International Journal of Agricultural Technology 2025 Vol. 21(1):107-124
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Distribution of weed species and soil nitrogen, phosphorus, and potassium across various land uses in coastal areas

Muktamar, Z.[1*], Setyowati, N.[2], Utami, K.[1], Haris, H. A.[2], Nurjanah, U.[2], Sukisno, S.[1] and Hindarto, K. S.[1]

[1]Department of Soil Science, University of Bengkulu, Indonesia; [2]Department of Crop Production, University of Bengkulu, Indonesia.

Muktamar, Z., Setyowati, N., Utami, K., Haris, H. A., Nurjanah, U., Sukisno, S. and Hindarto, K. S. (2025). Distribution of weed species and soil nitrogen, phosphorus, and potassium across various land uses in coastal areas. International Journal of Agricultural Technology 21(1):107-124.

Abstract The survey identified a total of 81 weed species, which included 42 species of broadleaf weeds, 25 grasses, 9 sedges, and 5 ferns. The oil palm plantation exhibited the most weed diversity, with a total of 40 species, including 19 broadleaf, 13 grasses, 3 sedges, and 5 ferns. In contrast, the rice farm had the lowest weed diversity, consisting of just 8 species, including 3 broadleaves, 3 grasses, and 2 sedges. The number of weed species in oil palm plantations was comparable to that in rubber plantations, although greater than in coconut plantations. In coconut and oil palm plantations, broadleaf weed species were the most common, accounting for 58.05% and 50.89% of the total weed population, respectively. On the other hand, in rubber plantations and swamp land, grasses were the dominating weed species, making up 44.68% and 56.24% of the Summed Dominance Ratio (SDR), respectively. *Melastoma affine* D. Don was the dominant weed species in oil palm and rubber plantations, with an SDR of 9.44% and 7.09%, respectively, while *Borreria alata Aubl*. is the primary weed species in coconut plantations, with an SDR of 12.70%. However, in swamp land, *Isachne globosa* (Thunb.) O.K., a type of grass, makes up 14.43% of SDR. Furthermore, the swamp land exhibited the highest soil nitrogen concentration (5982.53 mg/kg). The coconut plantation had the highest soil phosphorus level (2.76 mg/kg), while the rice farm had the highest soil potassium (226.18 mg/kg). The Pearson correlation analysis revealed a negative association between the prevalence of broadleaf weed species and grasses. Likewise, there was a negative correlation between broadleaf weeds and soil N, suggesting that these specific weeds can compete under low nitrogen. The discovery of this study has advantageous implications for the management of weed control in coastal environments.

Keywords: Coastal regions, Land use, Plantations, Soil nutrient, Weed diversity

Introduction

Weeds are considered as plants undesirable in a specific location or interfere with the growth of other plants. Weeds in agriculture impair

[*] **Corresponding Author**: Muktamar, Z.; **Email**: muktamar@unib.ac.id

agricultural production by competing for light, water, and plant nutrients, resulting in drastically lower crop yields and quality. The potential yield loss varies among the crops, soybean 50-75% and groundnut 45-71%. The loss is dependent on the crops and soil types (Gharde *et al.,* 2018). Winter wheat yield loss can reach 34.4%, equivalent to approximately 10.5 billion kg (Flessner *et al*. 2021). Weed invasion resulted in a 30.1% decline in rice yield (Widayat and Purba, 2015). Oerke and Dehne (2004) calculated yield losses of 35%, 39%, and 40% for maize, potatoes, and rice, respectively.

Understanding weed distribution patterns benefits farmers and plantation managers by allowing them to deploy targeted weed management strategies, reducing the demand for broad-spectrum herbicides while minimizing environmental deterioration. Similarly, understanding weed ecology aids in predicting potential weed incursions and developing long-term management strategies. This proactive approach not only increases crop output and sustainability but also contributes to the overall health of the plantation ecosystem (Swanton and Murphy, 1996; Ghersa *et al*., 1994; Harker and O'Donovan, 2013).

An analysis of prevalent weed species in various types of plantations indicates a diverse range of troublesome plants that can substantially influence agricultural output. *Avena fatua* (wild oat) and *Chenopodium album* (common lambsquarters) are commonly found in cereal crop plantations and are known to compete strongly with the major crops (Holm *et al*., 1997; Heap, 2022). Bermuda grass (*Cynodon dactylon*) and cogongrass (*Imperata cylindrica*) are frequently found in sugarcane farms, presenting notable difficulties because of their vigorous growth (Rathika *et al*., 2023). *I. cylindrica*, *Spigelia anthelmia*, and *Ageratum conyzoides* are commonly found in oil palm farms due to their fast and challenging growth, making them difficult to control (Sahari *et al*., 2023). Comprehending the dispersion and attributes of these prevalent weed species is crucial for formulating efficient integrated weed management strategies customized to certain plantation types. In some ways, the growth of weeds depends on the nutrient content of the soil.

