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RESEARCH ARTICLE

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Preliminary checklist of the naturalised and pest plants of Timor-Leste

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Key words

flora
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weeds

Abstract Timor-Leste is one of the world's newest nations, but the island of Timor has a long history of human habitation and land use which has played a significant role in shaping the current vegetation and flora. Movement of people, plants and materials has seen the introduction of hundreds of plants to Timor from foreign lands, many of which have established naturalised populations, with some exerting detrimental impacts on Timorese agriculture, the environment and livelihoods. Plant health surveys conducted by Timorese and Australian biosecurity agencies have enabled compilation of an inventory of more than 500 naturalised and pest plant species based largely on recent field collections (now lodged in herbaria) supplemented by observational and literature records. The composition of the naturalised flora in terms of plant family and life form is described and the origin status of introduced plant species is referenced and summarised by continental region and likely mode of introduction.

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INTRODUCTION

The Democratic Republic of Timor-Leste, established in 2002, is one of the world's newest nations. By contrast, the island of Timor has one of the oldest known histories of human habitation in Southeast Asia, dating back some 11 000 to 44 000 years ago (Glover 1971, O'Connor et al. 2002, Oliveira 2008, Hawkins et al. 2017). Timor, one of the Lesser Sunda Islands, is situated amongst the outer Banda Arc in the eastern Indonesian archipelago. Timor arose from the ocean after the margin of the Australian continental plate subducted below the Eurasian plate about four million years ago (Monk et al. 1997, Blewett et al. 2012). Geologically, the land is relatively recent comprising mainly marine sediments such as limestone and lesser areas of metamorphics, e.g., shale. Soils are predominantly derived from uplifted coral terraces and are generally shallow, alkaline and susceptible to erosion.

The island features significant mountain ranges, plateaux and extensive hill country and lies between 7 and 10 degrees south of the equator in the monsoonal tropical zone characterised by a pronounced extended dry season.

Biogeographically Timor is part of Wallacea, a biologically rich region transitional between the contrasting Indo-Malayan and Australasian biogeographic realms (Wallace 1869, Van Welzen et al. 2005, Trainor et al. 2007, Andersen et al. 2013). Timor sits some 860 km east of Wallace's line and 450 km from north-western Australia and supports a flora derived in part from that of both the Sunda and Sahul shelves.

Forest and woodland are the predominant original vegetation throughout much of Timor. Tall evergreen forests grow in areas of high rainfall while semi-deciduous and tropical monsoon forests occur where the climate is drier and conditions are more seasonal. Montane forest is found above 1 000 m (sometimes considerably lower), where it occurs in mosaics with near-treeless areas characterised by grass/heath vegetation. Limited littoral forest, strand and dunal vegetation are present in coastal environs, and woodlands or savannas are most extensive along the north coast from sea level to moderate elevations. These include savanna woodlands with an open canopy dominated by *Eucalyptus alba* Reinw. ex Blume (*Myrtaceae*), palms (*Borassus flabellifer* L. or *Corypha utan* Lam.) or acacia (*Vachellia leucophloia* (Roxb.) Maslin, Seigler & Ebinger). Open forest dominated by *Eucalyptus urophylla* S.T.Blake (*Myrtaceae*) is found at higher altitude. Discussion of the native vegetation of Timor can be found in Van Steenis (1979) and Monk et al. (1997); with Metzner (1977) giving an account of the vegetation of the Baucau-Viqueque district and Cowie (2006) describing that of far eastern Timor-Leste.

The vegetation of Timor-Leste has been substantially modified by human activities, particularly those associated with agriculture and livestock raising. Timorese subsistence was traditionally based on hunting and gathering with farmers collecting wild foods and medicines in conjunction with cultivation of ancient crops such as sorghum, Job's tears, millet, mung bean, rice and cucurbits (Piggin 2003, Oliveira 2008). Following the 17th century introduction of maize from America, Timorese agriculture moved to a swidden (shifting) system based on slash-and-burn cultivation of forest edges (Fox 1977, Metzner 1977, Shepherd & Palmer 2015). Present day cropping is based on swidden cultivation of maize, cassava, mung bean and pumpkin with some peanuts, rice, sweet potatoes and other vegetables, and irrigated rice in flat lands (Fox 2003, Piggins 2003). Animal husbandry, which is relatively recent in Timor, greatly expanded last century to become the major source of cash for villagers (Djogo 1994, Da Cruz 2002) and increased stock numbers are placing pressure on fallow lands.

Much of the natural forest has been denuded by decades of slash-and-burn agriculture (Glover 1971, McWilliam 2001, Oliveira 2008, Shepherd & Palmer 2015) resulting in an increase in the area of grasslands and unproductive degraded lands (Djogo 1994). Depending on how forest is defined, Timor-Leste has lost between 50–70 % of its original forest cover with only 6 %

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of the remaining cover believed to be primary forest (Grantham et al. 2011). Most of the remaining forest is concentrated in the steep central mountainous regions and the remote eastern districts, with intact native vegetation now mostly absent from fertile lowlands. A recurring element of the landscape is modified vegetation communities comprising a limited suite of native and introduced species including robust adaptable plants that have benefited from human disturbance activities and the impacts of livestock. Some vegetation communities, such as those on the narrow northern coastal plain, are dominated by plants that are either spiny, poisonous or otherwise unpalatable to goats and other livestock.

