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# Phytosociological study for seasonal comparison of herbaceous angiosperms in Narmada canal command area of Saurashtra region, Gujarat state, India

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**Abstract**
The Narmada canal command area (NCCA) of the Saurashtra region supports plethora of herbaceous angiosperms. The portion of NCCA located in Bhavnagar, Botad, Morbi and Surendranagar districts had been investigated for inventorying in pre-monsoon and post-monsoon seasons from February 2018 to November 2019 through quadrat and transect methods. The Narmada canal command area (NCCA) in Saurashtra region is inhabited by 201 species during the pre-monsoon season and 259 herbaceous species during the post-Monsoon season. In the canal command area density, abundance, frequency and species composition of various species of herbs and grasses varied seasonally. The Simpson diversity index changed only slightly indicating that species diversity did not change noticeably between pre-monsoon (lean) season and post-monsoon season. Moreover, Menhinick's index of species richness also indicated that herbaceous plant species richness did not change noticeably from pre-monsoon to post-monsoon period in the NCCA. Relatively good status of species richness and species diversity of herbaceous species during pre-monsoon (lean) season possibly due to water availability from Narmada canal might be a reason for such insignificant difference between pre-monsoon and post-monsoon scenarios.

**Keywords:** herbaceous species, Narmada canal command area (NCCA), pre-monsoon season, post-monsoon season, Saurashtra region, vegetation

