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Yasuní Forest Dynamics Plot, Ecuador

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Site Location, Administration, and Scientific Infrastructure

The Yasuní Forest Dynamics Plot is located in mature terra firme forest in Yasuní National Park and Biosphere Reserve. The park and adjacent Huaorani territory comprise 1.6 million ha, representing the largest protected area of mature forest in the Amazon region of Ecuador. The 50-ha Yasuní Forest Dynamics Plot is located in the northwest corner of the park, on a ridge above the Tiputini River, a tributary of the Napo River (fig. 38.1). It was initiated in 1995 by the Pontificia Universidad Católica del Ecuador, the Smithsonian Tropical Research Institute, and the University of Aarhus (Denmark). The enumeration of all trees $\geq$1 cm dbh was completed for the first 25 ha on the western side of the plot in November 1999; the enumeration of all trees $\geq$10 cm dbh was completed for the second 25 ha in April 2001. At present, the enumeration of all trees $\geq$1 cm dbh is underway but not yet completed for the second 25 ha. In this chapter, we report on results from the first 25 ha.

The Yasuní Biological Research Station, managed by the Pontificia Universidad Católica del Ecuador in Quito, is approximately 1 km from the Yasuní Forest Dynamics Plot and 47 km south of the Napo River. The station is a permanent facility managed strictly for scientific research, with electricity, simple laboratories, accommodations for 60 people, classroom and dining facilities, and a herbarium.

Climate

Over a 53-month period from 1995 to 1999, annual rainfall averaged 3081 mm at the Yasuní Research Station. These figures agree closely with more extensive records analyzed by Pitman (2000). Using data from eight long-term sites in lowland Amazonian Ecuador, he concluded that annual rainfall averaged 3214 mm. Although the area had no mean monthly rainfall below 100 mm, the data did show clear seasonal rainfall variation, with two peaks and two troughs per year and the rainiest month averaging 72% more rain than the driest month. The wettest months were April–May and October–November, with the earlier peak slightly rainier than the latter one. Drier months were characterized by both fewer days

