The economic cost of managing Navua sedge (*Cyperus aromaticus*) - a monocot weed of tropical Queensland, Australia

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Summary Weeds incur yearly up to $4 Billion economic loss to Australia agriculture. Despite this knowledge, quantitative data on yield loss and control cost caused by weeds to the industry are few. We report herein, the economic cost of managing the invasive Navua sedge (*Cyperus aromaticus*) to the grazing and cropping (sugarcane) industries of northern Queensland, Australia. Navua sedge, was first documented in the wet tropical region of northern Queensland in 1970s, and now appear to be spreading fast and impacting negatively on both conservation and agricultural landscapes. Between 2020-2023, through elicitation and survey questionnaire given to impacted stakeholders (farmers), information relating to control (labour, chemical and machinery) cost, yield loss, and infestation history were documented. Invasion history is recent (mean time: 15 yrs; 95% CI range: 10-22 yrs), and infestation level varies significantly amongst properties (mean proportion of individual property infested: 30.8%; CI range: 15-46%; mean property size: 767.84 acres, range: 341-1193 acres). Cost of managing Navua sedge averaged $80 per hectare ($32.60 per acre), translating to $89/hectare ($36.02/acre) present value. This cost did not vary between land use types (grazing vs. cropping); however, the labour component (compared to chemical and machinery) of the control cost was the greatest, especially in the grazing industry. Correlation analyses suggest control cost will continue to increase with increasing levels of Navua sedge infestation over time, especially in grazing lands. Farmers show willingness to impose strict biosecurity measures and practice integrated weed management tactics while waiting for promising biocontrol agents to minimize the spread and impact of the weed.

Keywords: Biosecurity-measure, control cost, herbicides, stakeholders, weed impact

INTRODUCTION

Navua sedge (*Cyperus aromaticus* (Ridl.) Mattf. & Kük. (Cyperaceae) is a monocot weed of recent incursion in the coastal, northern part of the State of Queensland (QLD), Australia (Osunkoya *et al.* 2021, Shi *et al.* 2021). Following its introduction into the region in the 70's, Navua sedge has now become an aggressive weed affecting the beef, dairy, and sugarcane industries in both coastal and upland parts of the QLD wet tropics (see Shi *et al.* 2021). The weed spreads through both seeds and underground rhizomes in varying soil and land use types, including roadsides and along railway lines. It can form dense monospecific stands by replacing palatable tropical pasture species (Chadha *et al.* 2022a; Shi *et al.* 2021; 2022). Despite the above trends and challenges, there are no data on the yield loss or control cost to the grazing and/or cropping industries caused by Navua sedge. This study fills this knowledge gap, and hence the main purpose of this report is to gauge the pulse of impacted stakeholders on the economic cost of management of the weed through quantification of control cost and property productivity loss.

MATERIALS AND METHODS

In consultations with field biosecurity officers of The Queensland department of Agriculture and Fisheries (DAF), impacted (graziers and cropping) farmers, and pest management officers of local government (LG) areas in northern QLD, we formulated a set of questionnaires of 23 questions relating to Navua sedge weed management (labour, herbicide and machinery) cost and tactics including paddock spelling, and invasion history that can be answered within 30-45 minutes by stakeholders. We subjected the questionnaires through a series of iterations amongst above-listed groups before final approval by DAF in-house ethics committee. Collated data were analyzed using mainly non-parametric statistics due to skewed and/or qualitative nature of many of the responses.

RESULTS

Sample size (number of respondents) was moderate (N = 29), but confidence in stakeholders' response was very high and consistent (mean ($\pm$ SE) level of confidence: 80.8% ± 3.63). The history of awareness and spread of Navua sedge is recent on most stakeholder's properties (average time since infestation, ~ 10 to 20 years). Consequently, the proportion of stakeholder's land infested by the weed is currently low (30.81% $\pm$ 7.38%).