The importance of soil nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), in the growth of plants and the overall health of ecosystems is significant. Nitrogen has a vital role in the production of amino acids, proteins, and chlorophyll, directly affecting photosynthesis and overall plant growth (Hawkesford *et al*., 2012). Phosphorus is crucial for conveying energy through ATP, root development, and flowering. It plays a vital role in the reproductive success and productivity of crops and eliciting physiological responses to abiotic stress (Schachtman *et al*., 1998; Khan *et al*., 2023). Potassium regulates various physiological processes, such as protein synthesis, sugar transport, N and C metabolism, and photosynthesis (Xu *et al*., 2020), enhancing plant resilience and productivity (Marschner, 2012). The balanced presence of these macronutrients ensures robust plant growth, which subsequently sustains soil structure, microbial diversity, and overall ecosystem health.

Soil nutrient concentration significantly influences weed proliferation and distribution. High nitrogen levels frequently stimulate the proliferation of nitrophilous weeds like lambs quarters (*C. album*) and pigweed (*Amaranthus spp*.), which can outperform crops by efficiently utilizing accessible nutrients (Kousta *et al*., 2023). On the other hand, low nutrient concentrations may promote the growth of weed species that are better able to withstand and reproduce in soils with limited nutrients. This dynamic can alter weed composition and distribution patterns within agricultural fields, which can possibly complicate weed management strategies. Studies have demonstrated that altering soil nutrient levels through fertilization practices can unintentionally promote the growth of certain weeds. This condition highlights the necessity for comprehensive weed control strategies that take into account nutrient management in conjunction with other cultural, mechanical, and chemical methods (DiTomaso, 1995; Blackshaw *et al*., 2002).

The environmental condition also significantly affects the proliferation and the spread of weeds. The coastal environment plays a significant role in shaping plant and weed species diversity due to the presence of saline soils, sandy soils, and frequent disturbances from tidal actions. The prevailing conditions in this ecosystem provide a challenging habitat that supports the growth of salt-tolerant and halophytic species while preventing the survival of non-adapted plants. Consequently, coastal areas frequently have a unique collection of plants that thrive in saline environments (Cirillo *et al*., 2018). The study aimed to assess the distribution of weed species in various land uses in coastal areas, compare the content of N, P, and K across different land uses, and examine the relation between weed dominance and soil nutrient content.

Materials and methods

Study area and sampling

The study took place in the Air Napal Sub-District, located in the North Bengkulu District of Bengkulu Province, Indonesia, covering an area of 156 square kilometers. This location spans approximately 15 kilometers along the Indian Ocean coastline, thereby experiencing considerable influence from the coastal environment. The sampling technique involved dividing the study area into strata based on similar land use, with samples taken from each stratum. The location features five distinct types of agricultural land use: oil palm plantations, rubber plantations, coconut plantations, swamp land, and rice farms. Weed and soil samples were collected randomly within each land use area, using specific coordinates as collection points.

Coordinates for weed and soil sampling were determined using a working map created by overlaying several existing maps and satellite images and processing them with ArcGIS software. The existing maps included the Indonesian earth map of Bengkulu at a 1:50,000 scale, a land use map, the administrative map of Air Napal Subdistrict, and a satellite image. The resulting working map is shown in Figure 1.

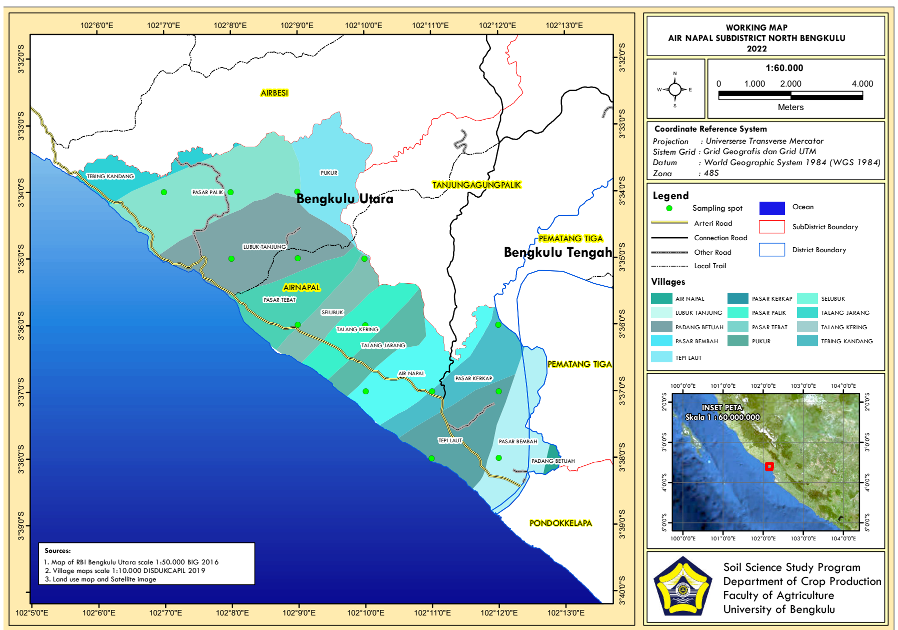

Figure 1. Coordinates of weed and soil sampling in the SubDistrict of Air Napal, North Bengkulu

Each coordinate within the corresponding land use was sampled for weeds using the quadrant method, with an area of 100 cm x 100 cm. When the spot was located in a sloping area, weed samples were collected using the transect method at the top, middle, and bottom of the slope, and samples were taken purposefully to ensure they were representative of the area. Soil samples were taken compositely from five spots within a 0-20 cm depth. These soil samples were then air-dried, ground, and sieved with a 0.5 mm screen. The samples were analyzed for total soil nitrogen (TSN) using the Kjeldahl method, available phosphorus (P) using the Bray-I method, exchangeable potassium (K) using the flame photometric method, and pH using a pH meter with a 1:1 ratio of soil to distilled water.