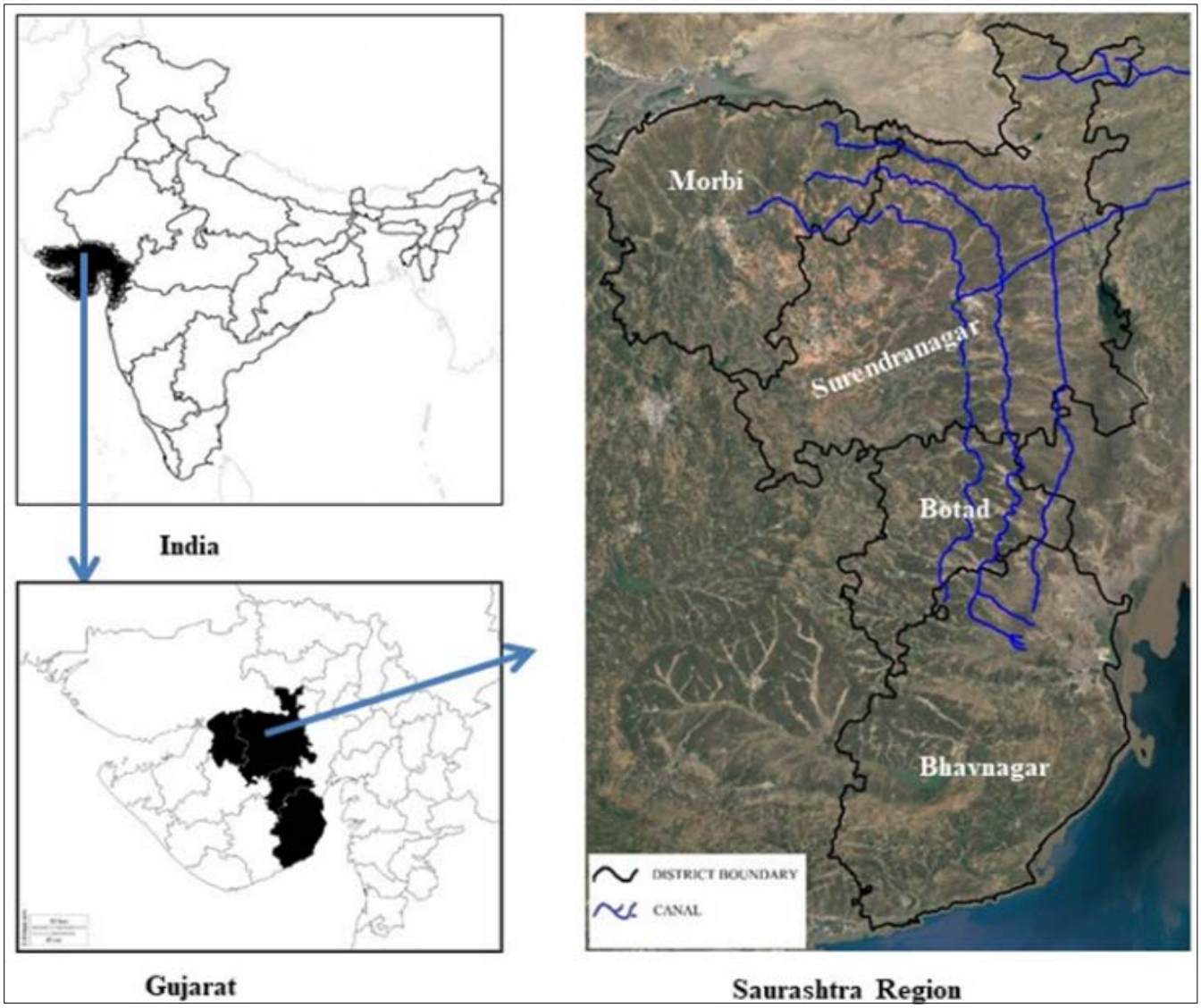
## Introduction

Vegetation is one of the basic resources on earth which play an important role in ecosystem balance (Heydari and Mahdevi 2009) [6]. The plant species richness, diversity and composition vary from place to place as per geographical and climatic conditions (Yadav *et al* 2018) [11]. A phytosociological study is one of the very important ways to know qualitative and quantitative characteristics of vegetation in an area and status of all plant species existing in the area. The growth of plant species in any area may be affected inter alia by the availability of surface water. The interaction between weather, vegetation and water cycle in arid and semi-arid regions is an extensively discussed issue (Yang *et al* 2009) [14]. Water also plays an important role in vegetation dynamics which is largely dependent on water availability from various water sources (Baudena *et al* 2007) [4]. Canals provide water to crops and natural vegetation existing in the area, which in turn, makes all vegetation phenologically healthy and rich. In Gujarat State, Narmada canal passes through three geomorphological divisions of 17 districts of the State which cover humid, semi- arid and arid areas of the State (SSNNL 2020) [10]. Based on the available water resources in Gujarat State, it can be divided into four zones, *viz*., South and Central Gujarat, Saurashtra, North Gujarat and Kachchh. These zones of Gujarat State cover about 58% of geographical area of the State. Saurashtra, North Gujarat and Kachchh share 16, 11 and 2% total water resources of the State, respectively (Yadav and Chauhan 2011) [13]. In the canal command area of Saurashtra region, very scanty information is available on vegetation that can help in understanding floristic composition of the area. Water availability is considered as a key element bringing change in the floristic composition, species richness etc. in any area over a period of time. Therefore, in the present study, an attempt has been made to know composition of herbaceous plants qualitatively and quantitatively through phytosociological investigations in pre- monsoon season and post-monsoon seasons.

## Material and Methods

### Study Area

The phytosociological study was conducted in Narmada canal command area (NCCA) of Saurashtra region (Gujarat State) which included 4 districts, *viz*., i.e. Bhavnagar, Botad, Surendranagar and Morbi (Figure 1). This region is located in south-western part of Gujarat and it is spread over 60,900 km$^2$ area of the State (Dhanapriya *et al* 2018) [5]. It is bound on the south and southwest by the Arabian Sea, on the northwest by the Gulf of Kachchh and on the east by the Gulf of Khambhat. This region geographically lies between 22º30´ N latitudes and 70º78´ E longitudes and as per agroclimatic zonation, it has been categorised in agroclimatic zones VI-South Saurashtra and VII-North Saurashtra (Pandey and Patel 2011) [7]. In most of the area of Saurashtra, the climatic condition is dry and the soils are clayey (fine textured) in most of the areas.




[Source: India Map (Anon 2020a) and Gujarat Map (Anon 2020b)]

**Fig 1:** Narmada Canal Command Area of Saurashtra region

A total of 10% of benefitted villages in NCCA of each of the 4 districts were considered for sampling of herbaceous vegetation. The enumeration of diversity of herbaceous plants (herbs and grasses) was carried out using transect and quadrat methods as per study done by Yadav *et al* (2020) [12]. During the study, a total of 25 transects and 455 quadrats were laid in different habitats of sampling villages of the NCCA in Saurashtra region. On each transect, a quadrat (each of 1m x 1m size) was laid at regular interval (i.e. of 500 m).

**Data Analysis**

All the collected data have been analysed qualitatively and quantitatively. The quantitative analysis has been carried out using common measurable vegetation attributes such as density, frequency, abundance and species composition. In addition, biodiversity indices (Simpson diversity index and Menhinick index of species richness) were also calculated to know the status of plant diversity in the canal command area of Saurashtra region.

**Results and Discussion**

**Qualitative Analysis**

During the pre-monsoon season, a total of 201 plants species (156 species of herbs and 45 species of grasses) belonging to 43 families were recorded. During the post-monsoon floristic study in NCCA, a total of 259 species of herbaceous plants (208 species of herbs and 51 species of grasses) belonging to a total of 49 families were recorded in the same area that was sampled in pre-monsoon season. A similar study was carried out by Pandya and Pathak (1995) [8] two decades ago in NCCA of Saurashtra and Kachchh regions, which had shown that the regions were inhabited by a total of 273 herbaceous plants species belonging to 53 families. Family-wise analysis for post-monsoon season showed Poaceae as the most dominant family followed by Asteraceae, Fabaceae, Malvaceae, Amaranthaceae, Acanthaceae, Cyperaceae, Euphorbiaceae, Lamiaceae and Solanaceae families in that order (Figure 2). During pre-monsoon season also Poaceae was the dominant family followed by Asteraceae, Fabaceae, Amaranthaceae, Malvaceae, Acanthaceae, Lamiaceae, Solanaceae, Cyperaceae and Euphorbiaceae families in that order.

