

# Kakadu Plum (*Terminalia ferdinandiana*) as a Sustainable Indigenous Agribusiness

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**Kakadu Plum (*Terminalia ferdinandiana*) as a Sustainable Indigenous Agribusiness.** In northern Australia, commercial use of plant products can provide Aboriginal people with important livelihood opportunities. Kakadu Plum (*Terminalia ferdinandiana* Exell.) is a species endemic to northern Australia with exceptional phytochemical properties and industry applications. Aboriginal people have a long history of customary use of many parts of this plant, and as scientific research provides evidence for commercial applications, it is under increasing demand. It has the highest level of ascorbic acid of any fruit in the world and also commercially important antioxidants. This paper reviews the unique characteristics of *T. ferdinandiana* fruit as a commercial plant product, the people and landscapes in which it grows, and the current state of knowledge for building a successful agribusiness based on these factors. It demonstrates the great potential *T. ferdinandiana* has as a sustainable Indigenous business and identifies the important research and development gaps that need to be addressed. These include improved understanding of taxonomy, floral biology, and drivers of variability in the properties in *T. ferdinandiana* leaves and fruit; better understanding of aspirations of Aboriginal suppliers for participation in the agribusiness supply chain; and specific supply chain models that suit Aboriginal suppliers of *T. ferdinandiana* to service a range of potential national and international markets.

**Key Words:** Aboriginal, enterprise, antioxidant, Indigenous ecological knowledge.

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## Introduction

The aim of this paper is to bring a multidisciplinary approach to assessing Kakadu plum (*Terminalia ferdinandiana* Exell.) for Indigenous agribusiness development. *T. ferdinandiana* is an endemic Australian native plant, with exceptional nutritional and health properties and potential commercial applications. It is an abundant and widespread savanna

tree, occurring across northern Australia on lands owned and managed by Indigenous people. There is widespread interest within the Australian Indigenous community in the potential to benefit livelihoods via enterprise business income based on *T. ferdinandiana*. It is hoped that the framework developed in this study will shed light on issues of concern for the growing interest in this agribusiness and how best to address them. It is anticipated that identifying knowledge gaps will inform future policy initiatives and the creation of the research and development agendas of Australian Governments at all levels, as well as industry and philanthropic groups engaged in directing funds for capacity building for Indigenous enterprise development.

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<sup>1</sup>Received 28 April 2019; accepted 27 September 2019; published online 20 November 2019

Received 18 April 2019; accepted 11 August 2019.

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Globally, many Indigenous people still have a high dependence on plant products for their health, nutritional, cultural, and spiritual well-being (WWF 2018). Equally so, “Western” markets are also very dependent on wild genetic stock, with some 25% of prescription drugs currently in use today having plant origins. Plant compounds contribute to approximately 75% of the new anticancer drugs marketed between 1981 and 2006 (Newman and Cragg 2007; Walsh 2003). There is also a growing demand for “functional foods,” which potentially have a positive effect on health above their nutritional value, such as in the prevention and management of health conditions (Tapsell et al. 2006). In 2015, the global functional foods market was valued at USD 129.39 billion and it is forecast to grow to USD 225.10 billion by 2024 (Grand View Research 2016). This rapid market growth is due to increasing consumer consciousness about health, diet, and the environment, and greater awareness of foods that are produced in safe and sustainable production systems.

Australia is well positioned to take advantage of this growing demand for functional foods based on its diversity of endemic flora and Indigenous customary use and knowledge of plant products. Australia has a very diverse array of native flora comprising over 19,324 vascular plants, with the clear majority (~ 95%) being endemic (Chapman 2009). Many of Australia’s endemic plants have commercial applications in the fields of pharmacy, medicine, food, beverage, cosmetic, perfumery, and aromatherapy (Bindon 1996; Clarke 2012; Graham and Hart 1997; Lands 1987; Sultanbawa and Sultanbawa 2016), with increasing international and national demand. Australian agriculture has an excellent international reputation for its environmental stewardship, the quality of products, and agricultural practice (Daly et al. 2015), which positions it well to grow its existing supply chains and to service a larger section of the functional foods market. However, to develop these chains and grow a share in the international market, while including the requirements of Aboriginal suppliers, requires careful planning, research, and development, including interdisciplinary knowledge across several areas of consideration.

Australian Aboriginal people are the custodians of the oldest continuous culture on earth and have an extensive ecological knowledge and deep, spiritual connection to their country. Their customary use of natural resources over many thousands of years has resulted in an

exceptional knowledge of the value of use of plant products, which has been transferred across generations (Lindsay et al. 2001; Puruntatameri et al. 2001). Wild plants and animals continue to be important in contemporary identity building of Aboriginal people, and wild food networks will undoubtedly offer opportunities to urban, peri-urban, and rural Aboriginal people (Low Chow et al. 2013). There is much that modern medicine and other sectors can gain from this knowledge and, through equitable partnership agreements, the Australian agribusiness sector and Aboriginal people can also benefit greatly (Janke 2018; Robinson 2010).

*T. ferdinandiana*, best known by the common name “Kakadu Plum,” is one of Australia’s native species that has potential to grow into a significant agribusiness. This species has exceptional phytochemical properties in the leaf and fruit which have commercial application and market demand from several industry sectors. It has the highest levels of ascorbic acid of any fruit in the world and high levels of commercially important antioxidants such as flavonoids and polyphenolics (including gallic and ellagic acids) (Cunningham et al. 2009; Netzel et al. 2007; Williams et al. 2014). A significant amount of research and development directed toward the commercialization of this species has already been conducted, but there are clearly knowledge gaps that need to be identified and addressed in growing this from a small-medium scale enterprise to a large-scale agribusiness.

Northern Australia is struggling with the incongruity of having unique and abundant cultural and natural resources, but also an Aboriginal population suffering from major socioeconomic disadvantage (Australian Institute of Health and Welfare 2015). Yet the customary knowledge that Aboriginal people have regarding plant and animal resources (Jones and Clarke 2018) could be the basis of an improvement of their socioeconomic status through creating much needed employment opportunities and continued connection to country. A “two tool box approach” (Aslin and Bennett 2005) is required in sharing this knowledge and commercialization through partnerships of industry and research with the Aboriginal custodians. This approach for collaborative action has worked well in the land management sector. This has occurred as traditional land management practitioners work together with contemporary “western” land management practice through Indigenous Ranger groups (Aslin and Bennett 2005).

A similar strategy is needed in business collaborations that sit between the very different socioeconomical constructs of remote Aboriginal communities, which are still strongly influenced by traditional culture, with potentially contrasting conventional business structures that function according to western business principles. Therefore, sustainability involves not only ecological but also economic, social, and cultural considerations. All of these are important for realizing the internationally recognized Millennium Development Goals, which are so important in Indigenous development (Millennium Development Summit 2000).

An agribusiness development requires at the very least a supply of and a demand for a product, as well as “actors” willing and able to provide services along the value chain. Within this paper, the main consideration is supply of a plant product from Aboriginal lands. We review the unique characteristics of *T. ferdinandiana* fruit as a commercial plant product, the people and landscapes in which it grows, and the current state of knowledge for building a successful agribusiness based on these factors. First, we discuss the economic geography of northern Australia and provide a snapshot of the landscapes, the Aboriginal communities, and their cultural values. Second, we review some of the biophysical properties of *T. ferdinandiana* and the commercial use of plant products by Aboriginal people as a livelihood option, with a focus on *T. ferdinandiana*. Third, we consider the trajectory of the growing commercial use of *T. ferdinandiana* and the challenges that this industry sector will face. This trajectory is then considered in the context of the social and cultural embeddedness that exists in Indigenous businesses globally (Cahn 2008). Enterprise and business developers in this context will need to link with a very different set of conventional business principles, expectations, and behaviors. This will require careful planning, communication, and perhaps formulation of new models and approaches (Scoones 1998).

### Northern Australian Landscapes, History, and Socioeconomic Status of Indigenous People

In this section, we will focus on the part of northern Australia in which *T. ferdinandiana* is found which, at its narrowest definition, includes the wet/dry tropics of the Northern Territory (NT) and the Kimberley region of Western Australia

(WA) (Cunningham et al. 2009). These areas have an annual rainfall of 600–1,600 mm, which is spread over a 4–7-month period (Lansberg et al. 1966).

#### NORTHERN AUSTRALIAN LANDSCAPES

The wet/dry tropics of the NT and the Kimberley of WA are characterized by their vast and relatively intact landscapes with extremely low population densities. Outside of the cities the population is sparse, and it is predominantly Aboriginal-owned land. Native Title claims and Aboriginal Land Rights have progressed more in the NT than other states of Australia, with about 50% of the land and 85% of the coastline under Aboriginal ownership (National Museum of Australia 2019). This land is held either as Aboriginal freehold, leasehold, or other tenures that exist concurrently with Native Title. The NT encompasses hundreds of clan estates (AIATSIS 2019a), with many either permanently or seasonally occupied in small family or clan settlements, referred to as “outstations.” These outstations are generally serviced by regional townships, many of which were started as missions or government outposts when Aboriginal people were dispossessed from their land (AIATSIS 2019b).