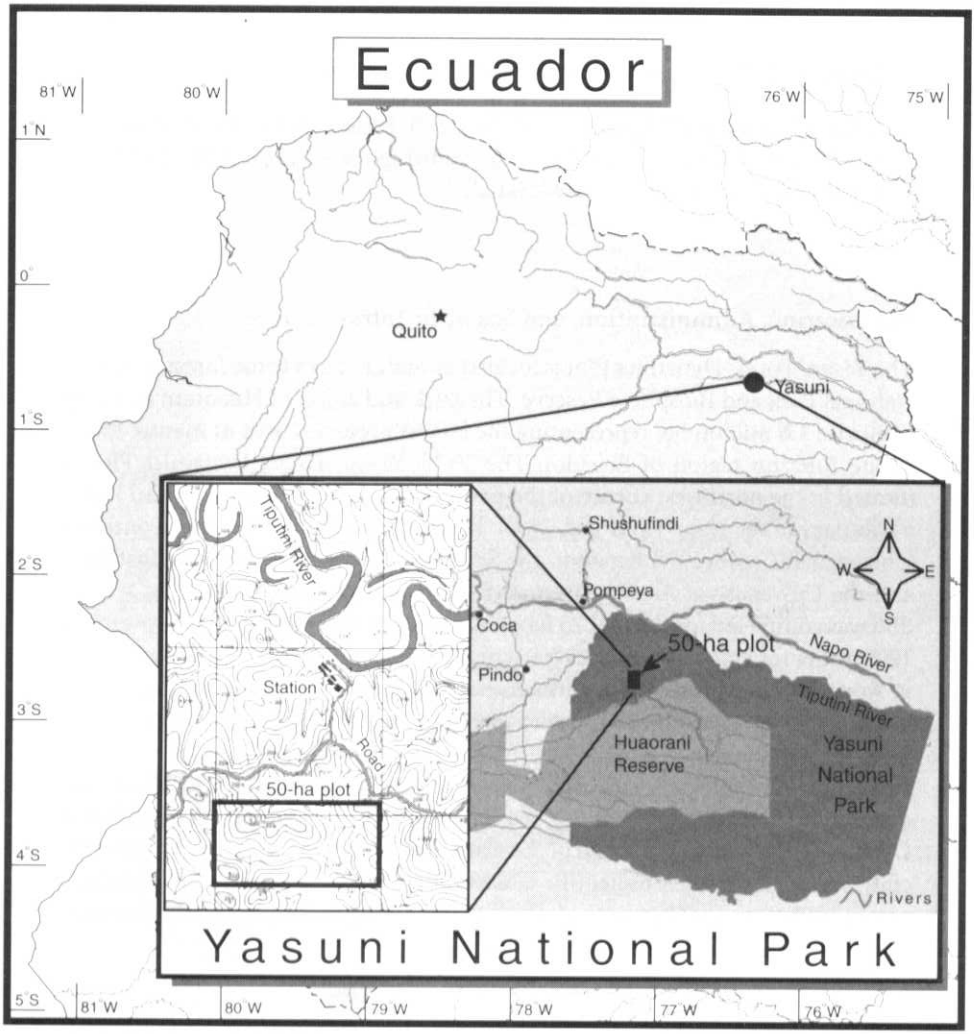

Fig. 38.1. Location of the 25-ha Yasuni Forest Dynamics Plot.

of rain and smaller daily maximums, and accounted for proportionally more of the annual solar radiation and potential evapotranspiration budgets (359.9 cal/cm^2/day [174 watts/m^2] and 1033 mm/year respectively; data from Tiputini Research Station, reported in Marengo 1998, cf. Pitman 2000). At all sites, relative humidity averaged 80–94% throughout the year. The average annual maximum

Table 38.1. Yasuni Climate.Data

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total/ Averages
Rain (mm)	226	344	200	253	412	374	227	193	174	253	196	229	3081
ADTMx (°C)	33.7	35.4	34.8	34.8	33.5	33.9	34.2	35.2	36.6	36.6	36.1	35.1	35.0
ADTMn (°C)	21.7	23.4	22.0	21.7	21.4	21.3	21.3	21.2	21.2	21.4	21.5	21.7	21.7

Notes: Mean monthly rainfall and average daily temperature are based on climate data measured at the Yasuní Research Station from 1995 to 1999. Monthly records with incomplete data (i.e., <26 days; the great majority have 30 or 31 days) were excluded. Thus, some of the monthly temperature means and rainfall means, maxima, and minima were averaged from only 4 years during this period, with 7 months of data excluded. The weather station is in full light.

temperature from 1995 to 1999 at the Yasuní Biological Station is 35°C in the full sun. More recent climate data (January 2000 to May 2001) from the station revealed a cooler average annual maximum temperature by a couple of degrees, but a similar average annual minimum temperature (Garwood and Persson unpublished data). See table 38.1.

Topography and Soil

The 50-ha Yasuní Forest Dynamics Plot is located at 230 m above sea level and the difference between the plot's lowest and the highest points is 33.5 m (figures 38.2 and 38.3 illustrate the west 25-ha half of the 50-ha plot where all the woody plants ≥1 cm dbh were enumerated mapped and identified to date). The average slope of the plot is 13%. The plot is bound by two ridges, each dominated by red clays. The ridges are composed mostly of gently sloping hills, though steep slopes are found along erosion gullies. Bottomlands, characterized by brown or gray alluvium, separate the ridges. The bottomland includes several small permanent streams and a small swamp (frequently flooded) in the eastern half of the plot.

Detailed soil analyses have not been carried out in the Yasuní Forest Dynamics Plot. However, soil studies within the Yasuní National Park concluded that topographic variation is generally low. In upland areas, most soils are clayey, acidic, low in most cations while rich in aluminum and iron, and lacking rocks and pebbles (Korning et al. 1994; Pitman 2000). Most soils in Yasuní are classified as udult Ultisols. The remainder of soils in Yasuní are those influenced by flooding, either in swamps or floodplains, with that in the swamps classified as Histosols (Pitman 2000). However, in a wetland approximately 4 km away from the study plot, two layers of about 10 cm of volcanic ash have been found some 5 m below the surface (Athens 1997), providing evidence of some volcanic influence on soil formation. The terra firme hills in Yasuni are composed of sediments of the Curaray and Chambira formations (Lips and Duivenvoorden 2001).