Amongst rural communities a rich enduring cultural knowledge of local plants and their uses persists, and some documentation of this valuable ethnobiology exists (see Cinatti 1954, Collins et al. 2006, McWilliam 2006, Cunningham et al. 2011, 2015, Erskine et al. 2016).

Weeds

There are numerous and varied definitions for weeds. In general, weeds are regarded as exotic or alien plants that can cause economic loss, ecological damage or create health problems for humans or animals. Most simply, weeds are plants that are undesirable where they are growing. In this paper, weeds are considered to be introduced plant species that are now naturalised, that is, they reproduce and sustain populations without direct intervention by humans (Richardson et al. 2000). The term 'pest plant' as used here refers to plants (either native or naturalised) that impact detrimentally upon agricultural and gardening activities or those invasive in natural or semi-natural systems. This paper presents a preliminary list of the introduced flora of Timor-Leste with an indication of the putative origin of most species and an initial assessment of pest plant status.

METHODS

Plants included on the list (Supplementary Table) are:

- introduced species that have become naturalised, i.e., capable of maintaining self-sustaining populations without human assistance; and
- pest plants (irrespective of origin) defined as those that impact detrimentally on agriculture, livelihoods or the environment.

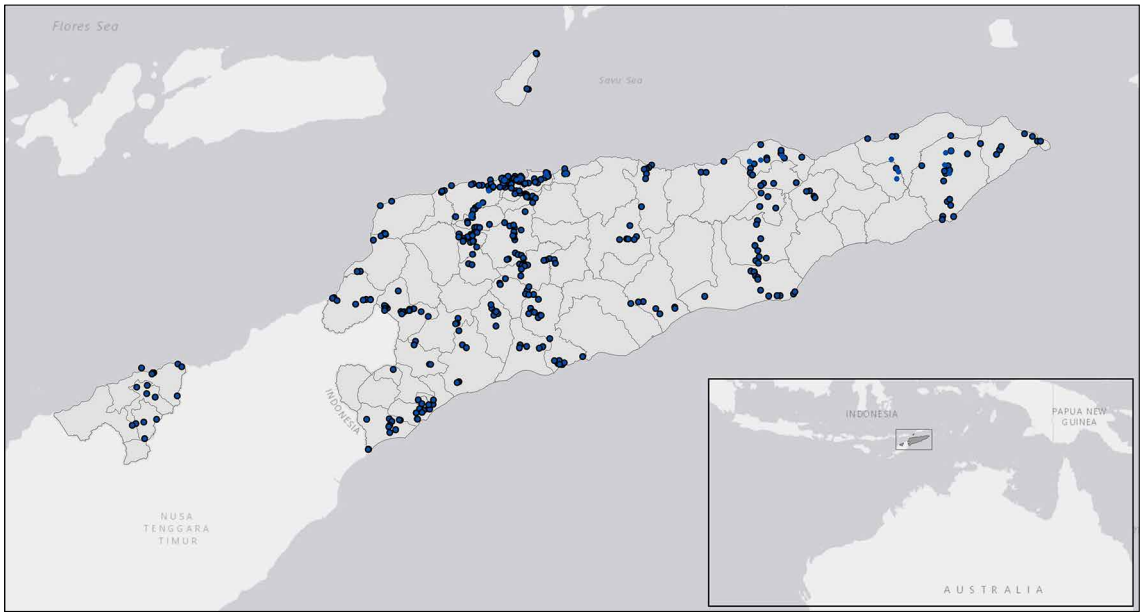
Introduced and native plants that have a history of invasion/naturalisation in other countries are included. The list does not include the many plant species introduced for food and ornamentals that have not established naturalised populations.

The list has been compiled predominantly from records of the Northern Australia Quarantine Strategy (NAQS) and International Plant Health Surveillance Program, of the Australian Government Department of Agriculture and Water Resources. Records were gathered during plant health surveys undertaken by NAQS with staff of the National Directorate of Quarantine and Biosecurity (DNQB), and Department of Plant Protection, both of the Ministry of Agriculture and Fisheries (MAF), Democratic Republic of Timor-Leste. Surveys were undertaken on an almost annual basis since 2000 and concentrated on lowland agricultural areas including commercial farming enterprises and village gardens. Plant records were also gathered from adjacent lands such as roadsides and fallow fields. Highland areas were visited less frequently. Native and remnant vegetation was not surveyed (Map 1).

Most records are supported by herbarium collections (collector number given in Supplementary Table) which are housed primarily at the Northern Territory Herbarium in Darwin, Australia (DNA) with duplicate specimens lodged in Australian National Herbarium (CANB), Canberra, Australia and with DNQB in Dili, Timor-Leste. The Australasian Virtual Herbarium was utilised to search Australian herbaria (e.g., CANB, MEL) for collections from Timor. Some species included on the list are not supported by voucher specimens but are based on survey observation only (sight records, indicated in the Supplementary Table as 'sr').