The NT has an average population of 0.2 person/km<sup>2</sup> (ABS 2016). The low density of people living on the land is arguably the biggest threat to its natural and cultural resources, as landscapes need active land management at an appropriate scale. With the current low levels of occupation, wildfire, feral weeds, and animals are extremely hard to manage and have devastating ecological, cultural, social, and economic impacts. Land management and sustainable use of wildlife play an ever-increasing and important role in the livelihood opportunities of Aboriginal people on their land (Gorman et al. 2008, 2006; Nikolakis 2010). However, without appropriate livelihood opportunities to generate income, there may over time be a drift of Aboriginal people from their traditional lands into larger towns (as quoted in Vemuri and Gorman 2012).

#### HISTORY AND SOCIOECONOMIC STATUS OF INDIGENOUS PEOPLE

The remote Aboriginal economy has been described as a “hybrid” economy, made up of three sectors: customary or subsistence; the State (mainly welfare); and private sector (e.g., arts and crafts, tourism enterprise) (Altman 2001). Although the

proportion of these sectors has clearly changed over time, the customary or subsistence component of the hybrid economy is still very important to many Aboriginal people living in remote areas. The welfare sector in Aboriginal communities has largely been in the form of a “work for the dole” type scheme called the Community Development Employment Program (CDEP) (Gorman and Vemuri 2017). The funding and employment generated through CDEP have contributed greatly to development of remote regional areas often managed by Aboriginal development corporations, such as Bawinanga Aboriginal Corporation in Maningrida (Altman 2016) and Thamarrurr Development Corporation in Wadeye. This CDEP scheme, which has been in existence since the late 1970s, has in part been used as a training program that “employed” people in community-based projects. The CDEP scheme was initially intended to train and transition people onto “real” jobs, but there are few non-government jobs available in regional Aboriginal townships (Gorman and Vemuri 2017; Welter 2010). Over time, the federal and state governments have tried to rationalize expenditure on service delivery (such as for health and education) by trying to encourage Aboriginal people to move from smaller settlements into bigger townships. When this occurs, Aboriginal people inevitably end up disconnected from their clan estates, creating a loss of culture and language and often contributing to social disharmony in the more concentrated population centers (Kerins 2010).

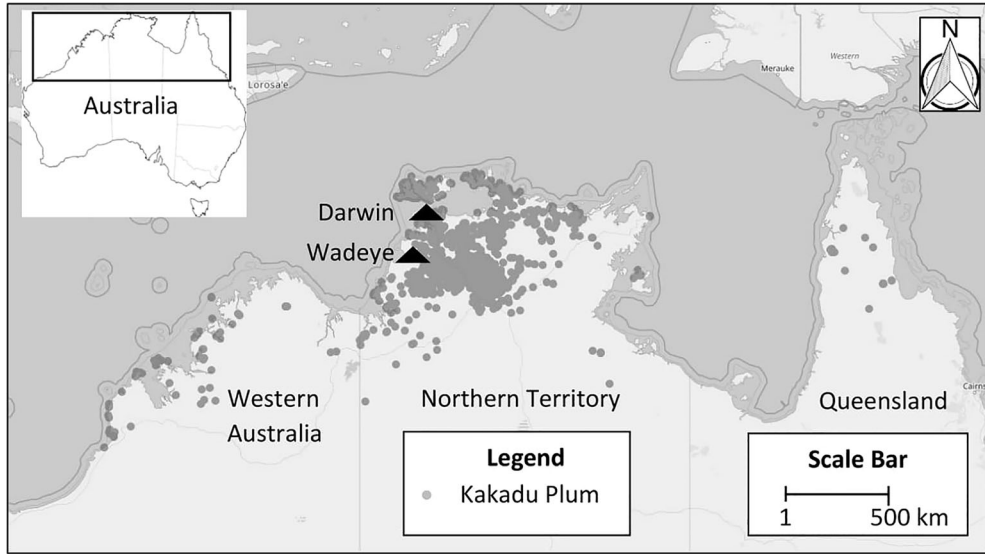
The private sector is also an important component of the hybrid economy (Altman 2001). On Aboriginal lands, the labor requirements of private sector activity typically have been mismatched with the existing Indigenous skills or have involved work opportunities that are not desirable to Indigenous people (Altman and Sanders 1991; McRae-Williams and Gerritsen 2010). This is reflected in workplace participation rates being extremely low outside of major cities (Altman and Sanders 1991). For example, the Aboriginal Township of Wadeye (Fig. 1) had a workplace participation rate of 16.7% in 2006. In contrast, culture-based enterprise activities have higher levels of Indigenous interest and engagement. They are often more flexible, can tie into with cultural and social obligations, and are based on existing knowledge systems and connections to country (Altman and Sanders 1991; Gorman et al. 2006, 2008). These include arts and crafts, tourism, natural and cultural resource management, and wildlife-based enterprise

(Koenig et al. 2011; Luckert et al. 2007; Nikolakis 2010; Tremblay and Wegner 2009; Zander et al. 2014).

In recent times, there has been a call by some Indigenous leaders for an increase in private sector investment (Mundine 2010; Pearson 2009; Yunupingu 2008). In encouraging this pathway, attention must be given to economic viability of enterprise and the process of choosing appropriate enterprises. Culture and social structure have an important role in decision-making in Aboriginal communities. Further complicating decision-making and governance in Aboriginal communities is that community members are often on the board of several organizations and part of important decision-making while, at the same time, also being part of a family group which is a beneficiary of these decisions. This could be viewed as being a conflict of interest, but given the size of some of these communities, the relatively small number of Traditional Owners who are decision makers, and the complexity of multi-cultural governance, it is difficult not to have such overlap. Cultural factors such as kinship systems, totems, and decision-making authority are factors that have potential to influence aspects of a natural resource-based enterprise by determining who can be involved, what country it can happen in, and when it can happen.

CDEP has been the mainstay of employment in Aboriginal communities since the late 1970s (Gorman and Vemuri 2017). Under this scheme, participants were expected to work four hours a day (36 hours a fortnight), which provided flexibility to participate in social and cultural activities. Many of these CDEP programs were initiated around social outcomes, and the author has observed high turnover of projects along with CDEP coordinators. Enterprises initiated under this scheme were seldom expected to be financially viable and could best be described as “social enterprise.” This has distracted from the real economic viability of business as many of the costs of operations have been subsidized by the CDEP scheme and the supporting organizations within the communities. True accountability of business will need to include all operational costs for them not to be dependent on subsidies that may not exist into the future.

Land management and sustainable natural resource-based activities and enterprise have been long identified by Aboriginal communities as high on their list of development aspirations (Gorman 2006, 2008; Whitehead 2012; Whitehead et al. 2006). This is because they provide a mechanism



**Fig. 1.** Map showing distribution of the endemic *T. ferdinandiana* (as plotted using tree records from Atlas of Living Australia 2019) and approximate location of Darwin and the Aboriginal Community Wadeye

to accommodate economic, social, and cultural priorities. Similarly, it has been found that Maori-led economic development also has a strong emphasis on cultural values and worldviews, and is essential in social and economic development in Maori communities (Bishop and Tiakiwai 2002; Carter et al. 2011).

In the Northern Territory, the Indigenous population has a much faster growth rate than other groups (Taylor et al. 2006). This further emphasizes the need for appropriate employment opportunities on Aboriginal lands. It is important that the approach to the development of employment opportunities is community-based. This will ensure that Aboriginal people are empowered and have ownership of the processes of economic development and can decide how to best maintain their cultural values and connections while at the same ensuring that their people are still able to access the economic and knowledge resources of mainstream society.

In summary, northern Australian landscapes are vast, relatively intact, with a rich natural and cultural diversity. The landscapes require active land management at an appropriate scale to maintain their natural and cultural values. There are many Aboriginal communities that are welfare dependent, arguably because of the history of establishment of the townships in which they live, contributing to a lack of appropriate employment opportunities through

the private sector. Land management and use of wildlife offer livelihood opportunities which Aboriginal people have a knowledge and interest in pursuing. Choosing and establishing such enterprise needs input and ownership from the communities who will service them. There are complex cultural, social, and institutional factors that influence decision-making and economic viability which need to be considered in developing natural resource-based enterprise. Much of Aboriginal land is under communal title and still governed by traditional lore and practice, requiring a different approach to conventional business development.

### *Terminalia ferdinandiana* Exell.

#### TAXONOMY

*T. ferdinandiana* is a member of the Combretaceae family (Wheeler 1992) and is endemic to northern Australia (Fig. 1). This family contains 20 genera and 500 species that are widespread in tropical and subtropical regions of the world (Dunlop et al. 1995). The genus *Terminalia* consists of about 200 species, of which 29 species or subspecies are native to Australia (Dunlop et al. 1995). Fourteen species occur in the Kimberley of Western Australia (WA), 12 in Northern Territory



(NT), and 16 in north Queensland (Pedley 1995), with some species overlapping in distribution.