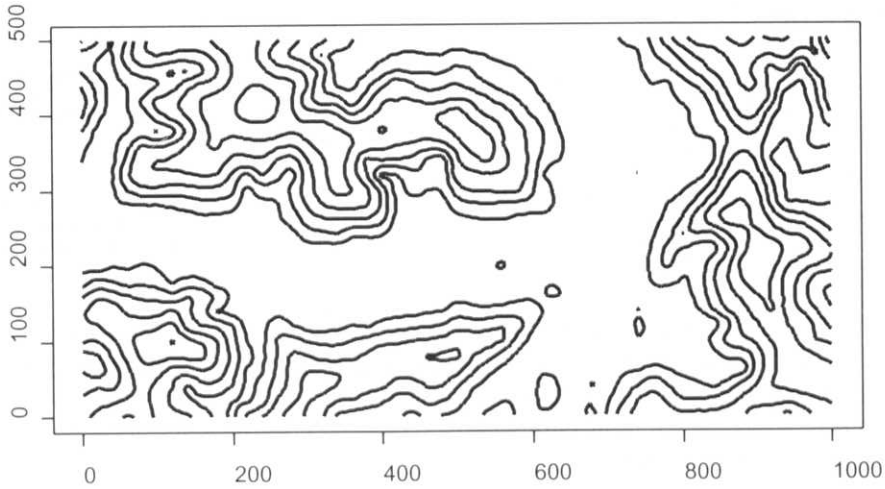

Fig. 38.2. Topographic map of the 50-ha Yasuni Forest Dynamics Plot with 5-m contour intervals.

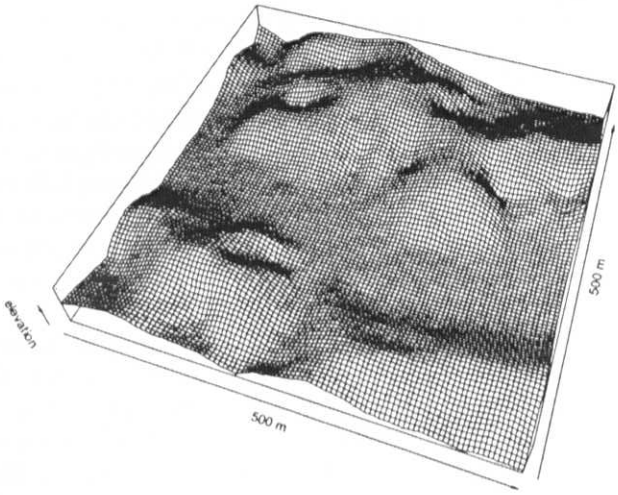

Fig. 38.3. Perspective map of the western-most 25 ha of the 50-ha Yasuni Forest Dynamics Plot, where census of trees $\geq$ 1 cm dbh has been completed.

Forest Type and Characteristics

The forest is evergreen lowland wet forest, with a canopy mostly 15–30 m tall and some emergent trees reaching 40 and rarely 50 m. The largest stem diameters are usually 2 m, frequently *Ceiba pentandra* (Bombacaceae) and the slightly smaller *Tessmannianthus heterostemon* (Melastomataceae). The forest around the plot

Table 38.2. Yasuní Plot Census History

Census	Dates	Number Trees (≥1 cm dbh)	Number Species (≥1 cm dbh)	Number Trees (≥10 cm dbh)	Number Species (≥10 cm dbh)
First	April 1995–November 1999	152,353	1104	17,546	820

Notes: One full census has been completed of the Yasuní Forest Dynamics Plot for trees ≥1 cm dbh in 25 ha; includes 4215 deaths before identification. The first recensus of the first 25 ha, not yet finalized, was initiated in September 2002.

Table 38.3. Yasuní Summary Tally

Size Class (cm dbh)	Average per Hectare							25-ha Plot				
	BA	*N*	*S*	*G*	*F*	*H′*	α	*S*	*G*	*F*	*H′*	α
≥1	33.0	6094	655	243	69	2.44	187.1	1104	328	81	2.57	161.1
≥10	27.3	702	251	132	47	2.11	141.7	820	274	69	2.37	178.3
≥30	13.4	81	55	41	24	1.65	80.8	397	180	57	2.25	147.2
≥60	4.1	8	6	6	5	0.73	20.5*	76	55	27	1.65	46.5

*Fisher's alpha based on 15 ha.