Control cost after adjusting for property size averaged \$15,661$\pm$ 5,444 per stakeholder, translating to \$79.17 ± 19.37 per hectare (\$32.04 ± 7.84 per acre, Fig. 1). The greatest component of current control cost is in labour: (mean: \$31.78 per ha, range: \$10.35 – \$51.42 or \$12.86 per acre, range: \$4.19 – \$20.81) chemical usage (mean: \$19.73 per ha, range: \$10.63 – \$29 or \$8.01 per acre, range: \$4.30 – \$11.74) machinery usage/maintenance (mean: \$18.34 per ha, range: \$2.45 – \$34.20 or \$7.42 per acre, range: \$0.99 – \$13.84) (Fig. 1). Farmers in the grazing industry are spending more on labour in control of the weed compared to other land use types (Fig 1). Chemical and machinery usage/maintenance cost are the same across land use types.

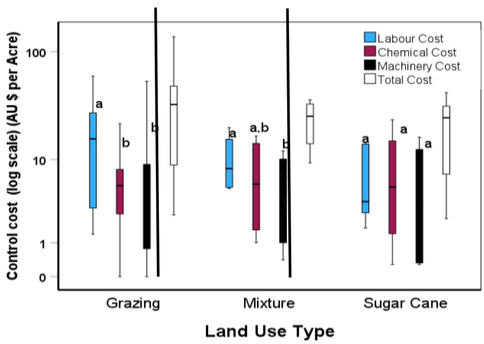

Figure 1. Box plots of three components of control (on a log scale) cost of Navua sedge weed infestation, with data for each land use type. Within land use type, cost median values that are significantly different (P <0.05) are indicated by different letters on the plots based on Kruskal-Wallis non-parametric test.

Management tactic (integrated weed management [IWM] vs chemical usage) did not differ between land use types, ($X^2_{2, 26}$ Fisher-Freeman exact test = 4.48: P = 0.09). Sempra^{TM} and Banjo™ adjuvant (Halosulfuron, with non-ionic surfactant) is the dominant post emergence herbicide being used; other infrequently used chemicals were Glysophate (Roundup^{TM}), Hexazinone, Triclopyr Picloram mix (Access^{TM}) and Paraquat. IWM tactics varied widely across farms, and novel options are often used - including rotational grazing, minimal tillage and discing, replanting following herbicide treatment with desirable pastures of Humidicola (*Brachiaria humidicola*) and para/signal grass (*Brachiaria mutica*), riparian corridor fencing, strict biosecurity protocol such as vehicle washdown, minimal/no slashing where properties abut roadsides maintain by LG councils.

In the grazing industry, average spelling time following chemical application to manage the weed was of the order of 2 to 4 weeks, and loss in terms of cost appeared negligible (\$55.67 per ha, range: \$0-\$192.96 or \$22.53 per acre, range: \$0-\$78.09), though this loss can be significant for large (> 1000 ha) properties (~\$300,000 per year). We found weak or no relationship between control cost and infestation level/time (Fig. 2), though it appears that cost of control increases with increasing weed infestation, up to 40-60% for grazing farmers, and then decreases thereafter; for sugarcane farmers, this threshold appears to be 25—20%. Nonetheless, pooled data suggest control cost increases with increasing Navua sedge weed infestation on properties (Fig. 2).

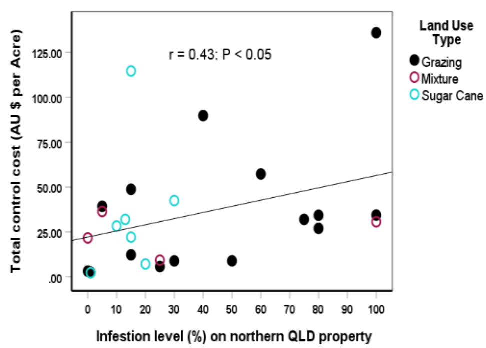

Figure 2. Total control cost (AU \$) of Navua sedge weed infestation as a function of fraction of individual northern Queensland property infested. Regression line is for pooled data across land use types.