*T. ferdinandiana* was originally named and described as *T. edulis* by Muell in 1860 (Cunningham et al. 2009). Later, the Australian Plant Census, which is the authority for Australian plant names, adopted Byrnes's (1977) *Revision of Combretacea in Australia*, and considered *T. ferdinandiana* and *T. latipes* as separate species. However, there is some dispute about this decision. Pedley (1995) in *Flora of Australia* merged *T. ferdinandiana* and *T. latipes* (while recognizing the latter as *T. ferdinandiana* subsp. *psilocarpa*). Currently, *T. ferdinandiana* is considered a synonym of *Terminalia latipes* subsp. *psilocarpa* and vice versa in many plant databases. However, the Northern Territory Herbarium does not recognize Pedley's (1995) revision and maintains Byrnes's (1977) version (where *T. ferdinandiana* and *T. latipes* are separate species). Additionally, there is also taxonomic uncertainty about whether a prostrate variety should be recognized as the distinct *Terminalia prostrata*, or as a prostrate form of the same species (Dunlop et al. 1995; Pedley 1995). Across northern Australia, there are also many natural hybrids among these *Terminalia* species (Keneally et al. 1996), making the taxonomy unclear.

These taxonomic uncertainties about the status of *T. ferdinandiana* need to be resolved. Wild harvest collection permits and export licenses require species identification and proof of appropriate management and a sustainable harvest plan (Australian Government 2018). Management of wild populations should be based on knowledge of species distribution and mitigation of threats, which requires taxonomic certainty. Taxonomic clarity will also inform further investigations of plant properties.

## ECOLOGY

*T. ferdinandiana* is a small to moderately sized semi-deciduous tree that is a dominant mid-storey species in *Eucalyptus tetradonta* and *E. miniata* woodlands in the upper rainfall band of the Australian wet/dry tropical savannas. The density of *T. ferdinandiana* mature trees of fruit-bearing age (> 2 m in height) has been recorded at more than 500 trees ha<sup>-1</sup>, with the highest densities on or near the coast (Woods 1995). In a separate study, the coastal strip in the greater Darwin region was found to have mature trees (> 2 m in height) at 272 ± 169 ha<sup>-1</sup> (Whitehead et al. 2006). While in central

Arnhem land, surveys conducted at 5-km intervals from the coast to 50 km inland, gave an average density of 14.4 ± 24.3 trees/ha. The highest density was found along the narrow coastal strip (82 trees/ha) and on clay soils 40 km inland (31 trees/ha) (Gorman et al. 2006; Whitehead et al. 2006). In some places, they could be considered "natural plantations" due to their high densities. However, further inland, the average density drops considerably with clay soils supporting slightly higher densities. *T. ferdinandiana* fruit from different regions across northern Australia have considerable variation in their phytochemical and antioxidant properties (Konczak et al. 2014). The cause for this variation is not well understood and could be related to a variety of genetic and/or biophysical relationships, e.g., soils, insect herbivory, response to ultraviolet light, rainfall, fire, pollinators, and other variables.

Soil water-holding capacity and fire regimes have been found to be important variables that determine occurrence of deciduous, non-eucalypts in this vegetation type (Lawes et al. 2011; Murphy et al. 2015). As an understory tree, it is difficult to define the distribution and density of *T. ferdinandiana* with any accuracy using remote sensing imagery. However, developments of land-based LIDAR imagery could be used for this purpose into the future. Fire ecology literature and field observations indicate that fire intensity and frequency are causing a "bottleneck" in recruitment of non-eucalypt, deciduous species in tropical savannas (Lawes et al. 2011; Lehmann et al. 2009; Murphy et al. 2015). This may be impacting the population dynamics of *T. ferdinandiana*. If fruit is to be harvested from the wild in large volumes, it will be important to know more about the species distribution, density, habitat preferences, and impact of disturbance factors such as fire. There are likely to be several arboreal mammals and birds that feed on the fruit of *T. ferdinandiana* that may be impacted upon under certain commercial harvest regimes. This requires further research.

An understanding of the reproductive biology of a plant is necessary to understand the factors that influence fruit quality and quantity. There is currently no information on the reproductive biology of *T. ferdinandiana* in the public domain, information which is critical to improve yielding and planning the layout of plantations. The structures of flowers, the pattern of opening, the sequence of activity of stamens and carpels, the self-compatibility, types of pollinators, and their rewards are all

important for understanding wild harvest and horticultural production. This is an important research gap to be filled.

Fire is also a key determinant of savanna structure and diversity. It will also be necessary to better understand the impact of fire regimes on population structure and on flowering and pollinators as this may influence yields. Land management and natural resource use offer important livelihood opportunities as well as increased health and well-being to Aboriginal people in their country (Burgess et al. 2009; Gorman et al. 2008, 2006; SRRATRC 1998). The issues for this type of enterprise development have been well documented and relate generally to remoteness as well as issues more specific to Aboriginal culture and social structure (Nikolakis 2010; Rose 1996).

#### TRADITIONAL USE

Customary use of plant products such as *T. ferdinandiana*, where there is existing knowledge about their nutritional or medicinal benefits, is often a “flag” for potential commercial pathways. There are many products that Aboriginal people are already familiar with, having harvested, often stored, and traded them for customary purposes (Blake et al. 1998; Pascoe 2014; Smith and Kalotas 1985; Smith and Wightman 1990; Wightman et al. 1992).

Plants of the genus *Terminalia* are globally well recognized as being widely used for traditional medicine (French 2013), and laboratory chemical analysis provides evidence to support their many medicinal uses (Cock 2015). *T. ferdinandiana* also has long been harvested by Aboriginal people as a food and for treatment of a variety of other ailments. The inner bark has been used to treat skin disorders and infections (wounds, sores, and boils) as well as fungal infections such as ringworm and bacterial infections including treatment of leprosy (Gorman et al. 2006). The fruit of *T. ferdinandiana* was consumed by Aboriginal people on hunting trips for quick energy and refreshment (Brock 2001). Central Arnhem Land clans regarded it as more a medicine than a food (Isaacs 1987). In addition to the fruit being eaten for medicinal purposes (to treat colds and congestion) (Lindsay et al. 2001; Puruntatameri et al. 2001; Raymond et al. 1999), the sap was roasted, and the bark was boiled in water and used to treat skin conditions and sores or drunk as a tea for colds and flu (Lindsay et al. 2001). Traditionally, both the fruit and seed of

*T. ferdinandiana* were eaten raw. Different Aboriginal language groups have different names, dreaming stories, and uses for this species (Lindsay et al. 2001; Puruntatameri et al. 2001; Raymond et al. 1999). Aboriginal people have a strong affiliation with this species through their long history of customary use, and there has been increasing involvement and expressed aspirations from Aboriginal people across its distribution to commercialize it (Gorman et al. 2016). Traditional foods are still a very important part of the diets of many Aboriginal people today, and a recent study conducted over five remote Aboriginal communities in the Northern Territory found 89% of the people interviewed consumed a variety of traditional food fortnightly (Ferguson et al. 2017). Wildlife-based enterprises involving traditional foods such as Kakadu Plum are likely to increase time on traditional lands, better facilitate intergenerational transfer of knowledge, allow for increased physical activity, and facilitate consumption of traditional foods, which will all contribute to better health and well-being (Burgess et al. 2009; Gorman et al. 2006).

#### PHYTOCHEMICAL PROPERTIES

*T. ferdinandiana* is well known for its phytochemical properties. It was first recognized for its extremely high levels of vitamin C (ascorbic acid) in 1982 through a study of the nutritional composition of bushfood used by Australian Aboriginal people (Brand et al. 1982; Miller et al. 1993). In this study, they found ascorbic acid contents of 2,300–3,150 mg per 100 g of fruit wet weight (2.3–3.1%). Recently, ascorbic acid levels have been recorded at  $14,038 \pm 701$  mg per 100 g of fruit dry weight (~14%) (Williams et al. 2014). As a comparison, the Barbados Cherry (or acerola, *Malpighia glabra* L.), a native to Brazil which previously laid claim to the highest levels of vitamin C in the world (Clein 1956), had an average vitamin C content of 1.7% wet weight (Johnson 2003). Citrus, which is very well known for its source of natural vitamin C, is about 0.5% by wet weight (Cunningham et al. 2009). So clearly, *T. ferdinandiana* has exceptionally high natural levels of ascorbic acid in the fruit compared to other species.