Overseas herbaria with electronic databases were also searched for specimens collected in Timor. These herbaria included the Naturalis Herbarium of the Netherlands at Leiden (L), Kew Herbarium (K) and Singapore (SING). These records have only been viewed on databases available across the internet, specimens have not been seen. Herbarium Bogoriense (BO) also holds specimens from Timor but these records are unavailable electronically as the collections are yet to be databased. Undoubtedly many BO specimens from Timor would represent duplicates of collections held at L.

Additional records have been provided by Ian Cowie (Northern Territory Herbarium) from vegetation and flora investigations of the Nino Konis Santana National Park in Lautem district and other surveys (Cowie 2006, Holtze 2017).



Map 1 Map of Timor-Leste indicating locations of NAQS-DNQB plant survey.

Taxonomy follows that of the Australian Plant Census (APC 2016) for those taxa that occur also in Australia, and The Plant List (2013) for those that do not. Some *Cyperaceae* and *Poaceae* may be under-represented due to comparative difficulties of species-level identification.

The putative origin of plants has been extracted from the literature where available but more often from desk-top internet searches, relying heavily on the following three valuable sources: The Centre for Agriculture and Bioscience International, Invasive Species Compendium (CABI 2017), Pacific Islands Ecosytems at Risk (PIER 2017) and Weeds of Australia (2016) websites. Listed countries of native occurrence have been amalgamated into broad regional categories (such as AM - Americas; AS - Asia; AF - Africa; E - Europe) to illustrate origin trends.

Naturalised plants were also categorised by the most-likely mode of introduction:

a - agricultural plants introduced as pasture species or as forage for livestock, to control soil erosion, and as a soil improvement species;
o - ornamental garden plants;
u - unintentional or contaminant of plant or other material;
f - introduced as cultivated food plant; or
m - introduced as medicinal plant.

Note that assignment of above categories is not taken from reports within Timor-Leste but simply an inferred most-likely cause of introduction based on the plant's life form and history of introduction and spread elsewhere; e.g., legumes and grasses typically for agricultural purposes; attractive flowering plants as garden ornamentals; plants with adhesive seed/fruits usually unintentional, etc. The proportion (rather than explicit number) of plants with various origin status and mode of introduction are displayed graphically in the results section to illustrate trends.

Weed species recognised as amongst the world's worst invasive species by the Invasive Species Specialist Group ISSG (Lowe et al. 2004), or amongst the world's worst weeds by Holm et al. (1977) or Australian Weeds of National Significance (WoNS) (Commonwealth of Australia 2017) are denoted in the Supplementary Table. Plants have also been assigned a relative impact grade, which is a subjective rating based on personal observation of prevalence (distribution and abundance) and/or seriousness of the pest plants, i.e., the level of impact on crops, village gardens or surrounding lands. Many species remain unrated if regarded as insignificant or those for which the author was unfamiliar. During surveys in 2017, some Timorese farmers and MAF extension officers from Aileu, Ainaro, Ermera and Manatuto districts were asked to nominate the most problematic weeds in their district. This information has been obtained for only few districts and ratings would have benefited from more local input but logistical difficulties precluded the gathering of more informed insights on impacts.

RESULTS

The list presented in the Supplementary Table documents the occurrence of 412 plant species thought to be introduced and naturalised within Timor-Leste and provides a reference to their region of origin. Additionally, about 93 native (indigenous) or presumed native species which are regarded as at least minor pest plants are included, bringing the total to more than 500 species thought to be either naturalised or pest plants in Timor-Leste at this stage.

Most are plants that were either intentionally introduced as fodder plants or garden ornamentals, or inadvertently introduced for example as contaminants of crops, cargo or produce. Some are native species that are considered minor pests usually on account of an undesirable morphological feature such as spines or prickles, e.g., *Achyranthes aspera* L. (*Amaranthaceae*), or that they compete directly in village gardens, e.g., *Imperata cylindrica* (L.) P.Beauv. (*Poaceae*), *Eclipta prostrata* (L.) L. (*Asteraceae*) and *Cyperus* L. (*Cyperaceae*) spp.

Others are native plants that have been successful colonisers and have increased (populations) under land modification, e.g., *Boerhavia diffusa* L. (*Nyctaginaceae*), *Ludwigia* L. (*Onagraceae*) spp., *Melochia corchorifolia* L. (*Malvaceae*), *Sesbania cannabina* (Retz.) Pers. (*Fabaceae*), *Xenostegia tridentata* (L.) D.F.Austin & Staples (*Convolvulaceae*). Also included are presumed native plants that have proved to be weeds elsewhere, e.g., fishbone fern *Nephrolepis cordifolia* (L.) C.Presl (*Lomariopsidaceae*), *Flemingia strobilifera* (L.) R.Br. ex W.T.Aiton (*Fabaceae*), *Eriochloa procera* (Retz.) C.E.Hubb. (*Poaceae*). Some species, e.g., *Caesalpinia decapetala* (Roth) Alston (*Fabaceae*) and *Albizia chinensis* (Osbeck) Merr. (*Fabaceae*) occur in Timor as both native populations and are also cultivated (e.g., as ornamentals) and occasionally naturalised as well.

