOLS Mollisols have deep, high organic matter, nutrient-enriched surface soil (A horizon), typically between 60–80 cm in depth, resulting from the long-term addition of organic materials derived from plant roots, and the typically have a soft, granular, soil structure.	Udolls	**Udolls** - humid climate; **udic*** moisture regime found in humid, temperate, and warm regions where maximum rainfall comes during growing season; has thick, very dark A horizons, brown B horizons, and paler C horizons.	(No description currently available)	(Not recognized)
	Ustolls	**Ustolls** - subhumid climate; **ustic** moisture regime and in a mesic or warmer temperature regime; may have a calcic, petrocalcic, or gypsic horizon.	Gray calcareous soils derived from pseudo-oolitic limestones. (CZ) Whitish gray, thin with high carbonate content. On areas of excessive relief with marked slopes where erosion has been severe. Easily distinguished from other soil groupings due to their whitish colour and small thickness. Darker and thicker on more level ground. AC or A (B) C type profile	CMC, CMCp, CMCd, CMCdp, PA, CZ, CZd, Czdp, CR, CRd, CEU, CEUd, CEUp, CEUdp, CLO, CLOp, CLOd, CLOdp, PXG, PXGp, PXGd, PXGd.

USDA ORDER	USDA SUB-ORDER	USDA Sub-Order description	Portuguese Soil Survey example soil description	Portuguese Soil Survey soil Codes* cross reference
INCEPTISOLS Soils that form quickly through alteration of parent material. They have no accumulation of clays, Iron, Aluminum or organic matter. They have a dominant ochreous a cambic, brown earth, subsurface horizon.	Umbrepts	**Umbrepts** - acid, freely drained, organic-matter-rich Inceptisols, displays a dark A horizon more than 25 cm. thick, brown B horizons, and slightly paler C horizons; soil is strongly acid, and clay minerals are crystalline.	Soil texture medium brown, thin and stony. (CDdp)	CDdp, CPdp.
	Aquepts	**Aquepts** - Inceptisols with a water table at or near the surface for much of the year.	Soil texture medium to heavy, yellowish to grey, deep and moderately stained. (AS)	AS.
	Ochrepts	**Ochrepts** - characterised by a warm soil temperature regime and an *ustic* soil moisture regime, lacking clay, sesquioxides, or humus and characerised by an upper surface with too little organic matter and light colour.	Red calcareous soils from pinkish limestone associated with igneous rocks. (VCe). Reddish brown clay, blocky structure. Often found alternating with soils derived from igneous rocks and shales. Profile of the ABR type	VX, VXp, VXd, VXdp, VCe, AR.
	Tropepts	**Tropepts** - characterized by moderately dark A horizons with modest additions of organic matter, B horizons with brown or reddish colors, and slightly pale C horizons; restricted to tropical regions with moderate or high rainfall.	Brown calcareous soils from limestone. (PF). Little developed, variable carbonate content along the profile. Grayish brown clay, when shallow containing a great deal of limestone fragments lying at the surface. Profile of the AC type, sometimes ABC type.	PF, PFp, PFd, PFdp, CFD, CFDp, CFDdp, PCC, PCCp, PCCd, PCCdp, VR, Vrp.

USDA ORDER	USDA SUB-ORDER	USDA Sub-Order description	Portuguese Soil Survey example soil description	Portuguese Soil Survey soil Codes* cross reference
ENTISOLS Soils that do not show any profile development other than an A horizon. An Entisol has no diagnostic horizons, and most are basically unaltered from their parent material, which can be unconsolidated sediment or rock.	Aquents	**Aquents** - permanently or usually wet soils formed on river banks, tidal mudflats etc. General wetness limits development, bluish gray or greenish gray in colour.	Limestone soil of heavy texture, yellow, gray or green, hydromorfic, very deep and rocky. (BCphpe).	BCph, BCphpe, G.
	Fluvents	**Fluvents** - alluvial soils where development is prevented by repeated deposition of sediment in periodic floods. Found in valleys and deltas of rivers, especially those with high sediment load, displays no identifiable horizons.	Heavy textured non-calcareous modern alluvial soils (Ap). Incipient soil from stratified alluvium deposits, often receiving sedimentary additions. Deep water table subject to fluctuations. Flooding is common. Dark clay.	AL, Alp, Am, Amp, AP, APh, APd, A3, Acl, Alep, Ame, Ape, Apeh, A2, A1, Ate, Atd, Atdp, Ath, Atl, Atm, Atp, AT, Atec, Atde, Atdpe, Atle, Atpe, BC!, BC2, BClp, BCm, BCp, BClc, BClpc, BCme, BCpe.
	Orthents	**Orthents** - shallow or "skeletal soils". Found on recent erosional surfaces or very old landforms, completely devoid of weatherable minerals, well drained and of medium or fine texture, usually shallow to bedrock and lacking evidence of horizonation which occur mostly on steep slope	Brown soils from non-calcareous materials (PE). Brownish loam or clay loam; abundant coarse material (gravel and coarse sand). Shallw soils occupying very slopey areas.	PE, PEd, PEdp.
	Psamments	**Psamments** - Entisols that are sandy in all layers where development is precluded by the impossibility of weathering the sand, characterized by a texture of loamy fine sand or coarser sand, and by a coarse ragment content of less than 35%.	Calcareous psammitic regosoils (RC). Incipient soils derived from unconsolidated materials. Generally rather deep. Made up of more or less coarse sandy debris. Sandy; high carbonate content, found along the coast. (A) C type profile	R, RC, CE, CEp, CEd, CEdp, CQ.