Weed species identification and dominance

Weed samples from each coordinate were sorted by species. Identification was conducted promptly to prevent damage to the weed parts, or the weeds were preserved for herbarium specimens. Each species' characteristics and morphologies of root, stem, leaf, and flower were matched to references such as "Weeds of Rice in Indonesia," "Flora for Schools in Indonesia," and/or "Weeds of 220 Sugar-Cane Fields in Java" to determine if they were broadleaf, grass, sedge, or fern weeds. The identified species were recorded and tabulated for further analysis. The dominance of weed species was represented by the Summed Dominance Ratio (SDR), calculated using the formula developed by Mangoensoekarjo and Soejono (2015) as follows:

Summed dominance ratio (SDR) = $\frac{RF+RD+RN}{3}$

Where:

The relative frequency (RF) = $\frac{\text{AF weed X}}{\text{AF all weed types}} \times 100\%$.

Absolute frequency (AF) is the number of weed species in the spot at each land use.

Relative dominance (RD) = $\frac{\text{AD weed X}}{\text{AD all weed types}} \times 100\%$.

Absolute dominance (AD) is the weight of weeds in the spot at each land use.

The relative density (RN) = $\frac{\text{AN weed X}}{\text{AN all weed types}} \times 100\%$.

Absolute density (AN) is the number of weed types in the spot at each land use.

Data analysis

Regression analysis at a 95% confidence level was used to determine the relationship between weed dominance and soil nutrients.

Results

Distribution of weed species

The distribution of weed species varied significantly across different land uses due to variations in environmental conditions and human activities, such as land management practices and agricultural methods, which play a crucial role in shaping weed distribution and dominance across landscapes. The weed survey in the study area identified a total of 81 weed species. Broadleaf weeds were the most prevalent, accounting for 42 species, followed by grasses with 25 species, sedges with 9 species, and ferns being the least common with 5 species. Number of species and SDR in each land use is presented in Table 1. Oil palm plantations exhibited the highest diversity of weeds with 40 species, followed by rubber and coconut plantations, while rice farms had the least diversity with only 8 species. In coconut and oil palm plantations, the majority of species were broadleaf weeds (Table 1). Conversely, grasses were more dominant in rubber plantations, swamp lands, and rice farms. Coconut plantations had the highest Summed Diversity Ratio (SDR) for broadleaf weeds, followed by oil palm plantations. Swamplands recorded the highest SDR for grasses, followed by rubber plantations. Rice farms achieved the highest SDR for ferns. Overall, coconut, oil palm, and rubber plantations had much lower SDRs of sedge compared to swamp lands and rice farms (Table 1).

Table 1. Number of species and summed dominance ratio (SDR) in the study area

Weed Group	Land Use				
	Coconut Plantations	Oil Palm Plantations	Rubber Plantations	Swamp Land	Rice Farms
	Number of species				
Broadleaf	20	19	22	7	3
Grass	7	13	7	9	3
Sedge	2	3	3	5	2
Fern	3	5	5	2	0
Total	32	40	37	23	8
	SDR (%)				
Broadleaf	58.05	50.89	40.41	15.97	35.29
Grass	34.11	40.21	44.68	56.24	20.50
Sedge	3.40	2.22	3.63	24.86	44.21
Fern	4.44	6.68	11.29	2.93	0.0

This study also showed that in coconut plantations, the broadleaf weed group predominates, accounting for 58.05% of SDR. The most dominant species were *B. alata* Aubl with an SDR of 12.70%, followed by *Elephantopus scaber* Linn at 6.28% and *Spermacoce remota* Lamk at 6.15%. The grass group was the second most prevalent, with 34.11% of SDR, and is led by *Axonopus compressus* (Sw.) Beauv with an SDR of 12.12%, while *Digitaria longiflora* (Rets.) Pers was the least prevalent at 4.44%. Weed groups of sedges and ferns were much less dominant, with SDRs of 4.44% and 3.40%, respectively (Table 2).