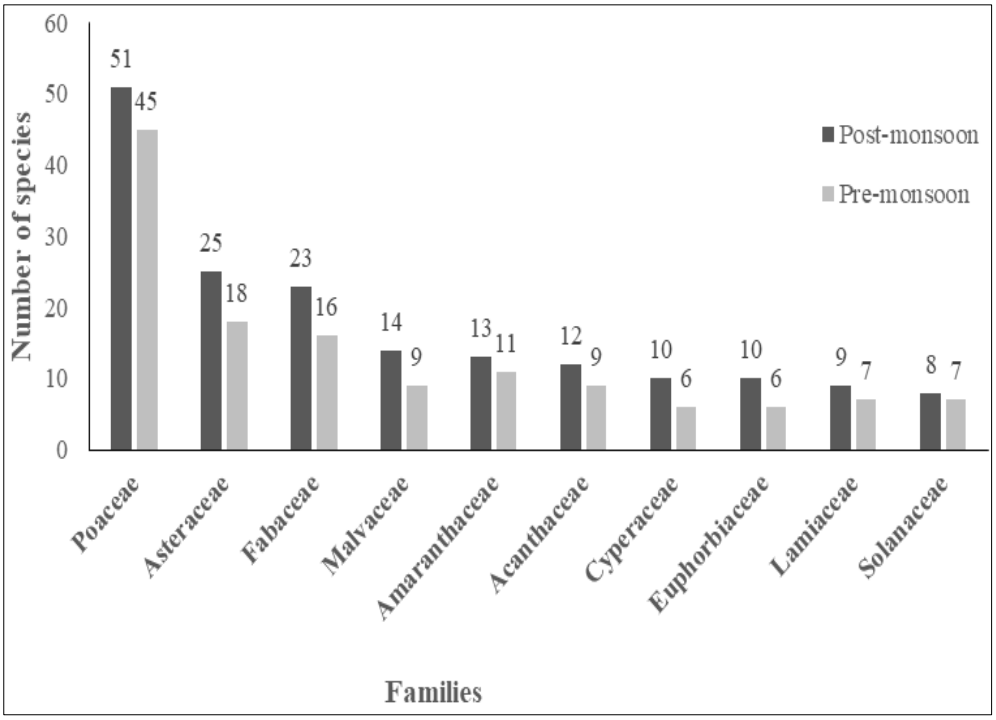



**Fig 2:** Dominant herbaceous plant families in NCCA, Saurashtra region

In the present study, all plant species in the area have been categorised based on their life-span such as annual, biennial and perennial. Analysis of plant species based on their life-span revealed that from pre-monsoon there was no changes in number of biennial species, small difference (5 species) in number of perennial species and moderate difference (17 species) in number of plant species that can either be annual or biennial or perennial (Figure 3).

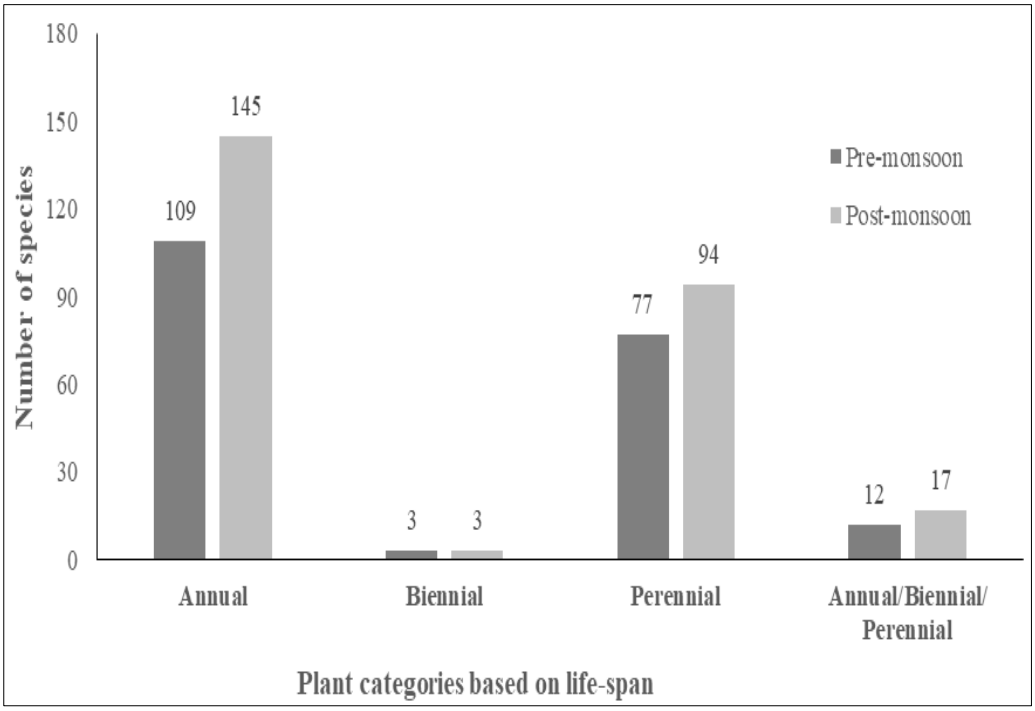



**Fig 3:** Classification of plant based on their life span of Saurashtra region

**Seasonal Quantitative Analysis of Herbaceous Species**

Herbs and grasses are important plants on the ground floor in any area and they are seasonally dynamic. In the present study, an analysis of herbaceous vegetation (herbs and grasses) revealed that the canal command area of Saurashtra region is inhabited by a total of 143 herbaceous species (73 annual species, 12 annual/perennial species and 58 perennial species) in quadrats laid in different habitats such as agriculture land, scrubland and

margins of wetlands. The variation in species diversity from pre-monsoon to post-monsoon season was observed. The Simpson diversity index for pre-monsoon and post-monsoon season was 0.96 and 0.98, respectively and Menhinick's species richness index for pre-monsoon season and pre-monsoon season was 1.01 and 1.21, respectively.

The quantitative analysis of herbaceous vegetation during pre-monsoon season showed that *Cynodon dactylon* (20439.56 ind./ha) had maximum density followed by that of *Schoenefeldia gracilis*, *Aristida funiculate* and *Dichanthium annulatum*. On the other hand, during post-monsoon season, maximum density was for *Cynodon dactylon* (17340.66 ind./ha) followed by *Aristida funiculata*, *Cyperus bulbosus* and *Indigofera linnaei*. During post-monsoon season, density status of some species (*Aristida funiculata*, *Cyperus bulbosus* and *Indigofera linnaei* etc.) had increased whereas some species (*Cynodon dactylon*, *Schoenefeldia gracilis* and *Dichanthium annulatum* etc.) showed relatively good density status even during pre-monsoon (lean) season (Table 1). In the entire sampled area of NCCA, the density of herbaceous species was varied from 21.98 to 20439.56 ind./ha during pre-monsoon and from 21.98 to 17340.66 ind./ha during post-monsoon season (Table 1).