Notes: BA represents basal area in m^2, *N* is the number of individual trees, *S* is number of species, *G* is number of genera, *F* is number of families, *H′* is Shannon–Wiener diversity index using $\log_{10}$, and α is Fisher's α. Basal area includes all multiple stems for each individual. 6943 individuals were not identified to species or morphospecies. Data are from the first census.

appears to be maturing, undisturbed for several centuries and possibly much longer. See census data and rankings in tables 38.2–38.6.

Species composition changes slightly between the ridges and the bottomland (chap. 9). A comparison between the ridge and an adjacent bottomland revealed that many more midcanopy species grow exclusively on the ridge than on the bottomland. Among the dominant species that preferred the ridge forest are *Brownea grandiceps* (Leguminosae), *Macrolobium* sp. nov. (Leguminosae), *Tachigali formicarum* (Leguminosae), *Protium aracouchini* (Burseraceae), and *Ocotea javitensis* (Lauraceae), whereas *Bauhinia brachycalyx* (Leguminosae), *Coccoloba densifrons* (Polygonaceae), *Guarea grandifolia* (Meliaceae), *Guarea pubescens* (Meliaceae), *Talauma ovata* (Magnoliaceae), and *Astrocaryum murumuru* (Palmae) dominate in the bottomland. The most common species, such as *Iriartea deltoidea* (Palmae), *Matisia oblongifolia* (Bombacaceae), *Matisia malacocalyx* (Bombacaceae), and *Marmaroxylon basijugum* (Leguminosae), grow abundantly in both habitats.

The swampy area in the eastern half of the plot is most notably different. The palm *Mauritia flexuosa* (Palmae), a *Sapium* sp. (Euphorbiaceae), and several species of *Piper* (Piperaceae) are found only in the swamp. This small swamp, topographically recessed, contains water throughout the year.

Families and genera listed in tables 38.4 and 38.5 are typical of species-rich tracts of lowland neotropical forests (e.g., Gentry 1988; Valencia et al. 1994). Among the shrubby genera not well sampled in the Yasuní Forest Dynamics Plot

Table 38.4. Yasuni Rankings by Family

Rank	Family	Basal Area (m^2)	% BA	% Trees	Family	Trees	% Trees	Family	Species
1	Leguminosae	112.1	14.9	13.0	Leguminosae	18,860	13.0	Leguminosae	108
2	Palmae	63.8	8.5	3.6	Bombacaceae	10,109	7.0	Lauraceae	81
3	Lecythidaceae	45.5	6.0	2.6	Lauraceae	8,055	5.5	Rubiaceae	80
4	Moraceae	41.7	5.5	4.2	Meliaceae	7,733	5.3	Melastomataceae	59
5	Cecropiaceae	41.3	5.5	2.2	Violaceae	7,239	5.0	Myrtaceae	56
6	Meliaceae	40.4	5.4	5.3	Euphorbiaceae	6,775	4.7	Sapotaceae	54
7	Euphorbiaceae	40.4	5.4	4.7	Rubiaceae	6,569	4.5	Moraceae	51
8	Lauraceae	39.1	5.2	5.5	Moraceae	6,136	4.2	Annonaceae	40
9	Bombacaceae	36.5	4.8	7.0	Myrtaceae	5,670	3.9	Meliaceae	39
10	Myristicaceae	35.5	4.7	1.8	Palmae	5,231	3.6	Euphorbiaceae	34

Notes: The top 10 families for trees ≥1 cm dbh are ranked in terms of basal area, number of individual trees, and number of species, with the percentage of trees in the plot. Data are from 25 ha of the first census.