DISCUSSION

Weed impacts can be measured as the direct financial costs of control (herbicide, machinery use, or labour need etc.), losses in production, changes in net financial benefits, and changes in welfare (Sinden *et al.* 2004). We recorded high confidence in the scoring and assessment by the stakeholders (at least 70%, irrespective of land use type) – suggesting a high reliability of the information provided. The high confidence reported reflects farmers awareness of the problem and their level of proactiveness/preparedness rather than reactiveness to the challenge; it shows farmers have the competences needed to manage the challenge (Campbell *et al.* 2023).

Though non-significant due to large variation within land-use type, it appears that cropping (sugarcane) farmers are spending less (mean and SE: \$59.31/ha ± \$19 or \$24 ± \$7.70 /acre) on control of Navua sedge compared to graziers (\$88.96 /ha ± 27.87 or \$36 ± \$11.28 /acre), even after adjusting for property size**.** Reasons for this difference are hard to deduce from this work, though factors such as level of awareness, belief that sugar canes in planted areas grow taller and hence outcompete the weed in the long run, thus no need to expend cost on the challenge, or there are other well established weeds of higher priority affecting the industry (e.g., nut grass [*Cyperus rotundus*], Kikuya grass [*Pennisetum clandestinum*], Johnstone grass [*Sorghum halepense*], and **Sicklepod [*Senna obtusifolia*])** (Ross & Fillols 2017**).** As our sample size was low and a limited number of other cropping (e.g., sweet potato, banana) farmers in the region participated in the survey, it is an area that deserved more attention.

We found that of the three components of control costs, labour is the most expensive (see also Ansong *et al.* 2021). Labour cost was the main driver of total control cost – increasing linearly with increasing proportion of property infested by the weed (Spearman rank $r = 0.43$, P = 002), and can be expected to increase even more with time in an industrialized economy like Australia where wages are often high. Thus, there is a need to automate labour component of control measures (e.g., via the use of drones/remote sensing to map weed distribution at the farm and landscape scales) such that herbicide (and biocontrol in the future) delivery are more targeted (see Costello *et al*. 2022).

Farmers reported use of both registered (e.g., Halosulfuron with a non-ionic surfactant, Sempra™ with Banjo™ as the wetting agent) and experimental/trial herbicides to manage the weed. Farmers have their own formulation because from their experience, the registered herbicide – Sempra™ - has not proven effective, due to persistent soil rhizome and seed banks of the species following chemical treatment, and hence reinfestation by the weed (see also Chadha *et al.* 2022a, b). Research is ongoing to develop other herbicides in view of this concern (Florentine Singarayer, personal communication). Many impacted farmers have also advocated and resorted to strict biosecurity measures around their properties, such as, fencing (especially along riparian corridors abutting their farms), minimal tillage and no pasture slashing on conservation (roadside) lands manage by local governments and abutting their farms.

Through stakeholders' consultation, we have derived a value of mean control cost for the Navua sedge of \$80.3 (i.e., with labour, chemical, machinery: \$32.78, \$24.37, \$26.42, respectively) per hectare or \$32.04 per acre (\$13.27, \$9.87, and \$10.7, respectively). These values, derived in 2021/202 can be integrated forward into present/future values using the expression: future value = present value *(1+inflation rate)^number of years); assuming average yearly inflation rate of 3%, the control cost per hectare at today's value will be \$89). These costs, when integrated backward are similar to values reported at the Australia commonwealth and State levels for control of weeds in both cropping and grazing environment (see Sinden *et al*. 2004, Llewellyn *et al*. 2016, Table 37). Our derived yield loss due to spelling for grazing land averaged \$55.77 per hectare but has a wide band (\$0- \$192) as some farmers do not spell at all (hence they report no or minimal dollar cost to spelling), but rather rotate their cattle between blocks, perhaps due to the large size of their properties and their willingness to impose strict biosecurity measures.