Abundance analysis for herbaceous vegetation during pre-monsoon season revealed that *Eragrostis tenella* (20.07 ind./quadrat) was most abundant followed by *Aristida funiculata*, *Lindenbergia indica* and *Scirpus littoralis*. On the other hand, during post-monsoon season, maximum abundance was recorded for *Aristida funiculata* (14.43 ind./quadrat) followed by *Schoenefeldia gracilis*, *Cyperus iria* and *Eragrostis tenella*. Thus, during the post-monsoon season, abundance of some species such as *Schoenefeldia gracilis* and *Cyperus iria* had increased as compared to pre-monsoon season, while abundance of some other species during pre-monsoon (lean) season was more than in post-monsoon season [*Aristida funiculata* (pre-monsoon–17.04 ind./quadrat and post-monsoon–14.43 ind./quadrat), *Apluda mutica* (pre-monsoon–5.20 ind./quadrat and post-monsoon–5.09 ind./quadrat) and *Enicostema hyssopifolium* (pre-monsoon–0.25 ind./quadrat and post-monsoon–7.0 ind./quadrat)]. In the entire sampled area of NCCA, the abundance of herbaceous species was vary from 1.10 to 20.07 ind./quadrat during pre-monsoon (lean) season and from 1.0 to 14.43 ind./quadrat during post-monsoon season (Table 1).

Frequency analysis for herbaceous vegetation during pre-monsoon season revealed that *Cynodon dactylon* (27.47%) had maximum frequency followed by that of *Vernonia cinerea*, *Dichanthium annulatum* and *Cressa cretica*. During post-monsoon, maximum frequency was for *Cynodon dactylon* (35.60%) followed by *Vernonia cinerea*, *Tridax procumbens* and *Achyranthes aspera*. During post-monsoon season, frequency status of some species improved (*Cynodon dactylon*, *Tridax procumbens* and *Achyranthes aspera*) while, for some species relatively was good (*Vernonia cinerea*, *Dichanthium annulatum* and *Achyranthes aspera*) even during pre-monsoon (lean) season (Table 1). In the entire sampled area of NCCA, the frequency of herbaceous species was found to vary from 0.22 to 27.47% during pre-monsoon season and from while 0.22 to 35.60% during post-monsoon (Table 1).

Species composition analysis for pre-monsoon season revealed that *Cynodon dactylon* (13.53%) was most dominant in herbaceous vegetation in the sampled area of NCCA followed by *Schoenefeldia gracilis*, *Aristida funiculata* and *Dichanthium annulatum*. During post-monsoon season, maximum species composition was for *Cynodon dactylon* (6.34%) followed by that of *Aristida funiculata Cyperus bulbosus* and *Indigofera linnaei*. Thus, during the post-monsoon season, species composition of some species such as *Cyperus bulbosus* and *Indigofera linnaei* had improved as compared to their species composition in pre-monsoon season, while species composition of several other species during pre-monsoon (lean) season had remained better than that in post-monsoon season [*Schoenefeldia gracilis* (pre-monsoon–6.85 ind./quadrat and post-monsoon–74.0 ind./quadrat), *Aristida funiculata* (pre-monsoon–6.20 ind./quadrat and post-monsoon–5.45 ind./quadrat) and *Desmostachya bipinnata* (pre-monsoon–2.69 ind./quadrat and post-monsoon–1.97 ind./quadrat)]. In the entire sampled area of NCCA, the species composition of herbaceous species was found to vary between 0.01 to 13.53% during pre-monsoon while 0.01 to 6.34% during post-monsoon (Table 1).