The fruit and leaf are also found to have extremely high levels of polyphenolic compounds. These include mainly ellagic and gallic acid which, along with vitamin C, provide high antioxidant values known to reduce the risk of several diseases, such as cardiovascular disease, cancer, stroke, and

rheumatoid arthritis (Mohanty and Cock 2012; Ohno et al. 1999; Sirdaarta et al. 2015; Tan et al. 2011; Willet 2002; William et al. 2014). Furthermore, *T. ferdinandiana* has much higher levels of ellagic acid ( $879.6 \pm 15.6$  mg per 100 g DW) than boysenberry ( $168.4 \pm 3$  mg per 100 g DW), which is a fruit considered to have high levels of ellagic acid (Williams et al. 2014). *T. ferdinandiana* was also found to have a much higher free to total level of ellagic acid (70.6%) compared to strawberry (3.3%) and boysenberry (3.3%), making it more available for uptake. It is thought that ascorbic acid plays a role in protecting the degradation of the ellagic acid (Williams et al. 2014). The leaves are found to have much higher levels of ellagic acid than the fruit, although there does appear to be much variability in these phytochemical levels between trees (Williams et al. 2016).

There are several possible explanations as to why the phytochemicals levels are high in *T. ferdinandiana* and why they are so variable. Herbivory rates are generally higher in tropical forests than in temperate forests, and the most damage to tropical leaves occurs when they are young and expanding. This is in contrast with temperate forest trees where the damage occurs mainly in the mature leaves (Coley and Barone 1996). As a defense mechanism to herbivory, plants have evolved chemical, mechanical, and phenological traits to protect themselves. We see these traits in *T. ferdinandiana* with extremely high levels of ascorbic acid and polyphenolic compounds; leaves which are fibrous with high tannin levels and not very palatable, especially as they age; and a synchronous leaf and flower flush in the later dry season, when insect numbers are at their lowest (Coley and Barone 1996). These strategies would help reduce herbivory from insects and arboreal mammals. This can be particularly important in areas where soils are relatively poor such as the monsoonal tropics (Coley and Barone 1996). The evolution of chemical defense mechanisms against predation has been found to be more pronounced in plants with long-lived leaves (Coley and Barone 1996). However, *T. ferdinandiana* have relatively short-lived, semi-deciduous leaves that drop in the middle of the dry season, contradicting common explanations for the heavy metabolic investment in chemical defense plants.

There is also evidence that phenolic compounds have antioxidant capacity, which may protect plants from photodamage (Close and McAuthur 2002). Plants grown under conditions

of high light or limited nutrients have been shown to produce increased amounts of leaf phenolics, including tannins (Close and McAuthur 2002). This was demonstrated in an early study on phenolic compounds, where leaves from the sun-exposed side of the canopy of *Prunus domestica* var. Victoria trees were seen to have significantly higher levels of phenolic compounds than leaves from the shaded side (Hillis and Swain 1959). The leaves of *T. ferdinandiana* have been found to have very variable levels of ellagic acid, and this may be due to different exposure of ultraviolet light among different trees and/or within the canopy of a single tree. More research is required to confirm this. However, if the leaf is to be commercially harvested, there is a need to better understand how and why ellagic acid levels vary throughout the life of the leaf and if this changes seasonally and between and within populations.

The seeds of *T. ferdinandiana*, which were previously discarded in the pulping process, have recently been identified as having potential to be utilized as a novel protein source for dietary purposes and a nonconventional supply of linoleic, palmitic, and oleic acids (Akter et al. 2018). The multiple uses of products from the fruit and leaves will continue to attract commercial attention and contribute to profitability when production and processing happen at scale. However, we need a better understanding of what is driving the exceptional levels of phytochemical compounds of both the *T. ferdinandiana* fruit and leaves and the variability. If variability is chiefly environmental, there may be ways to manipulate environmental factors (sunlight, pollination) to increase concentration of the desirable compounds, reduce variability, and hence increase economic returns.

## Historical and Potential Future Commercial Uses

Despite the exceptional properties of the *T. ferdinandiana* fruit and leaf, and the diversity of commercial applications it offers, the rate of growth of this industry has been slow and inconsistent (Gorman et al. 2016). Above, we referred to agribusiness in its simplest form as needing to involve a product supply, a demand, and participation of “actors” willing and able to provide the services along the value chain. In this section, we will review the progress of business development.



## PERMITS FOR WILD HARVESTED FRUIT

Legislation to harvest native plant products varies between states and territories in Australia. In the NT, permission to harvest is regulated by the Parks and Wildlife Commission within the Department of Tourism, Sport and Culture (administration of collecting permits), Department of Environment and Natural Resources (advice on the ecological sustainability of planned activities), and Department of Trade, Business and Innovation (administration of bioprospecting regulations and benefit sharing arrangements). Collection for commercial purposes involve permits to “Take” and “Return” fruit. “Take” permits are required for all commercial harvest offtakes on all titles of land. Applications for these permits need to provide details about the proposed harvest volume, area, and land title of the collection area. The applications are assessed for sustainability and appropriate sharing of benefits with the resources provider (i.e. land owner), before being granted. In the case of Kakadu Plum, a specific management plan exists (*Management Plan for Kakadu Plum 2019–2023*) (Gorman et al. 2019) which stipulates extra management considerations. At the end of harvest season, a “Return” permit must be completed with actual harvest volume, and, if harvested from Crown Land, a royalty (per kg) payment is required.

In the NT, any commercial activity on Aboriginal land requires consent from the Traditional Owners of that land, according to the Aboriginal Land Rights Act (Northern Territory) 1976. This needs to be facilitated through one of the NT Land Councils, which have regional jurisdictions within the NT. Subsequently, a Land Use Agreement (LUA) between the collecting party and the relevant Land Trust needs to be agreed to. Unfortunately, there are large backlogs and time delays in this process. In many cases in the past, harvest permits for Kakadu Plum have been granted by the relevant Land Council without going through the LUA process (Julian Gorman, pers. obs. 2019). This has occurred where the proponents have been Traditional Owners and their families on their own land, not involved in an exclusive activity, and where the collection has been small scale and mostly “trial” harvest, rather than a commercial activity.

The Northern Territory Government has introduced a Biological Resources Act 2006, administered by the NT, which is largely concerned with third parties making agreements related to bioprospecting on all tenure types. Partnership agreements are drawn up and monetary or non-monetary benefits discussed

if bioprospecting is being conducted. Issues around biological patents and property rights have been an important consideration in recent years, and there have been a number of examples of attempts to establish international patents for commercial products that use Kakadu Plum (e.g., Mary Kay patent attempts). These claims have been disputed on the basis of existing Traditional knowledge (Robinson 2010). These attempts over the years by international companies to patent products using Kakadu Plum ultimately benefit indirectly from Indigenous Knowledge. These patent attempts are likely to be contributing to a strong desire from Aboriginal groups to protect and manage their knowledge for their own enterprise development (Janke 2018).

## HISTORY OF COMMERCIAL USE

The growth of an agribusiness around *T. ferdinandiana* fruit has been characterized by inconsistent market demand, which in turn has contributed to poorly structured and resourced supply chains. Sustainable agribusiness chains will only develop in response to positive market signals. Inconsistent and variable market signals can be misinterpreted and lead to premature establishment of value chains, emphasizing the supply. The supply is more complex when it is predominantly from wild harvest and largely on Aboriginal lands, which are often remote and with limited infrastructure. Yields can also vary with annual weather events in the monsoonal north. Aboriginal communities are also often grappling with how to integrate the social and cultural connectedness of their businesses with conventional supply and value chains, which operate according to economically focused business principles. There are solutions to these issues, and over time the community members themselves will determine their own approach and priority of family vs. community benefits and business structure. Globally, indigenous peoples are dealing with similar issues. For example, people from Papua New Guinea blend introduced business concepts with indigenous ideals to create a unique form of entrepreneurship (Currie 1999, 2003). Cahn (2008) describes people in the Pacific Islands organizing enterprises around individuals, family, and kin while also achieving community outcomes and enhanced social networks.

The history of commercial use of *T. ferdinandiana* can be characterized by three main phases. The first was between 1996 and 2007, when processed fruit was in demand from the food and

beverage sector for its high vitamin C content and flavor. The second was between 2006 and 2010, when demand grew for its nutraceutical values. Coradji Pty LTD, an Australian, Sydney-based company, bought fruit from communities in the Kimberley, WA, and in the NT. This fruit was supplied to Coradji, trucked frozen to Sydney where it was pulped, and then to Melbourne where it was freeze dried into a powder. It was then distributed to an American manufacturing company called Mannatech, who used the *T. ferdinandiana* powder in a supplementary health tablet called “Ambrotose”<sup>®</sup>. In both of these early phases, Aboriginal people supplied the fruit but had little desire or opportunity to play a role further up the value chain. The third phase was based on subsequently discovered antimicrobial properties and an increased awareness of the exceptional properties of this species. This resulted in *T. ferdinandiana* powder being awarded the “Best Novel Food Ingredient” at the Natural Products Expo in West/Engredea Show in Anaheim, CA (USA) in 2014. At around this time, Aboriginal communities and their Resource Centres in the NT and the Kimberley started investing in and forming collection hubs, and increased their annual harvest from hundreds to thousands of kilograms of fruit per season. There was discourse around creating Aboriginal-owned cooperatives to consolidate production from different regions, taking on processing and product development and dealing with different markets. Several WA Aboriginal communities became more involved in horticulture, trialling a variety of production systems. Many established connections with small markets that they could work with as a community-based enterprise. A more in-depth history of commercial use of *T. ferdinandiana* can be found in Gorman et al. (2016).