Three hundred and sixty species (71 %) are supported by voucher specimens lodged at the Northern Territory Herbarium, Darwin, Australia (DNA), with duplicates held at the Australian National Herbarium (CANB) and in a newly established reference collection at DNQB, MAF in Comoro, Dili. Searches of other herbarium databases produced only few records of introduced species that were not already listed as NAQS collections. For example, L has 1 230 specimens from Timor-Leste (TL) of 822 taxa of which 24 are relevant records of introduced (or pest) flora that were not already vouchered at DNA. SING has 141 records from TL including 11 introduced species; and eight species have records supported by specimens at K. Additional entries on the list are based on field records by JW and Stephen McKenna or are noted in literature (see references in Supplementary Table) as occurring in Timor.

The 505 introduced and pest species are derived from a diverse array of 86 plant families. However, 71 % belong to just twelve families with *Fabaceae*, *Poaceae* and *Asteraceae* having the largest representation (Table 1; Fig. 1).

Herbaceous species were by far the most numerous life form with grasses and shrubs also well represented (Fig. 2).

Of the naturalised plant species with putative origin assigned it appears that many have originated from the New World with 39 % originally from the Americas, while 30 % originate from Asia and far fewer introductions from other regions of the world (Fig. 3).

Twenty-two percent of the naturalised flora are presumed to have been introduced for agricultural purposes such as pasture grasses and legumes for fodder, soil improvement or stabilisation. Twenty-six percent have their origin in horticulture being introduced as ornamental garden or amenity plants. Many others (23 %) are thought to have arrived accidentally or as propagule (especially seed) contaminants of plant produce, soil, equipment or other materials (Fig. 4).

High impact weeds

The species in Table 2 have been subjectively rated as high impact weeds. Most have a putative New World origin. A further 42 species are rated as moderate impact weeds and 79 as lower impact weeds (see Supplementary Table). Many other naturalised species are regarded as inconsequential in terms of impacts on Timorese agriculture, environment and livelihoods.

MAF district officers and vegetable farmers consulted for their opinions on their most problematic weeds nominated the species listed in Table 3.

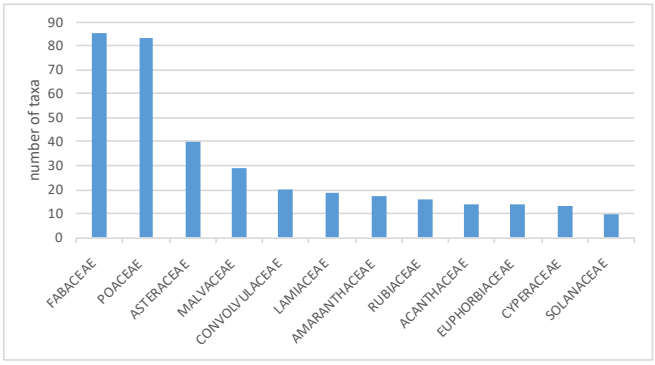


Fig. 1 Family composition of the naturalised and pest flora of Timor-Leste (only families with > 10 taxa shown).

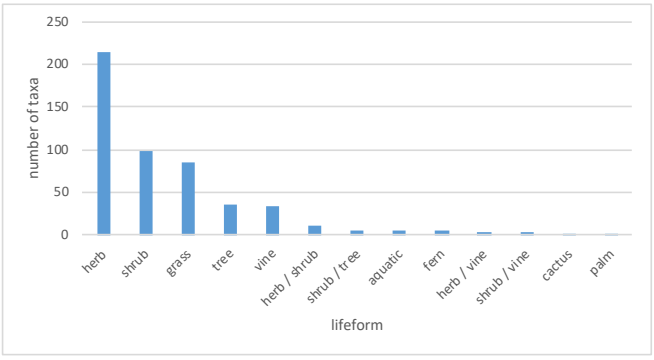


Fig. 2 Proportion of herbaceous and woody life forms amongst the naturalised flora of Timor-Leste.

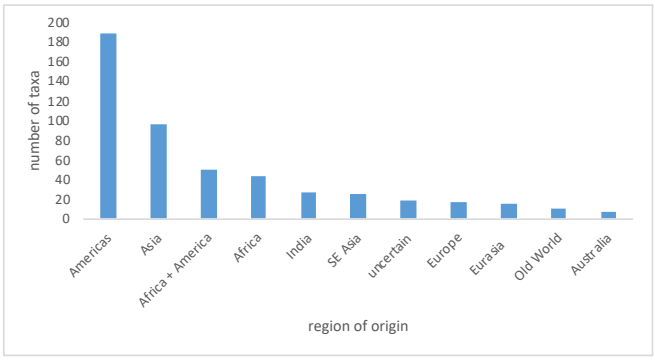


Fig. 3 Region of origin for the naturalised plants of Timor-Leste.