**Table 1:** Quantitative analysis of herbaceous plants species

| SN | Scientific Name | Density (ind./ha) | | Abundance (ind./quadrat) | | Frequency (%) | | Composition (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Pre-monsoon | Post-monsoon | Pre-monsoon | Post-monsoon | Pre-monsoon | Post-monsoon | Pre-monsoon | Post-monsoon |
| 1 | *Abelmoschus ficulneus* (L.) Wight & Arn. | NA | 241.76 | NA | 3.67 | NA | 0.66 | NA | 0.09 |
| 2 | *Abutilon muticum* (Delile ex DC.) Sweet | 747.25 | 813.19 | 2.27 | 1.95 | 3.30 | 4.18 | 0.49 | 0.30 |
| 3 | *Acalypha indica* L. | NA | 681.32 | NA | 2.58 | NA | 2.64 | NA | 0.25 |
| 4 | *Acanthospermum hispidum* DC | NA | 791.21 | NA | 4.50 | NA | 1.76 | NA | 0.29 |
| 5 | *Achyranthes aspera* Linn. | 1472.53 | 5978.02 | 2.23 | 2.78 | 6.59 | 21.54 | 0.97 | 2.19 |
| 6 | *A. lappacea* L. | 65.93 | 1252.75 | 1.00 | 2.85 | 0.66 | 4.40 | 0.04 | 0.46 |
| 7 | *Aeluropus lagopoides* (L.) Trin. Ex Thw | 1538.46 | 2000.00 | 4.12 | 3.96 | 3.74 | 5.05 | 1.02 | 0.73 |
| 8 | *Alternanthera sessilis* (L.) R.Br. ex DC. | 1912.09 | 307.69 | 5.80 | 1.75 | 3.30 | 1.76 | 1.27 | 0.11 |
| 9 | *A. paronychioides* A.St.-Hil. | NA | 3208.79 | NA | 3.40 | NA | 9.45 | NA | 1.17 |
| 10 | *Alysicarpus monilifer* (L.) DC. | NA | 1846.15 | NA | 2.33 | NA | 7.91 | NA | 0.67 |
| 11 | *Amaranthus spinosus* L. | NA | 175.82 | NA | 4.00 | NA | 0.44 | NA | 0.06 |
| 12 | *A. viridis* L. | 923.08 | 2197.80 | 3.50 | 3.13 | 2.64 | 7.03 | 0.61 | 0.80 |
| 13 | *Amberboa ramosa* (Roxb.) Jafri | NA | 1164.84 | NA | 2.30 | NA | 5.05 | NA | 0.43 |
| 14 | *Ammannia baccifera* L. | NA | 2175.82 | NA | 3.09 | NA | 7.03 | NA | 0.80 |
| 15 | *Andrographis paniculata* (Burm.f.) Nees | 1472.53 | 131.87 | 9.57 | 2.00 | 1.54 | 0.66 | 0.97 | 0.05 |
| 16 | *Apluda mutica* L. | 5252.75 | 3802.20 | 5.20 | 5.09 | 10.11 | 7.47 | 3.48 | 1.39 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 17 | *Argemone mexicana* L. | 329.67 | NA | 3.75 | NA | 0.88 | NA | 0.22 | NA |
| 18 | *Aristida adscensionis* Linn. | 3516.48 | 4021.98 | 3.90 | 4.07 | 9.01 | 9.89 | 2.33 | 1.47 |
| 19 | *A. funiculata* Trin. & Rupr. | 9362.64 | 14901.10 | 17.04 | 14.43 | 5.49 | 10.33 | 6.20 | 5.45 |
| 20 | *Bergia suffruticosa* (Delile) Fenzl | NA | 835.16 | NA | 2.53 | NA | 3.30 | NA | 0.31 |
| 21 | *Blepharis maderaspatensis* (L.) B.Heyne ex Roth | NA | 1406.59 | NA | 3.37 | NA | 4.18 | NA | 0.51 |
| 22 | *B. linariifolia* Pers. | NA | 1054.95 | NA | 4.80 | NA | 2.20 | NA | 0.39 |
| 23 | *Blumea lacera* (Burn f.) DC. | 373.63 | 3626.37 | 1.55 | 3.11 | 2.42 | 11.65 | 0.25 | 1.33 |
| 24 | *Boerhavia diffusa* L. | NA | 1692.31 | NA | 2.14 | NA | 7.91 | NA | 0.62 |
| 25 | *B. erecta* L. | NA | 417.58 | NA | 3.17 | NA | 1.32 | NA | 0.15 |
| 26 | *Brachiaria ramosa* (L.) Stapf | NA | 3912.09 | NA | 3.07 | NA | 12.75 | NA | 1.43 |
| 27 | *Caesulia axillaris* Roxb. | 263.74 | NA | 6.00 | NA | 0.44 | NA | 0.17 | NA |
| 28 | *Cassia holosericea* Fresen. | NA | 2263.74 | NA | 3.12 | NA | 7.25 | NA | 0.83 |
| 29 | *C. tora* L. | NA | 241.76 | NA | 1.57 | NA | 1.54 | NA | 0.09 |
| 30 | *Catharanthus pusillus* (Murray) G.Don | NA | 527.47 | NA | 4.80 | NA | 1.10 | NA | 0.19 |
| 31 | *Celosia argentea* L. | 43.96 | 109.89 | 1.00 | 2.50 | 0.44 | 0.44 | 0.03 | 0.04 |
| 32 | *Cenchrus biflorus* Roxb. | NA | 879.12 | NA | 3.64 | NA | 2.42 | NA | 0.32 |
| 33 | *Centella asiatica* (L.) Urb. | 527.47 | 65.93 | 6.00 | 1.00 | 0.88 | 0.66 | 0.35 | 0.02 |
| 34 | *Chenopodium album* L. | 439.56 | 21.98 | 5.00 | 1.00 | 0.88 | 0.22 | 0.29 | 0.01 |
| 35 | *Chloris barbata* Sw. | 6615.38 | 5098.90 | 4.18 | 3.36 | 15.82 | 15.16 | 4.38 | 1.86 |
| 36 | *C. montana* Roxb. | 2197.80 | NA | 7.69 | NA | 2.86 | NA | 1.45 | NA |
| 37 | *Chrozophora rottleri* (Geiseler) A.Juss. ex Spreng. | 285.71 | 263.74 | 1.86 | 1.50 | 1.54 | 1.76 | 0.19 | 0.10 |
| 38 | *Cleome viscosa* Linn. | NA | 769.23 | NA | 1.75 | NA | 4.40 | NA | 0.28 |
| 39 | *Coldenia procumbens* L. | 219.78 | NA | 10.00 | NA | 0.22 | NA | 0.15 | NA |
| 40 | *Commelina benghalensis* L. | 87.91 | 3318.68 | 2.00 | 3.43 | 0.44 | 9.67 | 0.06 | 1.21 |
| 41 | *Convolvulus prostratus* Forsk. | 307.69 | 1384.62 | 1.75 | 2.10 | 1.76 | 6.59 | 0.20 | 0.51 |
| 42 | *Corchorus aestuans* L. | 1406.59 | 1406.59 | 2.46 | 2.55 | 5.71 | 6.37 | 0.93 | 0.59 |
| 43 | *C. capsularis* L. | NA | 1098.90 | NA | 2.17 | NA | 5.05 | NA | 0.40 |
| 44 | *C. depressus* (L.) | 43.96 | 21.98 | 2.00 | 1.00 | 0.22 | 0.22 | 0.03 | 0.01 |
| 45 | *Cressa cretica* L. | 8087.91 | 3582.42 | 4.72 | 2.59 | 17.14 | 13.85 | 5.35 | 1.31 |
| 46 | *Crotalaria hebecarpa* (DC.) Rudd | NA | 879.12 | NA | 2.86 | NA | 3.08 | NA | 0.32 |