#### HORTICULTURAL PRODUCTION SYSTEMS

Monoculture horticulture and wild harvest from the bush lie at opposite ends of a spectrum of production systems. Contemporary horticulture requires the development of plant varieties that have the most desirable phenotypic qualities such as tree shape, growth vigor, flowering duration, fruit quality, and yields. This is based on identifying and crossing varieties with the best traits from across the distribution. Monoculture horticulture generally involves clearing, irrigation, and use of fertilizer and pesticides, with the aim of maximizing profit. There are alternative production systems that may

be better suited to Aboriginal lands, where cultural, totemic, and customary significance and social priority are considered. Alternatives to contemporary horticultural production systems include enrichment and multispecies plantings, managing natural stands for increased recruitment and yields, and growing high-performing, local phenotypes (Leakey et al. 2003; Lee and Courtenay 2016). It will be important to seek opinion of Aboriginal land owners about cultural attitudes to mixing genetics between populations, which may come from different clan estates. It will be necessary to make sure there is cultural authority for this, as plants and animals are totems and have different cultural significance to different Aboriginal clans.

Given that different markets focus on specific properties of processed *T. ferdinandiana*, it may be possible to link them with their best-matched supply region. This may allow for processing systems to be practiced in regions that suit the price structure of the appropriate market, perhaps reducing competition between regions for the similar market and allowing for a more regional development of wild enrichment management or horticulture systems of production and early processing systems for the relevant market. Product marketing could also benefit from links with regions with promotion of the culturally specific names and stories from that area. Further research is required to understand the reasons for phytochemical variations and to what extent they can be attributed to genetics and environmental factors, to fully realize market potential.

There have also been a number of industry- and government-funded research and development projects related to the horticulture of Kakadu Plum in recent years, and there are some existing plantations in both the Northern Territory and Kimberley Region. In the 1990s, there was commercial interest in Kakadu Plum from a private company, Access Business Group International LLC (ABG) (a business of the Alticor Group and sister company of Amway), in partnership with Cognis Australia Pty, Ltd. This agronomic research resulted in a plantation of approximately 6,000 trees being established just east of Darwin (NT), at Wildman River (Cunningham et al. 2009; Robinson 2010). However, in May 2004, ABG and Cognis Australia tried to export Kakadu Plum tissue culture to Amway’s facility in Brazil, without authority from the Australian Government, nor setting up benefit-sharing agreements with land owners where they had sourced the material. This controversial action ultimately led to the demise of this ABG and Cognis

Australia Research Group venture at Wildman River (Cunningham et al. 2009). A plantation of Kakadu Plum still exists at the Wildman River site, and in recent years, extra trees have been planted and the fruit harvested by Wild Harvest NT.

A number of different plantations exist in the Kimberley region of Western Australia. In 2007, the North Regional TAFE set up a training and research center just outside Broome in partnership with the WA Department of Conservation and Land Management and with the endorsement of the local Yawuru Traditional Owners. This site is called Balu Baru, which is a Yawuru term meaning “place of trees” (Lee and Courtenay 2016). A trial plantation of Kakadu Plum (locally named Gubinge) was set up as trial to test horticultural methods. There are now over 1,000 trees in place as enrichment plantings (i.e., supplementary planting among wild stands) (Lee and Courtenay 2016). Kim Courtenay, a horticulturalist with North Regional TAFE, has trained and facilitated development of many small plantations on Aboriginal lands in the Kimberley. The most productive of these is at Bidyadanga Aboriginal Community, 200 km south of Broome. They have established enrichment and monoculture plantations of mature trees that are yielding over one ton of fruit annually. Another group that has adopted the enrichment planting system is the Aboriginal Resource Centre, of the Mamubulanjin Aboriginal Corporation, in Broome. This group has a number of small plantations of Kakadu Plum and sell fruit wholesale.

With the exception of the plantation originally created at Wildman River in the NT, there are no significant plantations of Kakadu Plum under non-Indigenous ownership. The bulk of current supply is coming from wild-harvested sources. A significant opportunity exists for Indigenous groups to continue to work towards their “whole of business” approach based on wild harvest, while investigating other production systems to increase supply.

#### VALUE CHAINS AND BUSINESS MODELS

There has certainly been progress in many areas in developing value chains. Several Aboriginal groups have linked directly with industry partners and provided a supply of *T. ferdinandiana* as an ingredient for a variety of retail products. The Aboriginal business Twin Lakes Cultural Park, located on the Dampier Peninsula, north of Broome in Western Australia, is an example. They have had a partnership agreement for several years directly with

the company Loving Earth PTY Ltd. This company uses *T. ferdinandiana* powder as an ingredient in chocolate (Twin Lakes Cultural Park 2019). Other Aboriginal communities, such as those in the Thamarrurr Region of the NT (Fig. 1), have clearly demonstrated their capacity to wild harvest more than 10 tons of fruit in a season and have progressed up the value chain by processing this harvest locally (Thamarrurr Development Corporation, pers. comm. 2019). Processing procedures for pulping and freeze drying are already developed. The resulting pulp and powder have been assayed and found to be of pharmaceutical quality (Yasmina Sultanbawa, pers. comm. 2018). However, overall, the processing steps need to be tailored to the costs structure of individual markets and end products. Markets that are not reliant on high concentrations or nutraceutical grade phytochemicals may be serviced by more economical methods of local processing. The markets that are currently buying fruit for its anti-microbial properties are satisfied with the quality and a high price structure. Market signals suggest that substantially higher volumes of fruit will soon be demanded by this market. When this happens, there will be a need for coordination of supply chains to deliver in the quantities and quality required.

An important consideration going into the future is how the *T. ferdinandiana* business should develop to meet market demands and social and cultural concerns of suppliers. There has been some movement towards an alliance of Aboriginal companies supplying Kakadu Plum fruit and extracts for the Australian market. This initiative, which has been supported by the Indigenous Land Corporation, is called the Northern Australian Aboriginal Kakadu Plum Alliance (NAAKPA) and was established in August 2018 (NAAKPA 2018). NAAKPA is an alliance of Aboriginal companies that ethically harvests and process Kakadu Plum across northern Australia. They were established to protect the interests of Aboriginal enterprises and communities in the Kakadu Plum industry (NAAKPA 2018). One of the key objectives of NAAKPA is to become leaders in all aspects of the business (research, harvest, processing, and marketing) and to empower Aboriginal people to draw on land assets and the Traditional Ecological Knowledge and intellectual property within communities. The formation of NAAKPA and interest in this “whole of industry” development approach illustrates empowerment in driving an Aboriginal-led economic development strategy. Many would feel they are entitled to lead

this wildlife-based enterprise given they have hundreds of years of customary use of this product and decades of commercial participation. Another cooperative, trading under the business name Traditional Homeland Enterprises (T.H.E.), is supported by the philanthropic group Kindred Spirits Enterprises. T.H.E. has the stated goal of having an Indigenous, majority-owned company structure (Traditional Homeland Enterprises 2019). As the overall Kakadu Plum business grows, these company structures will continue to evolve. The success of the industry will require more coordinated supply chains, which align with the business realities while meeting the goals and aspirations determined by the Indigenous enterprises.

There are, however, many extenuating circumstances that make it difficult to initiate and operate business from remote Aboriginal communities. Often there is not enough time spent on clarification of Indigenous aspirations for enterprise and community-based approaches to map the types of enterprises they aspire towards and where they see their involvement along value chains. This will suit investors with capital and business expertise who can embrace the unique social geography of northern Australia and Aboriginal people, be adaptive in their partnerships, and be conscious of the importance of cultural and social embeddedness. Rather than pre-determine the way of doing business, this investor awareness may create the pathways for *T. ferdinandiana* and many other commercial opportunities that are currently linked with Indigenous knowledge systems.

There are non-Indigenous suppliers involved in both plantation production and wild harvest of *T. ferdinandiana*. In the WA Kimberley region, there are several short-value chains with Indigenous communities supplying fruit directly to markets in reasonably small volumes (Twin Lakes Cultural Park 2019). Given that northern Australia is vulnerable to cyclones and other disruptions, a more coordinated model that links across a broad geographic range to spread risks of losing markets may be another approach worth considering. Such a model would also be important for linking with a market that requires a large and consistent supply and in turn assist with risk management. As other production systems develop, it is likely that fruit with more consistency will be produced. However, wild harvest is likely to be the main source of fruit for the short term, and for some communities the longer term, as it will be their production system of choice.