Table 2. Weed dominance in coconut plantations

No	Weed species	Family	SDR (%)
	Broadleaf Group		
1	*Amaranthus gracilis* Desf	*Amaranthaceae*	1.95
2	*Borreria alata* Aubl.	*Rubiaceae*	12.70
3	*Borreria laevis* (Lamk.) Griseb	*Rubiaceae*	0.58
4	*Centella asiatica* (L.) Urb	*Apiaceae*	0.51
5	*Clidemia hirta* (L.) D. Don	*Melastomaceae*	2.32
6	*Desmodium triflorum* (L.) DC	*Fabaceae*	3.37
7	*Elephantopus scaber* Linn	*Asteraceae*	6.28
8	*Hedyotis diffusa spreng*	*Rubiaceae*	3.22
9	*Hyptis capitata* L.	*Lamiaceae*	0.73
10	*Melastoma affine* D. Don	*Melastomaceae*	5.68
11	*Passiflora foetida* L.	*Passifloraceae*	0.80
12	*Rostellularia sundana* Bremek	*Acanthaceae*	2.30
13	*Sida rhombifolia* L	*Malvaceae*	1.13
14	*Spermacoce remota* Lamk	*Rubiaceae*	6.15
15	*Sphagneticola trilobata* (L.) Pruski	*Asteraceae*	4.61
16	*Sphenoclea* zeylanica Gaertn	*Sphenocleaceae*	0.84
17	*Stachytarpheta indica* (L.) Vahl	*Verbenaceae*	0.85
18	*Stachytarpheta jamaicensis* (L.) Vahl	*Verbenaceae*	2.36
19	*Synedrella nodiflora* (L.) Gaertn.	*Asteraceae*	1.18
20	*Vernonia cinerea* (L.) Less	*Asteraceae*	0.50
	Total		58.05
	Grass Group		
24	*Axonopus compressus* (Sw.) Beauv	*Poaceae*	12.12
25	*Digitaria longiflora* (Rets.) Pers.	*Poaceae*	7.05
26	*Isachne globosa* (Thunb.) O.K	*Poaceae*	4.44
27	*Isachne Pulchella* Roth. M.R & S	*Poaceae*	2.29
28	*Paspalum conjugatum* Berg.	*Poaceae*	0.69
29	*Paspalum* sp.	*Poaceae*	2.52
30	*Zoysia japonica* Steud	*Poaceae*	4.99
	Total		34.11
	Sedge Group		
31	*Fimbristylis dichotoma* (L.) Vahl	*Cyperaceae*	2.56
32	*Fimbristylis tomentosa* Vahl	*Cyperaceae*	1.88
	Total		4.44
	Fern Group		
21	*Christella normalis*	*Thelypteridaceae*	0.56
22	*Lygodium palmatum* (Bernh.) Sw.	*Lygodiaceae*	1.66
23	*Lygodium scandens* (L.) Sw	*Lygodiaceae*	1.18
	Total		3.40
	Grand Total		100

Table 3. Weed dominance in oil palm plantations

No	Weed Species	Family	SDR (%)
	Broadleaf Group		
1	*Ageratum conyzoides* L.	*Asteraceae*	2.24
2	*Asystasia gangetica* (L.) T. Anderson	*Acanthaceae*	0.89
3	*Borreria alata* Aubl.	*Rubiaceae*	4.78
4	*Borreria laevis* (Lamk.) Griseb	*Rubiaceae*	2.86
5	*Clidemia hirta* (L.) D. Don	*Melastomaceae*	6.26
6	*Desmodium heterophyllum* Hook. & Arn	*Fabaceae*	0.24
7	*Desmodium triflorum* (L) DC.	*Fabaceae*	1.44
8	*Elephantopus mollis* Kunth	*Asteraceae*	0.57
9	*Elephantopus scaber* Linn	*Asteraceae*	4.70
10	*Eupatorim oduratum* L.	*Asteraceae*	2.16
11	*Hyptis capitata* L.	*Lamiaceae*	4.49
12	*Melastoma affine* D. Don	*Melastomaceae*	9.44
13	*Mikania micrantha* H.B.K.	*Asteraceae*	0.22
14	*Mimosa quadrivalvis* (L.)	*Fabaceae*	0.51
15	*Sida rhombifolia* L	*Malvaceae*	0.56
16	*Sphagneticola trilobata* (L.) Pruski	*Asteraceae*	6.71
17	*Stachytarpheta indica* (L.) Vahl	*Verbenaceae*	1.09
18	*Stachytarpheta jamaicansis* (L.) Vall	*Verbenaceae*	1.51
19	*Synedrella nodiflora* (L.) Gaertn.	*Asteraceae*	0.24
	Total		50.89
	Grass Group		
25	*Axonopus compressus* (Sw.) Beauv	*Poaceae*	6.86
26	*Chrysopogon argutus* (Nees ex Steud.) Trin. ex B.D.Jacks.	*Poaceae*	6.62
27	*Cynodon dactylon* (L.) Pers.	*Poaceae*	3.28
28	*Cyrtococeum acrescens* (Trin.) Stapf	*Poaceae*	1.69
29	*Digitaria ciliaris* (Retz.) Koel	*Poaceae*	0.48
30	*Digitaria fuscescnes* (J.Presl) Henrard	*Poaceae*	0.88
31	*Digitaria longiflora* (Rets.) Pers.	*Poaceae*	6.79
32	*Isachne globosa* (Thunb.) O.K	*Poaceae*	2.34
33	*Isachne Pulchella* Roth. M.R & S	*Poaceae*	0.47
34	*Ottochloa nodosa* (Kunth) Dandy	*Poaceae*	7.43
35	*Paspalum commersonii* Lamk	*Poaceae*	0.39
36	*Polytrias amaura* (Bucisa) D.K	*Poaceae*	0.35
37	*Zoysia*matrella (L.) Merr.	*Poaceae*	2.62
	Total		40.21
	Sedge Group		
38	*Eleocharis ochrostachys* Steud.	*Cyperaceae*	0.69
39	*Scleria lithosperma (*L.) Sw.	*Cyperaceae*	0.32
40	*Scleria sumatrensis* Retz	*Cyperaceae*	1.21
	Total		2.22
	Fern Group		
20	*Christella normalis*	*Thelypteridaceae*	1.25
21	*Gleichenia linearis*	*Gleicheniaceae*	1.40
22	*Lygodium microphyllum* (Cav.) R. Br.	*Lygodiaceae*	0.73
23	*Lygodium palmatum* (Bernh.) Sw.	*Lygodiaceae*	2.13
24	*Lygodium scandens* (L.) Sw	*Lygodiaceae*	1.17
	Total		6.68
	Grand Total		100