| 47 | *C. medicaginea* Lam. | 241.76 | 439.56 | 2.20 | 2.50 | 1.10 | 1.76 | 0.16 | 0.16 |
| 48 | *Cymbopogon citratus* (DC.) Stapf | 483.52 | 373.63 | 2.20 | 3.40 | 2.20 | 1.10 | 0.32 | 0.14 |
| 49 | *Cynodon dactylon* (L.) Pers. | 20439.56 | 17340.66 | 7.44 | 4.87 | 27.47 | 35.60 | 13.53 | 6.34 |
| 50 | *Cyperus bulbosus* Vahl | NA | 11736.26 | NA | 6.21 | NA | 18.90 | NA | 4.29 |
| 51 | *C. difformis* Linn. | NA | 21.98 | NA | 1.00 | NA | 0.22 | NA | 0.01 |
| 52 | *C. iria* L. | 4571.43 | 1384.62 | 6.30 | 10.50 | 7.25 | 1.32 | 3.03 | 0.51 |
| 53 | *C. laevigatus* L. | NA | 945.05 | NA | 2.87 | NA | 3.30 | NA | 0.35 |
| 54 | *C. rotundus* L. | 219.78 | 6153.85 | 10.00 | 4.75 | 0.22 | 12.97 | 0.15 | 2.25 |
| 55 | *Dactyloctenium aegyptium* (L.) P. Beauv. | 65.93 | 4329.67 | 1.00 | 3.58 | 0.66 | 12.09 | 0.04 | 1.58 |
| 56 | *D. scindicum* Boiss. | 1736.26 | NA | 5.64 | NA | 3.08 | NA | 1.15 | NA |
| 57 | *Datura metel* L. | 197.80 | 615.38 | 1.50 | 2.55 | 1.32 | 2.42 | 0.13 | 0.22 |
| 58 | *D. stramonium* L. | NA | 197.80 | NA | 3.00 | NA | 0.66 | NA | 0.07 |
| 59 | *Desmodium triflorum* (L.) DC. | NA | 109.89 | NA | 1.25 | NA | 0.88 | NA | 0.04 |
| 60 | *Desmostachya bipinnata* (L.) stapf | 4065.93 | 5384.62 | 3.49 | 4.80 | 11.65 | 11.21 | 2.69 | 1.97 |
| 61 | *Dichanthium annulatum* (Forsk) Stapf | 8791.21 | 6835.16 | 3.92 | 4.04 | 22.42 | 16.92 | 5.82 | 2.50 |
| 62 | *Digera muricata* (L.) Mart. | NA | 2131.87 | NA | 2.55 | NA | 8.35 | NA | 0.78 |
| 63 | *Dinebra retroflexa* (Vahl) Panz. | NA | 307.69 | NA | 2.80 | NA | 1.10 | NA | 0.11 |
| 64 | *Echinochloa colona* (L.) Link. | 21.98 | 524.47 | 1.00 | 3.00 | 0.22 | 1.76 | 0.01 | 0.19 |
| 65 | *Echinops echinatus* Roxb. | 725.27 | 3582.42 | 2.06 | 4.53 | 3.52 | 7.91 | 0.48 | 1.31 |
| 66 | *Eclipta prostrata* (L.) L. | 109.89 | 1142.86 | 1.67 | 2.74 | 0.66 | 4.18 | 0.07 | 0.42 |
| 67 | *Enicostema hyssopifolium* (Wild.) verdoon | 1802.20 | 2307.69 | 10.25 | 7.00 | 1.76 | 3.30 | 1.19 | 0.84 |
| 68 | *Eragrostis ciliaris* (L.)R. Br. | 549.45 | 9406.59 | 3.57 | 5.28 | 1.54 | 17.80 | 0.36 | 3.44 |
| 69 | *E. tenella* (L.) P. Beauv | 6175.82 | 3384.62 | 20.07 | 8.56 | 3.08 | 3.96 | 4.09 | 1.24 |
| 70 | *Eremopogon foveolatus* (Delile) Stapf | 153.85 | NA | 1.40 | NA | 1.10 | NA | 0.10 | NA |
| 71 | *Euphorbia hirta* L. | 197.80 | 2329.67 | 1.29 | 2.30 | 1.54 | 10.11 | 0.13 | 0.85 |
| 72 | *E. serpens* Kunth | NA | 857.14 | NA | 2.29 | NA | 3.74 | NA | 0.31 |
| 73 | *E. thymifolia* L. | NA | 3494.51 | NA | 4.08 | NA | 8.57 | NA | 1.28 |
| 74 | *E. heterophylla* L. | NA | 241.76 | NA | 3.67 | NA | 0.66 | NA | 0.09 |
| 75 | *Evolvulus alsinoides* (L.) L. | NA | 571.43 | NA | 2.36 | NA | 2.42 | NA | 0.21 |
| 76 | *Fagonia cretica* Linn | 747.25 | 505.49 | 3.40 | 2.56 | 2.20 | 1.98 | 0.49 | 0.18 |
| 77 | *Glinus lotoides* L. | 593.41 | 219.78 | 4.50 | 2.00 | 1.32 | 1.10 | 0.39 | 0.08 |
| 78 | *Grangea maderaspatana* (L.) Poir. | 21.98 | NA | 1.00 | NA | 0.22 | NA | 0.01 | NA |
| 79 | *Heliotropium supinum* L. | 43.96 | 417.58 | 1.00 | 3.17 | 0.44 | 1.32 | 0.03 | 0.15 |
| 80 | *H. indicum* L. | 307.69 | 1032.97 | 2.33 | 3.36 | 1.32 | 3.08 | 0.20 | 0.38 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 81 | *Hydrilla verticillata* (L.f.) Royle | 43.96 | 43.96 | 2.00 | 1.00 | 0.22 | 0.44 | 0.03 | 0.02 |
| 82 | *Hygrophila auriculata* (Schumach.) Heine | NA | 109.89 | NA | 2.50 | NA | 0.44 | NA | 0.04 |
| 83 | *H. polysperma* (Roxb.) T.Anderson | NA | 109.89 | NA | 2.50 | NA | 0.44 | NA | 0.04 |
| 84 | *Indigofera linnaei* Ali. | 1582.42 | 10813.19 | 3.43 | 6.74 | 4.62 | 16.04 | 1.05 | 3.95 |
| 85 | *I. glandulosa* Wendl. | 21.98 | NA | 1.00 | NA | 0.22 | NA | 0.01 | NA |
| 86 | *Laggera aurita* (DC.) Sch.Bip. ex Schweinf. | NA | 7648.35 | NA | 7.25 | NA | 10.55 | NA | 2.80 |
| 87 | *Launaea procumbens* (Roxb.) Ram. & Raj. | 417.58 | 3604.40 | 1.36 | 2.78 | 3.08 | 12.97 | 0.28 | 1.32 |
| 88 | *Lepidagathis trinervis* Nees | 3802.20 | 4461.54 | 4.33 | 3.33 | 8.79 | 13.41 | 2.52 | 1.63 |
| 89 | *Leucas aspera* (Wild.) Spr. | 131.87 | 2791.21 | 1.50 | 4.10 | 0.88 | 6.81 | 0.09 | 1.02 |
| 90 | *Lindenbergia indica* Vatke | 1274.73 | 65.93 | 11.60 | 3.00 | 1.10 | 0.22 | 0.84 | 0.02 |
| 91 | *Ludwigia adscendens* (L.) H.Hara | NA | 131.87 | NA | 2.00 | NA | 0.66 | NA | 0.05 |
| 92 | *Martynia annua* L. | NA | 43.96 | NA | 1.00 | NA | 0.44 | NA | 0.02 |
| 93 | *Medicago sativa* L. | 593.41 | NA | 5.40 | NA | 1.10 | NA | 0.39 | NA |
| 94 | *Melanocenchris jacquemontii* Jaub. & Spach | NA | 879.12 | NA | 2.67 | NA | 3.30 | NA | 0.32 |