## Conclusion

This paper has demonstrated that *T. ferdinandiana* has the inherent characteristics to be an Indigenous agribusiness and has potential to be sustainably commercialized. However, there are many multidisciplinary questions that need to be addressed. These questions relate to Indigenous aspirations, non-conventional business structure and function, *T. ferdinandiana* genetics, and production systems, and will be specific to each Aboriginal community.

Aboriginal stakeholders, as the main landowners across northern Australia, hold access rights to most of the genetic resources of this species and have knowledge, capacity, and desire to be involved and have ownership of the supply chain and connections to the diversity of markets. To facilitate participation along supply chains requires a multidisciplinary and multisector approach that can accommodate the social and cultural embeddedness of Indigenous business into the more conventional economic models. This will require the development of appropriate and sustainable supply chain models that service suppliers managing traditional estates as well as national and global markets.

There are many production and market directions this industry can take. As markets demand a greater volume of supply, there is bound to be interest from large horticultural ventures that can grow the product at considerable volume for a competitive price. This has not happened to date because market demand has been inconsistent, and the investment risks in establishing large-scale horticulture too high. There is a window of opportunity for Aboriginal landowners who have *T. ferdinandiana* of different varieties on their land to establish and service current market demands. This could be through wild harvest of managed and unmanaged landscapes as well as through establishment of regional varieties in a choice of production systems (enrichment, mixed, monoculture, and managed wild areas) suited to their cultural and social desires. As markets increase their demand for *T. ferdinandiana*, there will inevitably be greater interest from horticultural companies to service these markets. This will make production very competitive. Aboriginal communities currently have access to the wild stock and the genetic resources and land to increase production into the future. It is crucial that they establish themselves as suppliers and build the networks

and relationships to supply markets in this early phase of industry development if they are to take advantage of this opportunity.

There is, however, need for further research to progress this industry. A better understanding of the variability of phytochemical properties of the fruit and leaf from different regions, seasons, and populations could help direct markets to certain areas where the fruit has more of the desired property. The demand for a commercial application will determine the volume and price structure of the processed products and therefore will affect the most appropriate technique of processing according to the required quality of the end product demanded by different models.

Sustainable agribusiness requires a market, a supply, and “actors” along the value chain, and needs coordination for these components to align. When markets have production chains in place, they require the other sections of the value chain to be ready as well. Across northern Australia, this species occurs at densities which could supply an annual demand of around 100 tons of fruit. However, even wild harvest requires a large amount of upfront investment and coordination. The Aboriginal communities that have proven their ability to wild harvest tons of fruit in a season have had to invest in collection, storage, and processing infrastructure, and training and transferable knowledge. How, or if, these communities wish to join in a cooperative arrangement to supply large volumes is for them to decide. This will ultimately be determined by the markets they connect with and their ability to manage the many complexities of a supply chain.

There is generally a high failure rate of smaller businesses (Bickerdyke et al. 2000), but no evidence to suggest increased failure of business success in remote areas or for those operated by people who identify themselves as Indigenous (Whitehead 2012). However, initiating any sort of enterprise in remote Indigenous townships is difficult because of the transport and access costs, as well as many other cultural, social, and political factors (Rose 1996; Whitehead et al. 2006). As government approaches to welfare and outstation support change, Aboriginal people will need to become more economically independent. Their natural resources and knowledge may play an important role in providing future livelihood opportunities. For Aboriginal people to play a greater role in the whole value chain will require consideration to be given to training

and education, infrastructure support, governance, and business approaches and models.

*T. ferdinandiana* has many properties for commercial success, with its distribution being endemic to northern Australia and abundant on Aboriginal land. It offers great promise to provide opportunities for employment and income generation that are much needed by Aboriginal people in these areas. There are undoubtedly other native plants that have had long Aboriginal customary use that have commercial application. The value chains developed for *T. ferdinandiana* may well allow easier commercialization for these species into the future.

This paper demonstrates a great potential for *Terminalia ferdinandiana* to be a sustainable Indigenous business so long as the gaps identified are addressed. These gaps include improved understanding of taxonomy; floral biology and drivers of variability in the properties in *T. ferdinandiana* leaves and fruit; improved knowledge of the aspirations of Aboriginal suppliers for participation in the agribusiness supply chain; and understanding of the specific supply chain models that suit Aboriginal suppliers of wild harvested *T. ferdinandiana* to service a range of potential national and international markets.

### Acknowledgments

The authors would like to acknowledge the support of Charles Darwin University, Darwin, Northern Territory, Australia, who hosted this Ph.D. research. The community of Wadeye in the Northern Territory and the Thamarrurr Development Corporation provided valuable support and advice for many years.

### Literature Cited

- ABS (Australian Bureau of Statistics) 2016. Population Density. <http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/3218.0Main%20Features752016?opendocument&tabname=Summary&prodno=3218.0&issue=2016&num=&view>. Accessed Oct 2019
- AIATSIS (Australian Institute of Aboriginal and Torres Strait Island Studies). 2019a. AIATSIS Map of Indigenous Australia. <https://aiatsis.gov.au/explore/articles/aiatsis-map-indigenous-australia>. Accessed Oct 2019
- . 2019b. Remembering mission days. <https://aiatsis.gov.au/exhibitions/remembering-mission-days>. Accessed Oct 2019



- Akter, S., M. E. Netzel, M. T. Fletcher, U. Tinggi, and Y. Sultanbawa. 2018. Chemical and nutritional composition of *Terminalia ferdinandiana* (Kakadu Plum) kernels: A novel nutrition source. *Foods* 7(60).
- Altman, J. C. 2016. Bawinanga and CDEP: The vibrant life, and near death, of a major Aboriginal corporation in Arnhem Land. In: *Better than welfare? Work and livelihoods for Indigenous Australians after CDEP*, ed. K. Jordan, 175–218. Canberra: Centre for Aboriginal Economic Policy Research, Australian National University Press.
- . 2001. Sustainable development options on Aboriginal land: The hybrid economy in the twenty-first century. Discussion Paper 226/201. Centre for Aboriginal Economic Policy Research, ANU, Canberra.
- Altman, J. C. and W. Sanders. 1991. Government initiatives for Aboriginal employment: Equity, equality and policy realism. In: *Aboriginal employment equity by the year*, ed. J. Altman, 1–8. Canberra: Centre for Aboriginal Economic Policy Research.
- Aslin, H. J and D. H. Bennett. 2005. Two tool boxes for wildlife management? *Human Dimensions of Wildlife* 10: 95–107.
- Atlas of Living Australia. 2019. Mapping and Analysis. <https://www.ala.org.au/mapping-and-analysis/>. Accessed Oct 2019
- Australian Government. 2018. Application for Approval of a Wildlife Trade Management Plan. Department of Environment and Energy, Wildlife Trade Management Plans. <http://www.environment.gov.au/biodiversity/wildlife-trade/commercial/management-plans>. Accessed Oct 2019
- Australian Institute of Health and Welfare. 2015. The health and welfare of Australia's Aboriginal and Torres Strait Islander peoples. Cat. No. IHW 147. Canberra. <http://www.aihw.gov.au/publication-detail/?id=60129550168>. Accessed Oct 2019
- Bickerdyke, I., R. Lattimore, and A. Madge. 2000. Business failure and change: An Australian perspective. Staff Research Paper. Productivity Commission, Canberra.
- Bindon, P. 1996. Useful bush plants. Western Australian Museum, Perth.
- Bishop, R. and S. J. Tiakiwai. 2002. Building capacity for sustainable iwi development. He Puna Korero. *Journal of Maori and Pacific Development* 3(2): 31–39.
- Blake, N. M., G. Wightman, and L. Williams. 1998. Iwaidja ethnobotany. Aboriginal plant knowledge from Gurig National Park, northern Australia. *Northern Territory Botanical Bulletin* No.23. Parks and Wildlife Commission of the Northern Territory, Darwin.
- Brand, J. C., V. Cherikoff, and A. Lee. 1982. An outstanding food source of Vitamin C. *Lancet* 2(8303):873.
- Brock, J. 2001. Top end native plants: A comprehensive guide to the trees and shrubs of the top end of the Northern Territory. Sydney: Reed New Holland.
- Burgess, C., F. Johnston, H. Berry, J. McDonnell, D. Yibarbuk, C. Gunabarra, A. Mileran, and R. Bailie. 2009. Healthy country, healthy people: The relationship between Indigenous health status and “caring for country.”. *Medical Journal of Australia* 190: 567–572.
- Byrnes, N. B. 1977. A revision of the Combretaceae in Australia. Brisbane: Queensland Herbarium.
- Cahn, M. 2008. Indigenous entrepreneurship, culture and microenterprise in the Pacific Islands: Case studies from Samoa. *Entrepreneurship and Regional Development* 20(1) 1–18.
- Carter, L., R. Kamau, and M. Barrett. 2011. Te Pae Tawhiti Māori Economic Development Programme: Literature review and programme report. Ngā Pae o te Māramatanga, University of Auckland, New Zealand.
- Chapman, A. D. 2009. Numbers of living species in Australia and the world. 2nd ed. Report for the Australian Biological Resources Study, Canberra, Sept. 2009. ISBN 978 642 56860 1.
- Clarke, M. 2012. Australian native food stocktake. RIRDC No.12/066. Canberra: RIRDC.
- Clein, N. W. 1956. Acerola juice, the richest known source of Vitamin C: A clinical study in infants. *The Journal of Paediatrics* 48(2): 140–145.
- Close, D. C. and C. McArthur. 2002. Rethinking the role of many plant phenolics—Protection from photodamage not herbivores? *OIKOS* 99: 166–172.
- Cock, I. E. 2015. The medicinal properties and phyto-chemistry of plant of the genus *Terminalia* (Combretaceae). *Inflammopharmacology* 23(5): 203–229.
- Coley, P. D. and J. A. Barone. 1996. Herbivory and plant defences in tropical forests. *Annual Review of Ecology and Systematics* 27: 305–335.
- Cunningham, A. B., K. Courtenay, J. T. Gorman, and S. Garnett. 2009. Eco-enterprises and