Table 38.5. Yasuní Rankings by Genus

Rank	Genus	Basal Area (m^2)	% BA	% Trees	Genus	Trees	% Trees	Genus	Species
1	*Iriartea* (Palmae)	49.3	6.7	1.7	*Matisia* (Bombacaceae)	9188	6.6	*Miconia* (Melastomataceae)	45
2	*Inga* (Leguminosae)	38.3	5.2	6.0	*Inga* (Leguminosae)	8380	6.0	*Inga* (Leguminosae)	43
3	*Eschweilera* (Lecythidaceae)	35.3	4.8	1.7	*Rinorea* (Violaceae)	6023	4.3	*Pouteria* (Sapotaceae)	30
4	*Matisia* (Bombacaceae)	25.8	3.5	6.6	*Guarea* (Meliaceae)	5351	3.8	*Piper* (Piperaceae)	22
5	*Alchornea* (Euphorbiaceae)	21.8	3.0	0.2	*Miconia* (Melastomataceae)	4128	2.9	*Guarea* (Meliaceae)	20
6	*Pourouma* (Cecropiaceae)	19.3	2.6	1.8	*Zygia* (Leguminosae)	4042	2.9	*Neea* (Nyctaginaceae)	20
7	*Guarea* (Meliaceae)	18.8	2.6	3.8	*Piper* (Piperaceae)	3766	2.7	*Licania* (Chrysobalanaceae)	17
8	*Cecropia* (Cecropiaceae)	18.6	2.5	0.5	*Neea* (Nyctaginaceae)	3480	2.5	*Sloanea* (Elaeocarpaceae)	17
9	*Otoba* (Myristicaceae)	16.8	2.3	0.3	*Siparuna* (Monimiaceae)	2619	1.9	*Psychotria* (Rubiaceae)	16
10	*Virola* (Myristicaceae)	15.9	2.2	0.7	*Pourouma* (Cecropiaceae)	2534	1.8	*Trichilia* (Meliaceae)	15

Notes: The top 10 tree genera for trees ≥1 cm dbh are ranked by basal area, number of individual trees, and number of species with the percentage of trees in the plot. Data are from 25 ha of the first census.

Table 38.6. Yasuní Rankings by Species

Rank	Species	Number Trees	% Trees	Species	Basal Area (m^2)	% BA	% Trees
1	*Matisia oblongifolia* (Bombacaceae)	4581	3.2	*Iriartea deltoidea* (Palmae)	49.3	6.5	1.6
2	*Rinorea lindeniana* (Violaceae)	3241	2.2	*Eschweilera coriacea* (Lecythidaceae)	24.3	3.2	0.9
3	*Matisia malacocalyx* (Bombacaceae)	2323	1.6	*Alchornea triplinervia* (Euphorbiaceae)	21.8	2.9	0.2
4	*Iriartea deltoidea* (Palmae)	2313	1.6	*Otoba glycycarpa* (Myristicaceae)	16.8	2.2	0.3
5	*Brownea grandiceps* (Leguminosae)	2156	1.5	*Cecropia sciadophylla* (Cecropiaceae)	14.8	2.0	0.3
6	*Memora cladotricha* (Bignoniaceae)	2075	1.4	*Cedrelinga cateniformis* (Leguminosae)	14.6	1.9	0.0
7	*Piper* sp. (Piperaceae)	2074	1.4	*Apeiba membranacea* (Tiliaceae)	13.2	1.8	0.3
8	*Zygia basijugum* (Leguminosae)	1913	1.3	*Matisia malacocalyx* (Bombacaceae)	11.0	1.5	1.6
9	*Zygia heteroneura* (Leguminosae)	1764	1.2	*Pourouma bicolor* (Cecropiaceae)	10.5	1.4	1.1
10	*Inga auristellae* (Leguminosae)	1701	1.2	*Cedrela fissilis* (Meliaceae)	7.8	1.0	0.1

Notes: The top 10 tree species for trees ≥1 cm dbh are ranked by number of trees and basal area. The percentage of the total population is also shown. Data are from 25 ha of the first census.

census due to their small size, *Miconia* (Melastomataceae) is the most species-rich. In the Yasuní plot, only four species of *Miconia* are midcanopy trees. Yet, with 89 species, this genus is the most species-rich genus of all flowering plants in Amazonian Ecuador (Jørgensen and León-Yánez 1999; see also Renner et al. 1990).

Tree phenology was studied from February 2000 to March 2001 using 200 traps (74 × 74 cm) scattered inside the 50-ha plot, with a minimum distance between then of 13.5 m, following the same protocol used in the Barro Colorado Island and Pasoh Forest Dynamics Plots. Flowering in trees and lianas was inversely related to rainfall. However, when trees were in peak flowering, lianas flowered less, and vice versa. Flowers of Leguminosae and Palmae were the most common in the traps (Aguilar 2002).