| 95 | *Merremia gangetica* Cufod. | NA | 4835.16 | NA | 4.07 | NA | 11.87 | NA | 1.77 |
| 96 | *Mitracarpus hirtus* (L.) DC. | NA | 461.54 | NA | 3.50 | NA | 1.32 | NA | 0.17 |
| 97 | *Nothosaerva brachiata* (L.) Wight | NA | 307.69 | NA | 3.50 | NA | 0.88 | NA | 0.11 |
| 98 | *Ocimum canum* Sims | 1758.24 | 1252.75 | 5.71 | 2.59 | 3.08 | 4.84 | 1.16 | 0.46 |
| 99 | *O. sanctum* L. | NA | 87.91 | NA | 1.33 | NA | 0.66 | NA | 0.03 |
| 100 | *O. gratissimum* L. | 131.87 | NA | 3.00 | NA | 0.44 | NA | 0.09 | NA |
| 101 | *Oplismenus burmannii* f. cristata (J. Presl) Hier. ex Peter | NA | 3846.15 | NA | 6.73 | NA | 5.71 | NA | 1.41 |
| 102 | *Parthenium hysterophorus* L. | 4791.21 | 5076.92 | 5.89 | 3.98 | 8.13 | 12.75 | 3.17 | 1.86 |
| 103 | *Pedalium murex* L. | NA | 109.89 | NA | 2.50 | NA | 0.44 | NA | 0.04 |
| 104 | *Peristrophe bicalyculata* (Retz.) Nees | 1318.68 | 3362.64 | 2.14 | 2.64 | 6.15 | 12.75 | 0.87 | 1.23 |
| 105 | *Phragmites karka* (Retz.) Trin. ex Steud. | 395.60 | NA | 9.00 | NA | 0.44 | NA | 0.26 | NA |
| 106 | *Phyllanthus maderaspatensis* L. | NA | 1648.35 | NA | 3.57 | NA | 4.62 | NA | 0.60 |
| 107 | *P. niruri* L. | 109.89 | 2901.10 | 1.25 | 2.13 | 0.88 | 13.63 | 0.07 | 1.06 |
| 108 | *Physalis minima* L. | 615.38 | 2175.82 | 2.55 | 2.83 | 2.42 | 7.69 | 0.41 | 0.80 |
| 109 | *P. pruinosa* L. | 21.98 | 351.65 | 1.00 | 2.00 | 0.22 | 1.76 | 0.01 | 0.13 |
| 110 | *Portulaca oleracea* L. | 21.98 | 879.12 | 1.00 | 2.35 | 0.22 | 3.74 | 0.01 | 0.32 |
| 111 | *Pulicaria angustifolia* DC. | 483.52 | 615.38 | 2.75 | 2.33 | 1.76 | 2.64 | 0.32 | 0.22 |
| 112 | *P. wightiana* (DC.) C.B.Clarke | NA | 21.98 | NA | 1.00 | NA | 0.22 | NA | 0.01 |
| 113 | *Ruellia patula* Jacq. | NA | 109.89 | NA | 1.67 | NA | 0.66 | NA | 0.04 |
| 114 | *Rungia repens* (L.) Nees | 1076.92 | 197.80 | 5.44 | 1.13 | 1.98 | 1.76 | 0.71 | 0.07 |
| 115 | *Schoenefeldia gracilis* Kunth | 10351.65 | 10241.76 | 10.02 | 10.84 | 10.33 | 9.45 | 6.85 | 3.74 |
| 116 | *Scirpus littoralis* Flugge ex Rchb. | 703.30 | 43.96 | 10.67 | 2.00 | 0.66 | 0.22 | 0.47 | 0.02 |
| 117 | *Setaria glauca* (L.) P.Beauv. | NA | 461.54 | NA | 1.91 | NA | 2.42 | NA | 0.17 |
| 118 | *S. pumila* (Poir.) Roem. & Schult. | NA | 153.85 | NA | 3.50 | NA | 0.44 | NA | 0.06 |
| 119 | *Sida acuta* Burm.f. | NA | 791.21 | NA | 2.77 | NA | 2.86 | NA | 0.29 |
| 120 | *S. cordata* (Burm.f.) Borss.Waalk. | NA | 197.80 | NA | 4.50 | NA | 0.44 | NA | 0.07 |
| 121 | *S. cordifolia* L. | NA | 395.60 | NA | 3.60 | NA | 1.10 | NA | 0.14 |
| 122 | *Solanum surattense* Burm. f. | 1230.77 | 2747.25 | 1.47 | 2.40 | 8.35 | 11.43 | 0.81 | 1.00 |
| 123 | *S. nigrum* L. | NA | 263.74 | NA | 4.00 | NA | 0.66 | NA | 0.10 |
| 124 | *Sonchus oleraceus* (L.) L. | 43.96 | 2725.27 | 1.00 | 9.16 | 0.44 | 5.49 | 0.03 | 1.00 |
| 125 | *Sporobolus coromandelianus* (Retz.) Kunth | 153.85 | 153.85 | 3.50 | 3.50 | 0.44 | 0.44 | 0.10 | 0.06 |
| 126 | *S. indicus* (L.) R.Br. | 329.67 | 351.65 | 1.88 | 2.67 | 1.76 | 1.32 | 0.22 | 0.13 |
| 127 | *Suaeda nudiflora* (Willd.) D. Hou | 703.30 | 879.12 | 1.52 | 1.82 | 4.62 | 4.84 | 0.47 | 0.32 |
| 128 | *Taverniera cuneifolia* (Roth) Arn. | 1890.11 | 2791.21 | 2.15 | 3.74 | 8.79 | 7.47 | 1.25 | 1.02 |
| 129 | *Tephrosia purpurea* (L.) Pers. | NA | 21.98 | NA | 1.00 | NA | 0.22 | NA | 0.01 |
| 130 | *Themeda triandra* Forssk. | 87.91 | 153.85 | 2.00 | 1.75 | 0.44 | 0.88 | 0.06 | 0.06 |
| 131 | *Trianthema portulacastrum* L. | NA | 1868.13 | NA | 2.07 | NA | 9.01 | NA | 0.68 |
| 132 | *Tribulus terrestris* L. | NA | 725.27 | NA | 1.83 | NA | 3.96 | NA | 0.27 |
| 133 | *Trichodesma indicum* (L.) Lehm. | 241.76 | 1120.88 | 2.20 | 2.68 | 1.10 | 4.18 | 0.16 | 0.41 |
| 134 | *Tricholepis glaberrima* DC. | 1186.81 | 21.98 | 1.86 | 1.00 | 6.37 | 0.22 | 0.79 | 0.01 |
| 135 | *Tridax procumbens* (L.) L. | 4571.43 | 6593.41 | 2.97 | 2.68 | 15.38 | 24.62 | 3.03 | 2.41 |
| 136 | *Trifolium repens* L. | NA | 21.98 | NA | 1.00 | NA | 0.22 | NA | 0.01 |
| 137 | *Triumfetta pentandra* A.Rich. | 153.85 | 1230.77 | 3.50 | 3.11 | 0.44 | 3.96 | 0.10 | 0.45 |
| 138 | *T. rhomboidea* Jacq | 681.32 | 747.25 | 3.44 | 2.62 | 1.98 | 2.86 | 0.45 | 0.27 |
| 139 | *Typha domingensis* Pers. | 1406.59 | 197.80 | 5.33 | 3.00 | 2.64 | 0.66 | 0.93 | 0.07 |
| 140 | *Urena sinuata* L. | NA | 175.82 | NA | 2.00 | NA | 0.88 | NA | 0.06 |
| 141 | *Utricularia gibba* L. | NA | 65.93 | NA | 1.50 | NA | 0.44 | NA | 0.02 |
| 142 | *Vernonia cinerea* (L.) Less. | 6901.10 | 7428.57 | 2.57 | 2.99 | 26.81 | 24.84 | 4.57 | 2.72 |
| 143 | *Xanthium strumarium* L. | 2131.87 | 2945.05 | 2.55 | 2.85 | 8.35 | 10.33 | 1.41 | 1.08 |

