The project was initiated to counter the degrading effects on natural systems of altered fire regimes. Before the project, the Kimberley's fire patterns were dominated by frequent extensive wildfires in the mid-to-late dry season – which contributed to observed biodiversity losses, degradation of ecological processes and cultural values, and reduced pastoral production.

EcoFire aims to restore biodiversity, pastoral and cultural values by reducing the incidence of these fires in the central and north Kimberley. It achieves this through strategic coordinated regional fire management across the 14 properties (5 million ha). Each year, the effectiveness of EcoFire in decreasing the size of unplanned fires and increasing the patchwork of burnt and unburnt areas across the region is examined. Fire patterns are compared against five targets to measure whether the goal of less intense and patchier fires is being achieved.

To date, EcoFire's prescribed burn programme has resulted in a substantial change to regional fire patterns. After just 1 year, improvements were achieved in all five targets including shifting more fires into the early rather than the mid-to-late dry season (i.e. 41% of all fires occurred early in the dry season during 2007, compared with 4–27% in the previous three years), and decreasing the average size of mid-late dry season fires. This was accomplished by an aerial prescribed burning programme, excellent on-ground knowledge of conditions and fire histories, and full participation by landowners and managers in the project areas.

The success of the project has relied on having a coordinated and strategic approach to fire management; clear measureable outcomes; successful engagement by participants with diverse interests and backgrounds (including frequent and personal communication and encouragement of ownership); productive partnerships with state and local government agencies; employment of a project leader who is a member of the community; and the flexibility to allow participants with various backgrounds (pastoralist, indigenous, conservation managers) to approach fire management differently.

EcoFire is funded by the Natural Heritage Trust via the Rangelands Natural Resource Management Coordinating Group, who contracted the Australian Wildlife Conservancy (AWC) to undertake the project. Given the widespread concern about changed fire regimes and biodiversity, the popularity of the project in the region, and the potential for capitalizing on greenhouse gas emission reductions, AWC anticipates sourcing funding to continue this project indefinitely.

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WEEDS & FERAL ANIMAL ISSUES & SOLUTIONS

20.35

Potential for the dispersal of weed seeds on clothing: An example with Gamba Grass in northern Australia.

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Introduction

Humans are arguably the best seed dispersers in the animal kingdom, particularly as dispersal distances in a mechanized world can be enormous. Seeds are unintentionally carried by vehicles and farm machinery, and are often unknowingly present in freight, garden soil, shoes and garden clippings, among many other things (Hodkinson & Thompson 1997; Blanco-Moreno *et al.* 2004; Benvenuti 2007). This type of seed dispersal has important consequences for the management and conservation of undisturbed environments, because weed species could establish as a result of unintentional dispersal by visitors and their equipment. In places where weeds have already established, management regimes recognize the importance of minimizing seed spread (Lemcke 2006).

Gamba Grass (*Andropogon gayanus* Knuth) is a significant weed in the tropical savannas of northern Australia. It has a very high biomass, which reduces the diversity of native pasture grasses, supports much hotter fires than native vegetation, and increases nitrogen losses from the ecosystem (Rossiter *et al.* 2003; Rossiter-Rachor *et al.* 2008). Spreading Gamba Grass seeds to non-invaded savannas should therefore be strongly discouraged by land managers. People are advised to clean machinery before moving into areas where Gamba Grass is absent, in order not to transport seeds (Lemcke 2006). The emphasis on preventing seed movement by humans has been on seed transport via vehicles and machinery (e.g. slashers). This article describes the potential for Gamba Grass seeds to be dispersed on clothing and personal equipment. Specifically, it assessed the number and location of seeds that unintentionally attached to the clothing and backpacks of four people, while performing field work in a Gamba Grass-invaded savanna.

Methods

Unintentional seed transport is described using four research assistants as subjects during the course of field work for an unrelated study conducted near Batchelor, 60 km south of Darwin, Northern Territory. Before the work, the four subjects were asked to remove existing Gamba Grass seeds from their clothing and equipment. Subjects walked approximately 500 m over 3 h, collecting tree-related data in a savanna heavily invaded by Gamba Grass. Small tape measures and GPS units were regularly placed into, and taken out of, shirt and jean pockets. Immediately after the field work, subjects were asked to count the number of Gamba Grass seeds on each piece of clothing, in their hair, and on the inside and outside of their backpack (if applicable). Each subject wore long trousers, a long sleeved shirt, socks and sandshoes or boots, and three of them (Subjects 1, 2 and 4) carried a backpack. Subject 1's backpack featured three internal compartments and two open water bottle compartments on the outside, which were not present on the backpacks of Subjects 2 and 4.