- Kakadu Plum (*Terminalia ferdinandiana*): “Best laid plans” and Australian policy lessons. *Economic Botany* 63(1): 16–23.
- Currie, G. 1999. Markets, social embeddedness and pre-capitalist societies: The case of village trade stores in Papua New Guinea. *Geoforum* 30: 255–298.
- . 2003. Moving beyond post development: Facilitating Indigenous alternatives for “development.” *Economic Geography* 79: 405–423.
- Daly, J., K. Anderson, R. Ankeny, G. Farquhar, B. Harch, J. Rolfe, and R. Waterhouse. 2015. Securing Australia’s Future: Project 7. Australia’s Agricultural Future. ACOLA: <http://hdl.handle.net/102.100.100/92282?index=1>.
- Dunlop, C. R., G. J. Leach, and I. D. Cowie. 1995. Flora of the Darwin Region. Vol. 2. Northern Territory Botanical Bulletin No. 20. Conservation Commission of the Northern Territory, Darwin.
- Ferguson, M., C. Brown, C. Georga, E. Miles, A. Wilson, and J. Brimblecombe. 2017. Traditional food availability and consumption in remote Aboriginal communities in the Northern Territory, Australia. *Australian and New Zealand Journal of Public Health* 41(3): 294–298.
- French, B. 2013. Edible *Terminalia* fruit and nuts. *Food Plants International*. <http://foodplantsinternational.com/>. Accessed Oct 2019
- Gorman, J. and S. Vemuri. 2017. A precursor to entrepreneurialism on Aboriginal Lands of the Northern Territory of Australia. *International Journal of Entrepreneurship* 21(1).
- Gorman, J., P. J. Whitehead, and A. D. Griffiths. 2006. An analysis of the use of plant products for commerce in remote Aboriginal Communities of Northern Australia. *Economic Botany* 60(4): 362–373.
- Gorman, J., D. Pearson, and P. Whitehead. 2008. Assisting Australian Indigenous resource management and sustainable utilization of species through the use of GIS and environmental modelling techniques. *Journal of Environmental Management* 86: 104–113.
- Gorman, J., C. Brady, and T. Clancy. 2019. Management Program for *Terminalia ferdinandiana* in the Northern Territory of Australia 2018–2022. Northern Territory Department of Environment and Natural Resources
- Gorma C, Brady J., ———, and K. Courtenay. 2016. Commercialisation of *Terminalia ferdinandiana* Exell. in northern Australia. In: Australian native plants: Cultivation and uses in alternative medicine and the food industry, eds. Y. Sultanbawa and F. Sultanbawa, 89–104. CRC Press/Taylor and Francis Group.
- Graham, C. and D. Hart. 1997. Prospects for the Australian native bushfood industry. RIRDC No.97/022. Canberra: RIRDC.
- Grand View Research 2016. Functional Foods Report. <https://www.grandviewresearch.com/press-release/global-functional-foods-market>. Accessed Oct 2019
- Hillis, W. E. and T. Swain. 1959. The phenolic constituents of *Prunus domestica*. II. The analysis of tissues of the Victorian plum tree. *Journal of Science Food Agriculture* 10: 135–144.
- Isaacs, J. 1987. Bush food: Aboriginal food and herbal medicine. Sydney: Ure Smith Press.
- Janke, T. 2018. Issues for protection and management—Discussion Paper. Commissioned by IP Australia and the Department of Industry and Science, Australian Government, Canberra.
- Johnson, P. 2003. Acerola (*Malpighia glabra* L., *M. puniceifolia* L., *M. emarginata* D.C.): Agriculture, production and nutrition. *World Review of Nutrition and Diet*: 91: 67–75.
- Jones, D. S. and P. A. Clarke. 2018. Australian Aboriginal culture and food-landscape relationships: Possibilities of indigenous knowledge for the future Australian landscape. In: *Routledge companion to landscape and food*, eds. J. Zeunert and T. Waterman, 41–60. Routledge, London.
- Kenneally, K. F., D. Choules Edinger, and T. Willing. 1996. Broome and beyond: Plants and people of the Dampier Peninsula, Kimberley, Western Australia. Department of Conservation and Land Management, Perth.
- Kerins, S. 2010. The future of Homelands/Outstations. CAEPR Topical Issue No. 01/2010. Centre for Aboriginal Economic Policy Development, Australian National University, Canberra.
- Koenig J., J. Altman, and A. D. Griffiths. 2011. Artists as harvesters: Natural resource use by Indigenous wood carvers in Central Arnhem Land, Australia. *Human Ecology* 39: 407–419.
- Konczak, I., F. Maillot, and A. Dalar. 2014. Phytochemical divergence in 45 accessions of *Terminalia ferdinandiana* (Kakadu Plum). *Food Chemistry* 151(2014): 248–256.
- Lands, M. 1987. *Mayi*. Some bush fruits of Dampierland. Magabala Books, Kimberley Aboriginal Law and Culture Centre, Broome.

- Lansberg, H. E., H. Lippman, K. H. Paffen, and C. Troll. 1966. World maps of climatology. Berlin: Springer Verlag.
- Lawes, M. J., H. R. Adie, J. Russell-Smith, B. P. Murphy, and J. J. Midgley. 2011. How do small savanna trees avoid stem mortality by fire? The roles of stem diameter, height and bark thickness. *Ecosphere* 2(4): Article 42.
- Leakey, R. R. B., K. Schreckenberger, and Z. Tchoundjeu. 2003. The participatory domestication of West African indigenous fruits. *International Forestry Review* 5(4).
- Lee, L. S. and K. Courtenay. 2016. Enrichment plantings as a means of enhanced bush food and bush medicine plant production in remote arid regions: A review and status report. *Learning Communities: International Journal of Learning in Social Contexts*, Special Issue: Synthesis and Integration 19: 64–75.
- Lehmann, C. E. R., L. D. Prior, and D. M. J. S. Bowman. 2009. Fire controls variation in stand structure of four dominant tree species in mesic tropical Eucalyptus savanna. *Oecologia* 161: 505–515.
- Lindsay, B. Y., K. Waliwararra, F. Milijat, H. Kuwarda, R. Pirak, A. Muyung, E. Pambany, J. Marryridj, P. Marrfurra, and G. Wightman. 2001. MalakMalak and Matngala plants and animals—Aboriginal flora and fauna knowledge from the Daly River area, northern Australia. Conservation Commission of the Northern Territory, Darwin.
- Low Choy, D., P. Clarke, D. Jones, S. Serrao-Neumann, R. Hales, and O. Koschade. 2013. Indigenous climate change adaptation: Understanding coastal urban and peri-urban Indigenous people's vulnerability and adaptive capacity to climate change. A report for the National Climate Change Adaptation Research Facility. Griffith University, Brisbane.
- Luckert, M. K., B. Campbell, and J. T. Gorman. 2007. The case for Indigenous natural resources management: Promise and problems in the wet-dry tropics of the Northern Territory. Darwin: Charles Darwin University Press.
- McRae-Williams, E. and R. Gerritsen. 2010. Mutual incomprehension: The cross-cultural domain of work in a remote Australian Aboriginal community. *International Indigenous Policy Journal* 1(2), Article 2.
- Miller, J. B., K. W. James, and P. M. Maggiore. 1993. Tables of composition of Australian Aboriginal foods. Aboriginal Studies Press 256.
- Millennium Development Summit 2000. [http://www.un.org/en/events/pastevents/millennium\\_summit.shtml](http://www.un.org/en/events/pastevents/millennium_summit.shtml). Accessed Oct 2019
- Mohanty, S. and I. E. Cock. 2012. The chemotherapeutic potential of *Terminalia ferdinandiana*: Phytochemistry and bioactivity. *Pharmacognosy Review* 6 (11): 29–36.
- Mundine, W. 2010. Wrong Mr Abbott, let's just get down to business. ABC News, 29 September 2010. <https://mobile.abc.net.au/news/2010-04-30/33878>. Accessed Oct 2019
- Murphy, B. P., A. C. Liedloff, and G. D. Cook. 2015. Does fire limit tree biomass in Australian Savannas? *International Journal of Wildlife* 24: 1–13.
- NAAKPA. 2018. North Australian Aboriginal Kakadu Plum Alliance. <https://naakpa.com.au/>. Accessed Oct 2019
- National Museum of Australia. 2019. Defining Moments: Aboriginal Land Rights Act. <https://www.nma.gov.au/defining-moments/resources/aboriginal-land-rights-act>. Accessed Oct 2019
- Netzel, M., G. Netzel, Q. Tian, S. Schwartz, and I. Konczak. 2007. Native Australian fruits—A novel source of antioxidants for food. *Innovative Food Science and Emerging Technologies* 8: 339–346.
- Newman, D. J. and G. M. Cragg. 2007. Natural products as sources of new drugs over the last 25 years. *Journal of Natural Products* 70(3): 461–477.
- Nikolakis, W. 2010. Barriers to Indigenous enterprise development on community owned land. *Global Business and Economics Review* 12 (1/2).
- Ohno, Y., K. Fukuda, G. Takemura, M. Toyota, M. Watanabe, N. Yasuda, Q. Xinbin, R. Maruyama, S. Akao, K. Gotou, T. Fujiwara, and H. Fujiwara. 1999. Induction of apoptosis by gallic acid in lung cancer cells. *Anticancer Drugs* 10: 845–851.
- Pascoe, B. 2014. Dark emu: Black seeds—Agriculture or accident. Magabala Books. ISBN 9781922142443.
- Pearson, N. 2009. Up from the mission: Selected writings. Melbourne: Black.
- Pedley, L. 1995. Combretaceae. *Flora of Australia* 18: 255–293.
- Puruntatameri, J., R. Puruntatameri, A. Pangiraminni, L. Burak, C. Tipuamantymirri, M. Tipakalippa, J. Puruntatameri, P. Puruntatameri, J.B. Pupangamirri, R. Kerinaiu, D. Tipiloura, M.-M. Orsto, B. Kantilla, M.