The study further revealed that the broadleaf weed group was the most prevalent in oil palm plantations, with an SDR of 50.89%, followed by the grass group (SDR of 40.21%). This result indicated that the broadleaf group is 26.6% more dominant than the grass group. Among the broadleaf species, *M. affine* D. Don was the most predominant, with an SDR of 9.44%, followed by *Sphagneticola trilobata* (L.) Pruski at 6.71%, and *Desmodium heterophyllum* Hook. & Arn at 0.24%. In the grass group, *Ottochloa nodosa* (Kunth) Dandy was the most dominant species with an SDR of 7.43%, while *Polytrias amaura* (Bucisa) D.K was the least at 0.35%. Like coconut plantations, the sedge and fern weed groups had much lower SDRs, at 2.22% and 6.68%, respectively (Table 3).

A slightly different pattern is found in rubber plantations where the grass group is the most prevalent weed species, with an SDR of 44.68%, higher than the broadleaf group, which had an SDR of 40.41% (Table 4). The sedge group had the lowest SDR at 3.62%. The grass group was 11.3 times more prevalent than the sedge group. Within the grass group, *O. nodosa* (Kunth) Dandy was the predominant species, accounting for 25.34% of the SDR, while *Brachiaria mutica* (Forssk.) Stapf had the lowest SDR at 0.53%. Likewise, in the broadleaf group, *M. affine* D. Don was the most common weed with an SDR of 7.09%, and *Phyllanthus debilis* Klein ex. Wild had the lowest SDR at 0.63%. Similar to coconut and oil palm plantations, the sedge and fern groups contributed less than the other two.

It indicated that the grass group dominates the weed species in swamp land, with an SDR of 56.24%, 3.52 times higher than the SDR of the broadleaf group (Table 5). In contrast, the fern group had the lowest SDR at 2.92%. The table also showed that the predominant weed species in swamp land were *I. globosa* (Thunb.) O.K and *Leersia hexandra* Sw, with SDR of 14.43% and 13.99%, respectively, both belonging to the grass group. Additionally, the sedge weed group was 55.6%which more prevalent than the broadleaf group. Within the broadleaf group, *Merremia umbellata* (L.) Hallier f. was the most common, with an SDR of 3.67%, while *Polygonum barbatum* C. had the lowest SDR at 0.91%.

Table 4. Weed dominance in rubber plantations

No	Weed Species	Family	SDR (%)
	Broadleaf Group		
1	*Asystasia gangetica* (L.) T. Anderson	*Asteraceae*	2.96
2	*Borreria alata* Aubl.	*Rubiaceae*	1.30
3	*Borreria laevis* (Lamk.) Griseb	*Rubiaceae*	1.92
4	*Caladium bicolor*	*Araceae*	0.71
5	*Calyptocarpus vialis* Less.	*Asteraceae*	2.35
6	*Clidemia hirta* (L.) D. Don	*Melastomaceae*	0.84
7	*Desmodium heterophyllum* Hook. & Arn	*Fabaceae*	1.99
8	*Desmodium triflorum* (L.) DC	*Fabaceae*	0.55
9	*Elephantopus mollis* Kunth	*Asteraceae*	1.93
10	*Euphorbia hirta* L.	*Euphorbiaceae*	0.47
11	*Hyptis capitata* L.	*Lamiaceae*	0.56
12	*Ipomoea obscura* (L.) Ker Gawl.	*Convolvulaceae*	1.09
13	*Isotoma longiflora* (L.) C. Presl	*Campanulaceae*	0.78
14	*Melastoma affine* D. Don	*Melastomaceae*	7.09
15	*Merremia peltata* (L.)	*Convolvulaceae*	2.11
16	*Mimosa pudica* L.	*Fabaceae*	0.73
17	*Phyllanthus debilis* Klein ex. Wild	*Euphorbiaceae*	0.63
18	*Sida rhombifolia* L	*Malvaceae*	1.98
19	*Spermacoce remota* Lamk	*Rubiaceae*	0.45
20	*Sphagneticola trilobata* (L.) Pruski	*Asteraceae*	6.08
21	*Stachytarpheta indica* (L.) Vahl	*Verbenaceae*	1.87
22	*Stachytarpheta jamaicensis* (L.) Vahl	*Verbenaceae*	2.05
	Total		40.41
	Grass Group		
28	*Axonopus compressus* (Sw.) Beauv	*Poaceae*	0.68
29	*Brachiaria mutica* (Forssk.) Stapf	*Poaceae*	0.53
30	*Cyrtococeum acrescens* (Trin.) Stapf	*Poaceae*	6.45
31	*Digitaria longiflora* (Rets.) Pers.	*Poaceae*	4.46
32	*Imperata cylindrica* (l) Beauv. Var	*Poaceae*	1.16
33	*Isachne globosa* (Thunb.) O.K	*Poaceae*	6.06
34	*Ottochloa nodosa* (Kunth) Dandy	*Poaceae*	25.34
	Total		44.68
	Sedge Group		
35	*Cyperus babakan* Steud	*Cyperaceae*	0.93
36	*Cyperus Kyllingia* Endll	*Cyperaceae*	1.70
37	*Scleria sumatrensis* Retz	*Cyperaceae*	1.00
	Total		3.62
	Fern Group		
23	*Christellla normalis*	*Thelypteridaceae*	3.37
24	*Elephantopus scaber* linn	*Asteraceae*	2.75
25	*Lygodium microphyllum* (Cav.) R. Br.	*Lygodiaceae*	0.56
26	*Lygodium scandens* SW.	*Lygodiaceae*	4.13
27	*Nephrolepis* sp	*Nephrolepidaceae*	0.48
	Total		11.29
	Grand Total		100