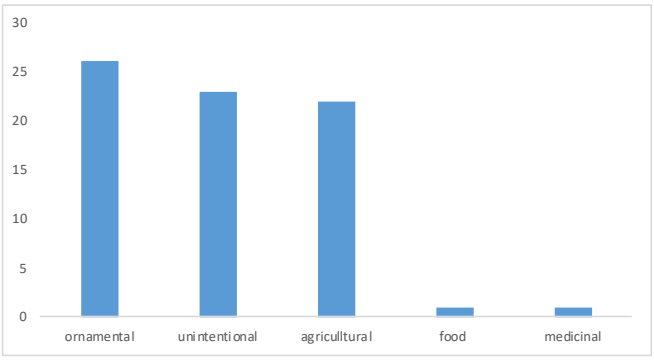


Fig. 4 Presumed mode of introduction of naturalised plants of Timor-Leste expressed as generalised percentage.

Table 1 Number of species in each of the twelve most well-represented families.

Family	taxa	Family	taxa
Fabaceae	85	*Amaranthaceae*	17
Poaceae	83	*Rubiaceae*	16
Asteraceae	40	*Acanthaceae*	14
Malvaceae	29	*Euphorbiaceae*	14
Convolvulaceae	20	*Cyperaceae*	13
Lamiaceae	19	*Solanaceae*	10

Table 2 Weed species assessed as having high impact on Timorese agriculture and environment.

Ageratina riparia (Regel) R.M.King & H.Rob.
Calotropis gigantea (L.) W.T.Aiton (*Apocynaceae*)
Chromolaena odorata (L.) R.M.King & H.Rob. (*Asteraceae*)
Jatropha gossypiifolia L. (*Euphorbiaceae*)
Lantana camara L. (*Verbenaceae*)
Leucaena leucocephala (Lam.) de Wit (*Fabaceae*)
Mesosphaerum suaveolens (L.) Poit. (*Lamiaceae*)
Mimosa diplotricha C.Wright (*Fabaceae*)
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth (*Fabaceae*)
Senna tora (L.) Roxb. (*Fabaceae*)
Sida acuta Burm.f. (*Malvaceae*)
Vachellia nilotica (L.) P.J.H.Hurter & Mabb. (*Fabaceae*)
Ziziphus mauritiana Lam. (*Rhamnaceae*)

Table 3 Plant species nominated by Aileu, Ainaro, Ermera and Manatuto district MAF officers as significant weeds.

Axonopus compressus (Sw.) P.Beauv. (*Poaceae*)
Chromolaena odorata (L.) R.M.King & H.Rob. (*Asteraceae*)
Commelina diffusa Burm.f. (*Commelinaceae*)
Cuphea carthagenensis (Jacq.) J.F.Macbr. (*Lythraceae*)
Cynodon dactylon (L.) Pers. (*Poaceae*)
Cyperus rotundus L. (*Cyperaceae*)
Dactyloctenium aegyptium (L.) Willd. (*Poaceae*)
Echinochloa colona (L.) Link (*Poaceae*)
Elephantopus mollis Kunth (*Asteraceae*)
Eleusine indica (L.) Gaertn. (*Poaceae*)
Eragrostis tenuifolia (A.Rich.) Hochst. ex Steud. (*Poaceae*)
Heliotropium indicum L. (*Boraginaceae*)
Imperata cylindrica (L.) P.Beauv. (*Poaceae*)
Lantana camara L. (*Verbenaceae*)
Leersia hexandra Sw. (*Poaceae*)
Melinis repens (Willd.) Zizka (*Poaceae*)
Mimosa diplotricha C.Wright (*Fabaceae*)
Paspalum conjugatum P.J.Bergius (*Poaceae*)
Pouzolzia hirta (Blume) Hassk. (*Urticaceae*)
Pseudoelephantopus spicatus (Juss. ex Aubl.) C.F.Baker (*Asteraceae*)
Rottboellia cochinchinensis (*Poaceae*)
Salvia misella Kunth (*Lamiaceae*)
Sida acuta Burm.f. (*Malvaceae*)
Sida rhombifolia L. (*Malvaceae*)
Tithonia diversifolia (Hemsl.) A.Gray (*Asteraceae*)

DISCUSSION

The indigenous flora of Timor is not well documented but has been estimated to be in the order of 2 500 vascular plant species (Cowie 2006). The 414 introduced species recorded for Timor-Leste in this list are those that have naturalised and are self-sustaining. There are many more (perhaps hundreds) of additional species introduced in Timor that are cultivated for food or as ornamental garden plants (Metzner 1977, Erskine et al. 2016) that have not naturalised and would not persist without the aid of humans. Compilation of this list has also included 93 native or presumed native species that (like weeds) are successful colonisers of disturbed sites such as cultivated soils and roadsides or are in some way undesirable to landholders. For example, native wetland species will naturally colonise and in some cases dominate wet sites such as rice fields, drainage ditches, etc. Distinction between native indigenous plant species and naturalised introductions is of little relevance to Timorese farmers whose concern is naturally more about how to deal with plants causing problems.