CONCLUSION

Through elicitation, we have captured stakeholders concern of the economic impact and control options for the invasive Navua sedge. Labour (compared to chemical and machinery) appeared to be the more expensive component of control cost. Registered herbicide (Sempra™) for the weed has low efficacy (as below-ground tubers are not destroyed nor seed bank affected). Consequently, while waiting for effective chemical and, more importantly, promising biological control agent/s (see Dhileepan et al. 2022), many farmers seem to have developed strong biosecurity protocols and experimental management tactics as part of their short-term arsenals to minimize the spread of the weed.

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REFERENCES

Ansong, M., Acheampong E., Echeruo J.B., Afful S.N. and Ahimah M. (2021) Direct financial cost of weed control in smallholder rubber plantations. *Open Agriculture* 6:346–355

Campbell, R., Height, K., Hawkes, G., Graham, S., Schrader, S., Blessington, L., and McKinnon, S. (2023). Meanings, materials and competences of area-wide weed management in cropping systems. *Agricultural Systems* 212, 103776.

Chadha, A., Osunkoya, O.O., Shi, B., Florentine, S.K., and Dhileepan, K. (2022a). Soil seed bank dynamics of pastures invaded by Navua sedge (*Cyperus aromaticus*) in tropical north Queensland. *Frontier In Agronomy*. 2022, 4, 897417

Chadha, A., Florentine, S. K., Dhileepan, K., Turville, C., and Dowling, K. (2022b). Efficacy of halosulfuron-methyl in the management of Navua sedge (*Cyperus aromaticus*): Differential responses of plants with and without established rhizomes. *Weed Technology*, 36, 397–402.

Costello, B., Osunkoya, O.O., Sandino, J., Marinic, W., Trotter, P., Shi, B., Gonzalez, F., and Dhileepan, K. (2022). Detection of Parthenium Weed (*Parthenium hysterophorus* L.) and Its Growth Stages using Artificial intelligence. *Agriculture* 12, 1838

Dhileepan, K., Musili, P. M., Ntandu, J.E., Chukwuma, E., Kurose, D., Seier, M. K., Ellison, C. A., and Shivas, R. G. (2022) Fungal pathogens of Navua sedge (*Cyperus aromaticus)* in equatorial Africa as prosp ective weed biological control agents. *Biocontrol Science and Technology*, 32, 114–120.

Llewellyn R., Ronning, D., Clarke, M., Mayfield A., Walker S., and Ouzman J. (2016). Impact of weeds in Australian grain production. Grains Research and Development Corporation, Canberra. Australia. https://www.grdc.com.au/__data/assets/pdf_file/0027/75843/grdc_weeds_review_r8.pdf.pdf

Osunkoya O.O., Lock, C.B., Dhileepan, K., and Buru, J.C. (2021) Lag times and invasion dynamics of established and emerging weeds: insights from herbarium records of Queensland, Australia. *Biological Invasions*, 23 (11), 3383- 3408.

Ross, P. and Fillols E. (2017). Weed management in sugarcane manual. BSES Ltd, Sugar Research Australia; 147 pages. https://www.sugarresearch.com.au/sugar_files/2017/03/Weed_Management_in_Sugarcane_Manual.pdf

Shi, B., Osunkoya, O.O., Soni A., Campbell S., and Dhileepan K. (2022) Growth of the invasive Navua sedge (*Cyperus aromaticus*) under competitive interaction with pasture species and simulated grazing conditions: Implication for management. *Ecological Research*,38(2), 331-336

Shi, B., Osunkoya O.O., Chadha A., Florentine, S.K., and Dhileepan, K, (2021). Biology, ecology and management of the invasive Navua sedge (*Cyperus aromaticus*)—A global review. *Plants* 10:1851

Sinden, J., Jones, R., Hester, S., Odom. D., Kalisch, C., James, R., and Cacho, O. (2004). The Economic Impact of Weeds in Australia. Technical Series No. 8. *Cooperative Research Centre for Australian Weed*

Management, Adelaide, South Australia, 65 pp. 25. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20053008790