- Kurrupuwu, P.F. Puruntatameri, T.D. Puruntatameri, L. Puruntatameri, K. Kantilla, J. Wilson, J. Cusack, D. Jackson, and G. Wightman. 2001. Tiwi plants and animals: Aboriginal flora and fauna knowledge from Bathurst and Melville Islands, northern Australia. Parks and Wildlife Commission of the Northern Territory and Tiwi Land Council, Darwin.
- Raymond, E., J. L. Blutja, M. Gingina, O. Raymond, L. Raymond, J. Raymond, Q. Brown, Morgan, D. Jackson, N. Smith, and G. Wightman. 1999. Wardaman ethnobiology. Government Printer of the Northern Territory, Darwin.
- Robinson, D. F. 2010. Traditional knowledge and biological product derivative patents: Benefit-sharing and patent issues relating to Camu Camu, Kakadu Plum and Acai plant extracts. Traditional Knowledge Bulletin—Tropical Issues Series, United Nations University.
- Rose, D. B. 1996. Nourishing terrains—Australian Aboriginal views of landscape and wilderness. Australian Heritage Commission, Canberra.
- Scoones, I. 1998. Sustainable rural livelihoods: A framework for analysis. IDS Working Paper 72, Institute of Development Studies, University of Sussex, U.K.
- Sirdarta J, B. Matthews, and I. E. Cock. 2015. Kakadu Plum fruit extracts inhibit growth of the bacterial triggers of rheumatoid arthritis: Identification of stilbene and tannin components. *Journal of Functional Foods* 17: 610–620.
- Smith, M. and A. C. Kalotas. 1985. Bardi plants: An annotated list of plants and their use by the Bardi Aborigines of Dampierland, in north-western Australia. Records of the Western Australian Museum 12(3): 317–59.
- Smith, N. M. and G. M. Wightman. 1990. Ethnobotanical notes from Belyuen, Northern Territory, Australia. Northern Territory Botanical Bulletin No.10. Conservation Commission of the Northern Territory, Darwin.
- SRRATRC. 1998. Commercial utilisation of Australian native wildlife. Report of the Senate Rural and Regional Affairs and Transport References Committee. Parliament of the Commonwealth of Australia, Canberra.
- Sultanbawa Y. and F. Sultanbawa. 2016. Australian native plants: Cultivation and uses in alternative medicine and the food industry. CRC Press/Taylor and Francis Group.
- Tan, A. C., I. Konczak, I. Ramzan, and D. M.-Y. Sze. 2011. Potential antioxidant, anti-inflammatory, and proapoptotic anticancer activities of Kakadu Plum and illawarra plum polyphenolic fractions. *Nutrition and Cancer* 63(7): 1074–1084.
- Tapsell, L. G., P. Williams, V. Droulez, D. Southee, C. Patch, and A. Lethbridge. 2006. Functional foods for the Australian industry. National Centre for Excellence in Functional Food, University of Wollongong.
- Taylor, J., D. Brown, and M. Bell. 2006. Population dynamics and demographic accounting in arid and savanna Australia: Methods, issues and outcomes. DKCRC Report No 16. Desert Knowledge CRC and Tropical Savannas CRC, Alice Springs and Darwin.
- Traditional Homeland Enterprises. 2019. <https://thekakaduplum.com.au/>. Accessed Oct 2019
- Tremblay, P. and A. Wegner. 2009. Indigenous/Aboriginal tourism research in Australia (2000–2008): Industry lessons and future research needs. Gold Coast, Qld. Cooperative Research Centre for Sustainable Tourism.
- Twin Lakes Cultural Park. 2019. <http://twinlakes.net.au/page8/page8.html>. Accessed Oct 2019
- Vemuri, S. and J. Gorman. 2012. Poverty alleviation in Indigenous Australia. *International Journal of Environmental, Cultural, Economic and Social Sustainability* 8.
- Walsh, G. 2003. *Biopharmaceuticals: Biochemistry and biotechnology*. 3rd ed. Chichester: Wiley.
- Welter, R. 2010. Typical labour markets require typical policy solutions. In: *North Australian political economy: Issues and agendas*, ed. R. Gerritsen, 55–69. Charles Darwin University Press, Darwin.
- Wheeler, J. R. 1992. “Family Combretaceae.” In: *Flora of the Kimberley Region*, ed. J. R. Wheeler, 551–559. Department of Conservation and Land Management, Como.
- Whitehead, P. 2012. Indigenous livelihoods background paper. NAILSMA Knowledge Series, Issue 011.
- Whitehead, P. J., J. Gorman, A. D. Griffiths, G. Wightman, H. Massarella, and J. Altman. 2006. Small scale commercial plant harvests by Indigenous communities. A Report for the RIRDC/Land and Water Australia/FWPRDC/MDBC Joint Agroforestry Program. RIRDC, Barton, ACT, Australia.
- Wightman, G. M., J. G. Roberts, and L. L. V. Williams. 1992. Mangarrayi ethnobotany. Aboriginal plant use from the Elsey area, northern Australia. Northern Territory Botanical Bulletin

- No.15. Conservation Commission of the Northern Territory, Darwin.
- Willet, W. C. 2002. Balancing life-style and genomics research for disease prevention. *Science* 296: 695–698.
- Williams, D. J., D. Edwards, S. Pun, M. Chaliha, and Y. Sultanbawa. 2014. Profiling ellagic acid content: The importance of form and ascorbic acid levels. *Food Research International* 66: 100–106.
- Williams DJ, Edwards D, Pun S, Chaliha, D. J., ———, ———, ———, B. Burren, U. Tinggi, and Y. Sultanbawa. 2016. Organic acids in Kakadu plum (*Terminalia ferdinandiana*): The good (ellagic), the bad (oxalic) and the uncertain (ascorbic). *Food Research International* 89: 237–244.
- Woods, B. E. 1995. A study of the intra-specific variations and commercial potential of *Terminalia ferdinandiana* Exell. (the Kakadu Plum). School of Chemical Science, Northern Territory University, Darwin, Australia.
- WWF. 2018. Poverty and conservation. [http://www.panda.org/our\\_work/people/people\\_and\\_conservation/wwf\\_social\\_policies/poverty\\_and\\_conservation/](http://www.panda.org/our_work/people/people_and_conservation/wwf_social_policies/poverty_and_conservation/). Accessed Oct 2019
- Yunupingu, G. 2008. Tradition, truth and tomorrow. *The Monthly*, Dec. 2008–Jan. 2009: 32–40.
- Zander, K., B. Austin, and S. Garnett. 2014. Indigenous people's interest in wildlife-based enterprise in the Northern Territory, Australia. *Human Ecology* 42: 115–126.