It is not surprising that the composition of the naturalised flora of Timor-Leste is dominated by the *Poaceae* and *Fabaceae*. Both are naturally large families but more importantly, grasses and legumes are commonly introduced worldwide for agricultural purposes (Dodd et al. 2015) due to their importance as food for humans, fodder plants for stock and the extensive use of legumes for soil improvement via nitrogen fixation. *Malvaceae*, *Convolvulaceae* and *Lamiaceae* are also well-represented on this list by the many introduced ornamental plants from these families that have escaped cultivation and established naturalised populations.

The most common life form amongst the introduced flora are herbs, especially annuals. This is not surprising given that the survey focus has been on village gardens, small cropping fields and modified areas such as roadsides and unused lands, where often annual, early successional, pioneer or ruderal species proliferate in recently disturbed soils. Many herbaceous weed species (e.g., *Synedrella nodiflora* (L.) Gaertn. (*Asteraceae*), *Sida acuta*, *Euphorbia hirta* L. (*Euphorbiaceae*), *Ruellia tuberosa* L. (*Acanthaceae*), *Cyanthillium cinereum* (L.) H.Rob. (*Asteraceae*)) are widespread and often locally abundant. They can be competitive and problematic for villagers cultivating food plants at the garden scale and are typically managed by manual labour or simply neglected. There are fewer species of woody weeds (i.e., trees and shrubs) but where such plants occur in dense aggregation (e.g., *Chromolaena odorata*, *Jatropha gossypiifolia*, *Calotropis gigantea*, *Ziziphus mauritiana*) they can severely restrict access and utilisation of land resources (Grice 1998, Csurhes 1999, McWilliam 2000) and perhaps exert greater detrimental impact on the lands overall. For instance, the Global Invasive Species Database (2005) record 27 tree or shrub species for Indonesia vs 20 herbs; and of the 75 important invasive plant species listed for Indonesia by Tjitrosoedirjo et al. (2016) 40 are trees and shrubs compared to 13 herbs and 5 grasses. In a study of the alien flora of a South Africa National Park Baard & Kraaij (2014) noted that almost all the high impact weeds, i.e., transformer species (Richardson et al. 2000) were trees.

One might expect that the largest proportion of plants introduced and now naturalised in Timor may have originated from nearby countries in Asia, especially Southeast Asia. However, a higher proportion actually originated from the New World, though many of these would have arrived indirectly from other Asian countries where they were similarly introduced either intentionally or otherwise. This parallels the situation in Java where, as Van Steenis (1965) describes it, an “astoundingly large percentage of the introductions to Java are of New World origin”. Similarly, in the Tamil Nadu region of southern India, Narasimhan et al. (2010) note that the majority of lowland naturalised/invasive plants are of tropical American origin, listing 120 species, while Sundarapandian & Subashree (2017) report that 61 % of the invasive species had migrated from tropical America. These New World introductions are in part a result of the extensive maritime trading that occurred in the 15th and 16th centuries when plants and varied materials were transported across the globe during colonial expansion. Many introductions are also likely to predate the colonial period as significant travel and exchange of produce occurred much earlier with Chinese and, to a lesser extent, Arabic maritime exploration (Ptak 1987, Szczepanski 2018). Tropical America in particular has been the origin of many plant species now present in Timor (and other Old World areas). Plants were not necessarily introduced directly into Timor from the Americas but are more likely to have arrived indirectly via Java, Malaysia, or elsewhere in Southeast Asia. Some American plants have been naturalised within Asia for so long that they have become integrated into human cultural systems, for example Narasimhan et al. (2010) list 40 tropical American species that are utilised medicinally in Tamil Nadu, India.

Many other weeds of Timor-Leste predictably have an Asian origin, most commonly India or China. By contrast few weeds in Timor have a European origin, despite the colonial history, and this may be due to the regions’ disparate climates. The exception to this are the several cool temperate Eurasian annual herbs, e.g., *Briza minor* L. (*Poaceae*), *Plantago major* L. (*Plantaginaceae*), *Rumex cripus* L. (*Polygonaceae*), *Veronica persica* Poir. (*Plantaginaceae*), *Vulpia* C.C.Gmel. (*Poaceae*) spp. naturalised in the central highlands of Timor-Leste.

Plants have been deliberately dispersed around the globe for centuries, with introduction rates increasing over time. For example, in neighbouring Australia, government plant introductions to enhance agriculture last century comprised some 8 200 species, including 2 200 legumes and 2 200 grass species (Cook & Dias 2006), while the United States Office of Plant Introduction claimed to have introduced nearly 200 000 species and varieties of plants from all over the world (Bryant 2002). A proportion of these deliberate introductions naturalise, with a subset becoming weeds or even invasive species (Richardson et al. 2000, Stone et al. 2008, Reed 2014). The vast majority of the plants that have become naturalised in Timor-Leste appear to have been introduced for either ornamental or agricultural purposes or arrived unintentionally (Fig. 4). Elsewhere, deliberate introductions were found to comprise one third of the Ukraine naturalised flora (Protopopova et al. 2006), almost half of the naturalised species in a region of New Zealand (Esler & Astridge 1987), and ornamentals were found to be the primary source of invasive plants in the United States (Lehan et al. 2013). Accidental arrivals have become an increasingly important source of plant naturalisations, with contaminated seed representing the chief means of accidental introductions to the United States (Lehan et al. 2013). Although explicit data are lacking, this is likely to also be the case for Timor-Leste.