Table 5. Weed dominance in swamp land

No	Weed Species	Family	SDR (%)
	Broadleaf Group		
1	*Eclipta prostrata (*L.) L.	*Asteraceae*	0.96
2	*Hedyotis corymbosa* (L) Lamk.	*Rubiaceae*	2.27
3	*Hedyotis difussa* willd	*Rubiaceae*	1.47
4	*Ludwigia perennis* L	*Onagraceae*	3.50
5	*Merremia umbellata* (L.) Hallier f.	*Convolvulaceae*	3.67
6	*Mikania micrantha* H.B.K.	*Asteraceae*	3.19
7	*Polygonum barbatum* C.	*Polygonaceae*	0.91
	Total		15.97
	Grass Group		
10	*Brachiaria mutica* (Forssk.) Stapf	*Poaceae*	2.40
11	*Commelina difussa* Burm. F.	*Commelinaceae*	0.73
12	*Digitaria ciliaris* (Retz.) Koel	*Poaceae*	0.78
13	*Isachne globosa* (Thunb.) O.K.	*Poaceae*	14.43
14	*Leersia hexandra* Sw.	*Poaceae*	13.99
15	*Leptochloa chinensis* (L.) Nees	*Poaceae*	10.08
16	*Oryza rufipogon* Griff	*Poaceae*	9.45
17	*Paspalum commersonii* Lamk	*Poaceae*	2.68
18	*Pharagmites vallatoria* (Pluk. Ex. L) Veldk	*Poaceae*	1.69
	Total		56.24
	Sedge Group	*Cyperaceae*	
19	*Cyperus kituiensis* Muasya	*Cyperaceae*	0.83
20	*Cyperus rotundus* L.	*Cyperaceae*	0.64
21	*Eleocharis ochrostachys* Steud.	*Cyperaceae*	5.61
22	*Fimbristylis dichotoma* (L.) Vahl	*Cyperaceae*	10.68
23	*Rhynchospora corymbosa* (L.) Britt	*Cyperaceae*	7.10
	Jumlah		24.86
	Feren Group		
8	*Christella normalis*	*Thelypteridaceae*	1.95
9	*Lygodium microphyllum* (Cav.) R. Br.	*Lygodiaceae*	0.97
	Total		2.92
	Grand Total		100

Rice farms exhibited the lowest number of weed species, with the fern group was the highest SDR at 44.21%, followed by the broadleaf group. This land use is shown the only one without any sedge species. The most dominant weed species in this land was *Fimbristylis miliacea* (L.) Vahl, with an SDR of 42.84%, belonging to the fern group, followed by *Sphenoclea zeylanica* Gaertn, with an SDR of 26.98%, belonging to the broadleaf group (Table 6). This land is managed intensively using synthetic agrochemicals such as fertilizers and pesticides.

Table 6. Weed dominance in rice farm

No	Weed Species	Family	SDR (%)
	Broadleaf Group		
1	*Alternanthera philoxeroides* (Mart.) Griseb.	*Amaranthaceae*	1.37
2	*Sphenoclea* zeylanica Gaertn	*Sphenocleaceae*	26.98
3	*Ludwigia perennis* L	*Onagraceae*	6.95
	Total		35.29
	Grass Group		
4	*Polytrias amaura* (Bucisa) D.K	*Poaceae*	3.80
5	*Echinochloa crus-galli* (L.) P.Beauv.	*Poaceae*	15.33
6	*Echinochloa colonum* (L.) Link	*Poaceae*	1.37
	Total		20.50
	Fern Group		
7	*Cyperus rotundus* L.	*Cyperaceae*	1.37
8	*Fimbristylis miliacea* (L.) Vahl	*Cyperaceae*	42.84
	Total		44.21
	Grand Total		100

Soil nutrient in various land uses

Nitrogen content varied across different land uses, with the highest levels found in swamp land and the lowest in rubber plantations, where it was nearly three times lower. Nitrogen content ranges from 4905.83 to 7059.23 mg/kg in swamp land, 307 to 3605 mg/kg in oil palm plantations, 32.7 to 3352.63 mg/kg in rubber plantations, 352.47 to 4177.3 mg/kg in coconut plantations, and 2925.52 to 3131.39 mg/kg in rice farms. However, the phosphorus content across these land uses was generally low and relatively uniform, with only slight variations. The available phosphorus ranged from 1.22 to 4.58 mg/kg in coconut plantations, 1.22 to 3.62 mg/kg in rubber plantations, 1.48 to 2.50 mg/kg in oil palm plantations, 1.25 to 3.28 mg/kg in swamp land, and 1.25 to 3.52 mg/kg in rice farms.