Results

Gamba Grass seeds attached to, and were carried by, each subject during the course of field work. There was however,

Table 1. Number and location of Gamba Grass seeds that attached to different areas of the body and the backpacks of four subjects (research assistants), after 3 h of field work in a savanna heavily invaded by Gamba Grass

Location on body		Number of seeds			
		Subject 1	Subject 2	Subject 3	Subject 4
Head	Hat	2			
	Hair	4	1		1
Upper body (shirt)	Exterior		9†		
	Pockets	8		8‡	
	Other (brassiere)				1
Lower body (jeans)	Exterior				
	Pockets	6			
Feet	Shoes	6	26	3	
	Socks				6
Backpack		39		–	
Total		65	36	11	8

†Data refer to the number of seeds on upper body overall; subject did not distinguish between seeds found on exterior and in pockets; ‡data refer to the number of seeds in all pockets (upper and lower body); subject did not distinguish between seeds found in shirt and trouser pockets.

a considerable difference in the number of seeds recorded on each subject. Subject 1 recorded the highest number of seeds (65), with the remaining subjects recording 36, 11 and 8 seeds. Over half (39 seeds, 60%) of the seeds recorded on Subject 1 were found on the backpack, whereas the head, upper body, lower body and feet areas each contained 6 or 8 seeds (Table 1). Most seeds recorded on the backpack had fallen into the outside water bottle compartments, although a few were located inside the main compartment. Seeds on the other subjects were also typically found in pockets (jeans and shirt) and in the crevices of shoes and socks, rather than on the exterior of clothes (Table 1). The backpacks carried by subjects 2 and 4, which did not possess external water bottle holders, did not trap seeds like subject 1.

Discussion

These observations demonstrate the potential for Gamba Grass seeds to be dispersed by people, on their clothing and personal equipment (such as backpacks). Gamba Grass seeds are not sticky and do not have sharp barbs, so they rarely attached to the exterior of clothing (i.e. shirts and trousers), but instead fell into crevices such as pockets and shoes. The high number of seeds in pockets (and external backpack pockets) probably relates to their use for storing equipment such as GPS units. Seeds were found to enter pockets on subjects' hands when equipment was being replaced. The difference in the number of seeds between subjects (8–65) was in part due to the design of the backpacks they carried, with open external compartments trapping many seeds.

Seed attachment on clothing and personal equipment, as described here, has important implications for the management of Gamba Grass in northern Australia, as well as other grassy weeds with similar seed dispersal mechanisms (e.g. Mission Grass, *Pennisetum pedicellatum* Trin. and *Pennisetum polystachion* (L.) Schult.; and Grader Grass, *Themeda quadrivalvis* (L.) Kuntze). While seeds are naturally dispersed by wind and water (and these agents of seed dispersal continue to be very important), human-dispersed seeds could be responsible for the establishment of some major, isolated populations. People who visit weed-infested areas (in northern Australia these include hunters, graziers, bushwalkers, land managers, trail bike riders, hobby farmers, etc.) should realize that they are likely to be unintentionally carrying seeds, which could easily be deposited in native vegetation by brushing against plants, or by taking equipment in and out of pockets. In addition, seeds may be transported much further afield (i.e. to a person's house) given the possibility for seeds to remain in pockets for extended periods. For Gamba Grass, seeds are known to remain viable for 3–6 years in laboratory conditions (Bowden 1964).

Strategies for reducing the unintentional dispersal of Gamba Grass seeds should include performing a full body check for seeds after working in invaded areas, as is recommended for Siam Weed (*Chromolaena odourata* (L.) R.M. King & H. Rob.; Biosecurity Queensland 2007). In reality, the time and effort required (10 min) probably prevents this precaution from being rigorously observed. As an alternative, albeit inferior, wearing shirts and trousers without pockets, ensuring that socks are fully covered (e.g. by boots), and carrying backpacks without exterior 'seed traps', could minimize seed attachment. Although not feasible for all situations, work could be restricted to periods after seed fall (late dry season and wet season), or after sites have been burnt, to minimize body contact with seeds. In conclusion, people who visit areas with weeds present should ensure that they do not carry and disperse seeds on their clothing and personal equipment, in addition to on their vehicles as is usually advised.

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References

Benvenuti S. (2007) Weed seed movement and dispersal strategies in the agricultural environment. *Weed Biology and Management* **7**, 141–157.

Biosecurity Queensland (2007) *Fact Sheet: Siam Weed (Chromolaena Odorata)*. Queensland Government, Department of Primary Industries and Fisheries, Brisbane, Qld. Available from URL: http://www.dpi.qld.gov.au/documents/Biosecurity_EnvironmentalPests/IPA-Siam-Weed-PP49.pdf.

Blanco-Moreno J. M., Chamorro L., Masalles R. M., Recasens J. and Sans F. X. (2004) Spatial distribution of *Lolium rigidium* seedlings following seed dispersal by combine harvesters. *Weed Research* **44**, 375–387.