Interestingly, only few of the presumably large number of species introduced for food or medicine have developed naturalised populations. This corresponds with the situation reported in the Floras of Java (Van Steenis 1965) and Tamil Nadu (Narasimhan et al. 2010), where respectively 78 % and 79 % of the introduced plants exists only under cultivation. Some weeds and invasive plants have evolved from domesticated ancestors (Gressel 2005), though a study of crops gone wild found only relatively few examples, such as weedy rice and sorghum, where evolution from domesticates was confirmed (Ellstrand et al. 2010).

Impacts

Despite the large list of introduced plants now established in Timor-Leste, only a relatively small proportion of these exert a significant detrimental impact on agriculture, livelihoods and the environment. Most of the naturalised flora are weeds of minor or even negligible concern, such as many ruderal or adventive herbs that may colonise newly disturbed soils but are either short-lived or outcompeted by other species. The actual number of serious weeds that have persistent high impacts is relatively few, but their combined impacts are very considerable, often degrading land, rendering it useless or demanding significant labour input for weed management.

Of the weeds rated as high impact (Table 2), Siam weed *Chromolaena odorata* probably has the greatest impact on Timorese agricultural activity and livelihoods (McWilliam 2000, Da Cruz 2002, McFadyen 2003, Day et al. 2013). It covers vast areas of both lowland and plateau country often forming extensive dense shrublands (Fig. 5a) that severely hinder the cultivation of gardens and the grazing of livestock. The bitter tasting alkaloids in *Chromolaena* plants deter livestock grazing, and if ingested can impact on liver health of animals (McFadyen 2003). Some weeds, including *Chromolaena odorata*, have the additional effect of allelopathy by which leachates inhibit the growth of other flora in the immediate surrounds (Hu & Zhang 2013).

The fast-growing shrubby weed, *Lantana camara*, was introduced to Timor (with Bali cattle) in 1912 (Djogo 1994). This toxic plant rapidly spread over the island and now covers much of the grazing and cropping lands. Some weeds can also be beneficial, e.g., *Leucaena leucocephala* is highly valued for fodder and fuel wood. Dutch authorities introduced this drought resistant leguminous tree to provide a source of high quality feed for cattle (Djogo 1994). *Leucaena leucocephala* has since been widely and successfully adopted in Timor-Leste for both swidden cropping and livestock systems (Piggin 2003, Friday 2005) but when left unchecked, it has become an invasive coloniser of disturbed ground.

Calotropis gigantea is a shrub with toxic milky sap that has invaded degraded rangeland pastures, river flats and coastal habitats throughout Timor-Leste (Fig. 6) to the exclusion of more desirable plants (pers. obs. JW; Cowie 2006). Similarly, the poisonous shrub *Jatropha gossypiifolia* inhibits growth of pasture grasses and can ultimately render floodplain and other pastures (Fig. 7) totally unproductive (Csurhes 1999, Weeds of Australia 2016). *Senna tora* is a perennial leguminous shrub that has a propensity to form dense tangled stands on fallow or disused land (Fig. 5b) making future cultivation of such sites problematic. *Ageratina riparia* is a perennial daisy that dominates open areas and eroded soils of the central highlands (Fig. 5c). *Croton bonplandianus* Baill. (*Euphorbiaceae*) is a low shrub that has a capacity to colonise bare ground and form dense aggregations in low lying sub-coastal areas often on calcareous soils (pers. obs. JW). It appears to be increasing across such habitats in Timor-Leste (Fig. 5d).

Introduced and native plants that have a history of invasion/naturalisation in other countries have been included in this compilation and these may be plants for which further import

Fig. 5 a. Infestation of Siam weed *Chromolaena odorata* near Hera on the north coast, Timor-Leste; b. the leguminous shrub *Senna tora* can occupy former gardens and potential grazing areas across rural Timor-Leste; c. the perennial daisy *Ageratina riparia* is an early coloniser of bare ground in the cool mountains of central Timor-Leste; d. the low shrub *Croton bonplandianus* can dominate open sites on poor coastal soils in Timor-Leste. — Photos by J. Westaway.