Potassium content was the highest in rice farms and lowest in oil palm plantations, with a difference of almost 3.2 times. The potassium content ranged from 104.92 to 150.98 mg/kg in coconut plantations, 59.86 to 80.56 mg/kg in oil palm plantations, 76.06 to 138.16 mg/kg in rubber plantations, 67.91 to 73.95 mg/kg in swamp land, and 188.35 to 264.01 mg/kg in rice farms. Additionally, the soil in all land uses was acidic, with the lowest acidity in rice farms and the highest in swamp land. Soil pH ranged from 4.22 to 4.40 in coconut plantations, 3.65 to 4.74 in oil palm plantations, 4.04 to 4.10 in rubber plantations, 3.65 to 4.12 in swamp land, and 4.18 to 4.74 in rice farms.

Table 7. Content of N, P, K, and soil pH across the land uses

Land Use	N	P	K	pH
	mg/kg			
Coconut plantations	2083.80	2.76	127.70	4.33
Oil palm plantations	2538.96	2.12	70.84	4.21
Rubber plantations	1400.386	2.43	115.61	4.06
Swamp Land	5982.53	2.27	73.94	3.88
Rice farms	3028.46	2.38	226.18	4.46

The relation between weed dominance with soil nutrient

Pearson correlation analysis revealed a very strong negative correlation between broadleaf weeds and grass weeds, with an r value of –0.85 (Table 8). The result indicated that as the presence of broadleaf weeds increases, the presence of grass weeds significantly decreased, and vice versa. Additionally, broadleaf weeds negatively correlated with soil nitrogen (r = -0.57), meaning they can thrive in low nitrogen conditions. There was a moderate positive correlation between grass weeds and soil phosphorus (r = 0.52), indicating that an increase in soil phosphorus content promotes the growth of grass weeds. In contrast, sedge weeds were positively correlated with soil potassium, with an r-value of 0.68.

Table 8. Pearson correlation between weed dominance and soil nutrients

	BL	GR	FN	NS	N	P	K	pH
BL	1.00	**-0.85**	0.23	-0.31	**-0.57**	0.36	-0.02	-0.18
		<.0001	0.4234	0.2551	**0.0272**	0.1913	0.9463	0.5124
GR	**-0.85**	1.00	-0.13	-0.20	0.35	**0.52**	-0.33	0.20
	<.0001		0.6524	0.4706	0.1942	**0.0448**	0.2260	0.4683
FN	0.23	-0.13	1.00	-0.46	-0.17	-0.04	-0.25	-0.38
	0.4234	0.6524		0.0934	0.5485	0.8717	0.3852	0.1754
NS	-0.31	-0.20	-0.47	1.00	0.36	-0.27	**0.68**	-0.07
	0.2551	0.4706	0.0934		0.1817	0.3335	**0.0050**	0.7916
N	**-0.57**	0.35	-0.17	0.36	1.00	0.29	-0.21	-0.23
	0.0272	0.1942	0.5485	0.1817		0.2960	0.4564	0.4108
P	0.36	**0.52**	-0.05	-0.27	0.23	1.00	-0.34	0.36
	0.1913	**0.0448**	0.8717	0.3335	0.2960		0.2170	0.1843
K	-0.02	-0.33	-0.25	**0.68**	-0.21	-0.34	1.00	0.25
	0.9463	0.2260	0.3852	**0.005**	0.4564	0.2170		0.3618
pH	-0.18	0.20	-0.38	0.07	-0.23	0.36	0.25	1.00
	0.5124	0.4683	0.1754	0.7916	0.4108	0.1843	0.3618	

Note: BL: Broadleaved weed; GR: Grass; FN: Ferns; NS: Sedge; N: Nitrogen; P: Phosphorous; K: Potassium. A value in each cell represents the coefficient correlation (r) and probability level.

Discussion

Weed species vary across land uses due to environmental conditions and human activities, such as land and crop management. Generally, broadleaf weeds are the predominant, followed by grasses, with ferns being the least prevalent. Broadleaf weeds are prevalent in coconut and oil palm plantations, while grasses are more common in swamp lands and rice farms. This pattern may be related to the specific characteristics of each land use. For example, coconut and oil palm plantations have denser canopies, resulting in lower light intensity than swamp lands and rice farms. Broadleaf weed species are more tolerant of shaded environments. A study by Basset *et al*. (2011) confirmed that the broadleaf weed *Alternanthera philoxeroides* (alligator weed) was unaffected by shading. Similarly, Munier-Jolain *et al*. (2014) found that broadleaf weeds were more tolerant of low light availability. Additionally, broadleaf weed species, such as duckweed (*Landoltia punctata*), significantly inhibit the germination and growth of grass weeds, including *Cyperus difformis*, *Eclipta prostrata*, and *Ammannia auriculata* (Xu *et al*., 2024).