USDA ORDER	USDA SUB-ORDER	USDA Sub-Order description	Portuguese Soil Survey example soil description	Portuguese Soil Survey soil Codes* cross reference
HISTOSOLS An order of wet soils consisting mostly of organic matter, popularly called peats and mucks.	Saprists	**Saprists** - histosols that are primarily made up of highly decomposed organic materials, often called muck, residues in which plant structures have been largely obliterated by decay; saturated with water most of the time.	Organic soil, black, deep and variable (TNH)	TNH
	Hemists	**Hemists** - histosols that are primarily made up of moderately decomposed organic materials, saturated with water most of the time.	Organic soil, black and thin. (TNHd)	TNHd

Notes:

*** Soil Codes:** Upper case letters define the Portuguese 'Soil Associations' approximately equivalent to USDA soil 'Orders'. Lower case letters define descriptive comments, eg. e = 'Thick', h = 'Thin', p = 'Stony', d = 'Drained'.

***Ustic moisture regime :** The ustic (L. *ustus*, burnt; implying dryness) moisture regime is intermediate between the aridic regime and the udic regime. Its concept is one of moisture that is limited but is present at a time when conditions are suitable for plant growth. The concept of the ustic moisture regime is not applied to soils that have permafrost or a cryic soil temperature regime (defined below). If the mean annual soil temperature is 22° C or higher or if the mean summer and winter soil temperatures differ by less than 6° C at a depth of 50 cm below the soil surface, the soil moisture control section in areas of the ustic moisture regime is dry in some or all parts for 90 or more cumulative days in normal years. It is moist, however, in some part either for more than 180 cumulative days per year or for 90 or more consecutive days.

If the mean annual soil temperature is lower than 22° C and if the mean summer and winter soil temperatures differ by 6° C or more at a depth of 50 cm from the soil surface, the soil moisture control section in areas of the ustic moisture regime is dry in some or all parts for 90 or more cumulative days in normal years, but it is not dry in all parts for more than half of the cumulative days when the soil temperature at a depth of 50 cm is higher than 5° C. If in normal years the moisture control section is moist in all parts for 45 or more consecutive days in the 4 months following the winter solstice, the moisture control section is dry in all parts for less than 45 consecutive days in the 4 months following the summer solstice.

In tropical and subtropical regions that have a monsoon climate with either one or two dry seasons, summer and winter seasons have little meaning. In those regions the moisture regime is ustic if there is at least one rainy season of 3 months or more. In temperate regions of subhumid or semiarid climates, the rainy seasons are usually spring and summer or spring and fall, but never winter. Native plants are mostly annuals or plants that have a dormant period while the soil is dry.

***Udic moisture regime :** The udic (L. *udus*, humid) moisture regime is one in which the soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years. If the mean annual soil temperature is lower than 22° C and if the mean winter and mean summer soil temperatures at a depth of 50 cm from the soil surface differ by 6° C or more, the soil moisture control section, in normal years, is dry in all parts for less than 45 consecutive days in the 4 months following the summer solstice. In addition, the udic moisture regime requires, except for short periods, a three-phase system, solid-liquid-gas, in part or all of the soil moisture control section when the soil temperature is above 5° C.

The udic moisture regime is common to the soils of humid climates that have well distributed rainfall; have enough rain in summer so that the amount of stored moisture plus rainfall is approximately equal to, or exceeds, the amount of evapotranspiration; or have adequate winter rains to recharge the soils and cool, foggy summers, as in coastal areas. Water moves downward through the soils at some time in normal years.

In climates where precipitation exceeds evapotranspiration in all months of normal years, the moisture tension rarely reaches 100 kPa in the soil moisture control section, although there are occasional brief periods when some stored moisture is used. The water moves through the soil in all months when it is not frozen. Such an extremely wet moisture regime is called perudic (L. *per*, throughout in time, and L. *udus*, humid). In the names of most taxa, the formative element "ud" is used to indicate either a udic or a perudic regime; the formative element "per" is used in selected taxa.