should be restricted. Although Timor Leste already hosts an impressive range of transformer weeds, there are other similarly high impact weeds present in neighbouring countries that are not yet known from TL, such as *Andropogon gayanus* Kunth (*Poaceae*), *Cryptostegia grandiflora* R.Br. (*Apocynaceae*), *Mikania micrantha* Kunth (*Asteraceae*), *Mimosa pigra* L. (*Fabaceae*), *Parthenium hysterophorus* L. (*Asteraceae*) and *Piper aduncum* L. (*Piperaceae*). Strengthened biosecurity measures would assist with preventing the arrival and establishment of such species. A range of problem weeds were nominated by district MAF officers and vegetable farmers, including several introduced *Poaceae*, but also two native grasses and one native herb (Table 3). Because these farmers are cultivating the soil, woody plants have less chance of establishment but fast-growing herbaceous species repeatedly colonise between crops. By contrast, grazing and untended lands where soils are not cultivated are more likely dominated by woody weeds. Farmers surveyed supported their assertions with reasons such as the following: *Chromolaena odorata* restricts fodder growth for pastoralists, *Imperata cylindrica* is able to colonise areas rapidly, *Eragrostis tenuifolia* causes productivity loss and *Mimosa diplotricha* and *Rottboellia cochinchinensis* cause problems with their troublesome prickles. Some farmers said they utilised the weeds by cutting and drying them and then digging them in to improve soil condition, or that the unwelcome biomass is converted to organic fertiliser by composting. Many weeds are also well known to be alternative hosts for several plant pathogens (Barnes & Chan 1990), and some farmers indicated that the main problem with weeds was that they harbour pest insects.

CONCLUSION

Timor-Leste has a rich and diverse naturalised flora as indicated in this preliminary list (Supplementary Table) which should be regarded as a work in progress. New plant naturalisations can be anticipated in the future. As further introduced or pest species are collected or recorded in Timor-Leste this list can be expanded.

Of course, such a list does nothing to assist Timorese farmers deal with the weeds affecting their crops but the first steps in

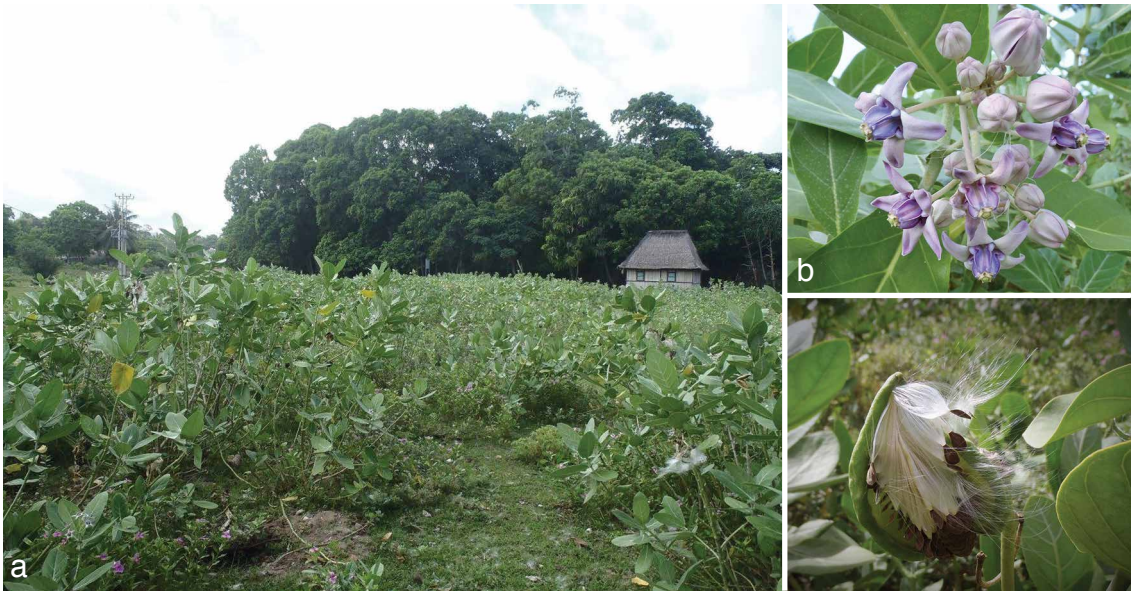


Fig. 6 a. *Calotropis gigantea* spreads by wind-borne seed and persists in lowlands aided by its toxic sap that renders plants unpalatable to stock; b. *C. gigantea* flowers; c. *C. gigantea* seed dispersal. — Photos by J. Westaway.

Fig. 7 a. *Jatropha gossypiifolia* is a poisonous shrub that can markedly reduce the productivity of grazing lands; b. *J. gossypiifolia* flowers and immature capsules; c. *J. gossypiifolia* dense new growth. — Photos by J. Westaway.

managing pest plants is knowing their identity and accurate taxonomy is important here. Publication of such a list provides a basis for further documentation of the introduced and pest flora of Timor-Leste and Malesia. It also provides a reference point for people working in agricultural, quarantine and related plant industries and may assist prioritisation of control measures.

The majority of these plants may be inconsequential, but some are serious weeds exerting detrimental impacts on rural Timorese livelihoods. These serious weeds are entrenched and not likely to be eradicated. Therefore, management, control and containment are more feasible objectives. Biological control agents may weaken or slow the spread of some species (e.g., *Ageratina riparia*, *Chromoleana odorata*, *Senna tora*, *Parkinsonia aculeata* L. (*Fabaceae*), *Jatropha gossypiifolia*, *Calotropis gigantea*, *Sida* spp.), but these plants, along with many less consequential weeds, are likely to be part of the Timorese flora of the future.

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