Bowden B. N. (1964) Studies on *Andropogon gayanus* III. An outline of its biology. *Journal of Ecology* **52**, 255–271.

Hodkinson D. J. and Thompson K. (1997) Plant dispersal: the role of man. *Journal of Applied Ecology* **34**, 1484–1496.

Lemcke B. G. (2006) *Management of Kent Gamba Grass*. Northern Territory Government, Department of Primary Industry, Fisheries and Mines, Darwin, NT. Available from URL: http://www.nt.gov.au/dpifm/Content/File/p/Pasutre/672.pdf.

Rossiter N. A., Setterfield S. A., Douglas M. M. and Hutley L. B. (2003) Testing the grass-fire cycle: alien grass invasion in the tropical savannas of northern Australia. *Diversity and Distributions* **9**, 169–176.

Rossiter-Rachor N. A., Setterfield S. A., Douglas M. M., Hutley L. B. and Cook G. D. (2008) *Andropogon gayanus* (Gamba Grass) invasion increases fire-mediated nitrogen losses in the tropical savannas of northern Australia. *Ecosystems* **11**, 77–88.

BOOK REVIEWS

26.43

Farming With Nature: The Science and Practice of Ecoagriculture. Sara J. Scherr & Jeffrey A. McNeely (eds). Island Press, Washington, DC. XX + 445 pp.
ISBN 13: 978-1-59726-128-9. Price US$35 (paperback).

The term eco-agriculture was first coined in 2001 by McNeely and Scherr and refers to landscapes that achieve the joint objectives of sustainable agricultural production, biodiversity and ecosystem conservation, and rural livelihoods. The interest in the concept of eco-agriculture developed with the International Ecoagriculture Conference and Practitioners' Fair being held in Nairobi in September 2004. Some of the papers from the Nairobi conference have been presented in this book. The editors see the book providing a baseline for the science and practice of eco-agriculture; they have succeeded. It is an excellent book and introduces and develops some of the key issues that underpin successful sustainable production in agricultural landscapes.

The editors also anticipated that eco-agriculture innovators would adopt the concept of adaptive management. I am not as sure that this has been achieved, but that discussion is beyond the scope of this review, as is a discussion about the on-ground relevance of much of our ecology to the important agricultural-driven changes in our landscapes globally. I raise the last point as the editors of this book are making a plea for more eco-agricultural science; this can be achieved in many ways, but essentially needs to result in more researchers undertaking high quality relevant research.

The first chapter of the book provides an introduction to eco-agriculture and it is well worth reading. Scherr and McNeely are very capable ambassadors for eco-agriculture. They provide a case for eco-agriculture and provide guidance for researchers. It is not entirely clear if all contributing authors have the same intellectual and practical grasp of eco-agriculture, but that is a minor criticism. The first chapter more than makes up for the less than convincing treatment of eco-agriculture in a few of the subsequent chapters.

The book is divided into three parts that respectively cover agriculture production in eco-agriculture landscapes, biodiversity and ecosystem management in eco-agriculture landscapes, and institutional foundations for eco-agriculture. The latter is extremely important and covers community stewardship, leadership, planning, partnerships, incentive measures, and policy implications. Unless these institutional foundations are established and reinforced, it is doubtful that much of the wisdom outlined in the preceding sections will be of use.

The value of the book is the introduction of the new paradigm of eco-agriculture which is defined as integrated conservation-agriculture-landscapes where biodiversity conservation is an explicit objective of agriculture and rural development, and the latter are explicitly considered in shaping conservation strategies. This is seen as an inevitable and necessary consequence of the ecological footprint of agriculture – agricultural crops or planted pastures are the dominant land-use on nearly a third of the world's landmass, and a quarter of land is under extensive livestock grazing. The footprint is large and increasingly recognized as unsustainable. Furthermore, it is contended that the adverse outcomes from agriculture for biodiversity and wider ecosystem services are unlikely to be met by the solutions most widely advocated today, namely, industrial agriculture, the Green Revolution, sustainable agriculture and natural resource management, or even agro-ecologic or eco-technologic approaches. This may seem a radical claim, but it does raise the ante for agriculture and established food production mechanisms. The ante is also raised for ecologists and environmentalists with further statements that biodiversity conservation needs to move beyond the focus on wild biodiversity and the modest goals of integrated conservation and development projects. Rather, eco-agriculture is seen as a fully integrated approach to agriculture, conservation and rural livelihoods within a landscape or ecosystem context. It explicitly recognizes the economic and ecological relationships and inter-dependencies among agriculture, biodiversity and ecosystem services, and the need to reduce conflicts and promote synergies. It is not seen as an easy transition – the papers though clearly promote it as necessary and achievable.