The root systems of both weed groups might also contribute to their adaptability. Broadleaf weeds typically have deep taproots and fibrous roots, enabling them to more effectively compete for water and nutrients. Our study reveals that broadleaf weeds are predominant in areas with low nitrogen content. Dai *et al*. (2024) discovered that *Wedelia trilobata* thrives under nitrogen stress by employing antioxidant defense mechanisms such as catalase, peroxidase, and superoxide dismutase. Furthermore, similar weeds can inhibit soil-borne pathogens through their root exudates (Xiang *et al*., 2023). The study also indicated a negative correlation between the prevalence of broadleaf weeds and grass-type weeds. In short, broadleaf weeds are often more aggressive than grass-type weeds due to their prolific reproductive strategies, rapid and spreading growth habits, adaptability to various conditions, efficient resource utilization, and resilience to control measures. These factors contributed to their ability to dominate and outcompete other plants in a particular area.

B. alata Aubl, a broadleaf weed, was predominant in coconut plantations, with an SDR of 12.70%. These weed species can adapt to low-fertility soils with high sand content, and organic matter accelerates their growth (Fitriana *et al*., 2013; Soerjani *et al*., 1987; Sari and Rahayu, 2013). They also thrive in somewhat shaded areas. Most coconut plantations in the study area use 10 m x 10 m spacing and have trees that were mostly 20 years old, creating an environment favorable for these weeds. The second most prevalent weed species is *A. compressus* (Sw.) Beauv, a type of grass weed, with an SDR of 12.12%. Sufficient light availability in the area promotes the growth of this species. Tanasale *et al*. (2023) found *Stellaria holasta* L. as a predominant weed species in coconut plantations in Negeri Tial, Salahutu District, Central Maluku Regency. The difference might be related to varying environmental conditions.

Oil palm plantations in the study area are predominantly covered by broadleaf species, with *M. affine* D. Don accounting for 9.44% SDR. These weed species adapt quickly to infertile soils with high sand content (Sari and Rahayu, 2013) and can easily invade shaded environments (Yuliana and Lekito, 2018). The oil palm plantations in this study are primarily comprised of plants over 11 years old, with extensive canopy coverage. This environment supports the growth of these weed species. Conversely, rubber plantations are mainly dominated by *O. nodosa* (Kunth) Dandy, a type of grass, at 25.34% SDR. This species requires higher light intensity for growth, tolerating up to 50% shading (Suryana *et al*., 2020). In the study area, the light intensity is moderate, with only a portion of light reaching the plantation floor. Additionally, this weed can thrive across a wide range of altitudes, from coastal areas to highlands (Febrisusanto *et al*., 2018).

The study also found that *I. globosa* (Thunb.) O.K, a type of grass, dominated the swampland with an SDR of 14.43%. Waterlogged conditions with high light intensity are ideal for the growth of this weed species. According to Adriadi *et al*. (2012), this type of weed is predominant in peatland areas. In this study, the area is swampy with a water table of less than 50 cm and is often flooded. Additionally, rice farms are dominated by the fern-like weed, *F. miliacea* (L.) Vahl, with an SDR of 42.84%. Syaifudin *et al*. (2022) found that this weed is predominant in paddy fields, and Soerjani *et al.* (1987) also confirmed that the habitat of this weed species is waterlogged environments.

Overall, the study area revealed soil with low fertility, primarily characterized by low N, P, and K content, as well as a low pH. The spatial variation of nutrients and pH among various land uses demonstrates the influence of land management practices and environmental factors on soil characteristics. Swamplands have the highest quantities of nitrogen because they accumulate organic matter, while rice farms have the highest potassium levels, most likely because they are fertilized. Pearson correlation showed that the presence of weeds is associated with the nutrient content of the soil in the particular land use. Broadleaf weed is negatively correlated with soil N content, indicating that these types of weeds can compete at low N concentrations in the soil. Moreover, the grass type of weeds is more related to the soil phosphorus content, where higher available soil P will accelerate the growth of these types of weeds. A different pattern is found for fern types of weeds where K significantly affected the presence of these weeds. Higher K in the soil will contribute to the expansion of fern weed.

In conclusion, broadleaf weed species dominated in coconut and oil palm plantations, with SDRs of 58.05% and 50.89%, respectively. Grass types of weeds are most common in rubber plantations and swamp lands, with SDRs of 44.68% and 56.24%, respectively. Conversely, fern weeds dominated in rice fields, with an SDR of 42.84%. *M. affine* D. Don was the predominant weed species in oil palm and rubber plantations, with SDRs of 9.44% and 7.09%, respectively, while *B. alata* Aubl was the most prevalent weed species in coconut plantations, with an SDR of 12.70%. In swamp land, the grass species *I. globosa* (Thunb.) O.K. constitutes 14.43% of SDR. Generally, soil N, P, K, and pH levels were low across all land uses in the study area. The highest nitrogen levels are found in swamp lands, the greatest phosphorus levels in coconut plantations, and the highest potassium levels in rice farms. There was a negative correlation between broadleaf and grass types of weeds. These findings are valuable for managing weed control in the various land uses within the study area to optimize crop production.

Acknowledgments

The authors sincerely appreciate the financial support provided by the Directorate General of Research and Community Service, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, through contract No. 3937/UN30.15/PT/2024. They also extend their gratitude to the Faculty of Agriculture, University of Bengkulu, for providing the facilities to execute this research project.

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(Received: 2 September 2024, Revised: 5 January 2025, Accepted: 10 January 2025)