**Diversity Indices**

The current study shows that Simpson diversity index slightly varied seasonally for herbaceous species. During the pre-monsoon season, the Simpson diversity index of herbaceous species was 0.96 (Table 2), whereas during the post-monsoon season it was 0.98. Almost similar type of value (0.93) was found by Sakachep and Rai (2021) [9] in herbaceous vegetation. The standard values of the Simpson diversity index are known to range from 0 to 1 and if the Simpson diversity index increases, it means the plant diversity has increased and vice versa (Anon 2017). The values of Simpson diversity index during pre-monsoon and post-monsoon seasons indicated that herbaceous plant diversity increased only slightly from pre-monsoon to post-monsoon seasons. Only small difference between pre-monsoon to post-monsoon seasons indicates relatively good plant status in pre-monsoon (lean) season and it might be due to water availability from Narmada canal even during pre-monsoon (lean) season. The Menhinick's species richness index had also increased only slightly from pre-monsoon season (1.01) to post-monsoon season (1.21). This also indicates relatively good herbaceous plant status in pre-monsoon season, most likely due to water availability from Narmada canal.

**Table 2:** Biodiversity index of herbaceosus species

| Biodiversity Index | Pre-Monsoon Season | Post-Monsoon Season |
|---|---|---|
| Simpson diversity index | 0.96 | 0.98 |
| Menhinick's index of species richness | 1.01 | 1.21 |

**Conclusion**

Good habitat conditions for herbaceous angiosperms have prevailed in the Narmada canal command area. The canal command area in Saurashtra region (Bhavnagar, Botad, Surendranagar and Morbi districts) supported a total of 259 herbaceous angiosperms considering pre-monsoon and post-monsoon seasons together. The canal command area has been supporting maximum number of annual plant species followed by perennial and biennial species. The Simpson diversity for pre-monsoon season and post-monsoon season remained almost same in pre-monsoon and post-monsoon season. Relatively good species diversity of herbaceous plants in pre-monsoon (lean) season leads to an inference that water availability from Narmada canal might have benefitted herbaceous vegetation status even in lean season. But, for several species, these values were higher in pre-monsoon season that in post-monsoon season indicating that water availability from Narmada canal during pre-monsoon season might have helped in maintaining herbaceous vegetation scenario at reasonably good level.

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