Fauna

Yasuní National Park, including the area around the research station, has an essentially intact vertebrate fauna, including the larger species of birds and mammals. The nest of a harpy eagle (*Harpia harpyja*) was found a few kilometers from the station, macaws (*Ara* spp.) and guans (*Aburria pipile*) are numerous, and pumas (*Felis concolor*) and giant anteaters (*Myrmecophaga tridactyla*) occur in

the area. White-lipped peccaries (*Tayassu pecari*), tapirs (*Tapirus terrestris*), and jaguars (*Felis onca*) have been seen in the Yasuní Forest Dynamics Plot. There are 11 monkey species near the station, and many are bold and easy to observe. The ecology and behavior of woolly monkeys (*Lagothrix lagothricha*) and other species of monkeys have been investigated within a 350-ha plot close to the station. Inventories of other groups of vertebrates and invertebrates are underway. To date there have been 84 species of amphibians and 77 species of reptiles recorded around the Yasuní Research Station (S. Ron personal communication), whereas 60,000 species of insects are estimated to exist in a hectare of forest at Yasuní (T. Erwin personal communication).

Natural Disturbances

Most canopy disturbances are from small treefall gaps created when one or a few trees fall. The importance of large-scale wind storms is unknown. Occasionally significant blowdowns do cause major disturbance in the forest, as occurred in March 2002 when 96 trees over 10 cm dbh were downed by a wind storm. During that event, big trees such as *Cedrelinga cataeniformis* (>100 cm dbh) together with other Leguminosae species (especially *Inga*, *Lonchocarpus*, and *Parkia*) and Cecropiaceae (*Cecropia* and *Pourouma*) accounted for more than 40% of the total fallen trees. There is no indication that El Niño events have any impact in the region.

Human Disturbance

In 1995, an archeological survey was carried out on a hilltop near the northwest corner of the study plot. There were ceramic shards just 50 cm below the forest floor, estimated to be roughly 500–1000 years old (Netherly 1997). The artifacts may belong to the nomadic Huaorani Indian group, which formerly opened small clearings or used natural gaps for plantations of manioc and temporary home sites. Evidence of prehistoric burnings, presumably for agriculture or subsistence, were found in soil cores taken near the study site and preliminarily dated to 7700 years before the present (Athens 1997). There is evidence of Native American settlements in the area, but the existence of extensive clearings is unknown.

The most conspicuous present day human disturbances are concessions for oil exploitation and new settlements of indigenous groups along a new road. The large oil reserves in the national park were leased to various oil companies for prospecting and exploitation in the 1990s. From 1992 to 1995, the oil company Maxus established facilities for oil exploitation, including an underground pipeline and a 150-km road that crosses the northwestern part of the park. Although the oil company controls the road access to prevent human colonization,

in the last several years Huaorani and Quichua settlements have appeared near the station. A new Huaorani settlement of about 20 people has arisen 4 km east of the NE corner of the plot, as well as a bigger settlement about 12 km to the west. All Huaorani communities have given up their nomadic lifestyle for permanent houses. Consequently, hunting intensity has increased along the road. The Huaorani occasionally hunt in the 50-ha Forest Dynamics Plot, which is only 100 m from an oil road. Recent evidence indicates that hunting along the road has already had an impact on mammal populations. Monkey densities are lower now than they were 5 years ago in a study plot near a road and only 10 km from the Yasuní Research Station. Sites further from the road appear to be unaffected (S. Suarez personal communication). The vast majority of Yasuní National Park, however, is largely inaccessible and its forests remain undisturbed.

A 1-ha area near the southwest corner of the plot—presently dominated by *Cecropia* species (Cecropiaceae)—was a heliport used for oil exploration before 1990. In addition, the exotic plant *Muntingia calabura* (Elaeocarpaceae) grows inside the plot.

Plot Size and Location

Yasuní is a 50-ha, 1000 × 500 m plot; its long axis lies east-west. The western 25 ha have been fully enumerated for all trees ≥1 cm dbh; in the eastern 25 ha, all trees ≥10 cm dbh have been enumerated. The southwest corner is at 00°41′14″ S and 76°23′72″ W. The southeast corner is at 00°40′84″ S and 76°23′72″ W. The northwest corner is at 00°41′14″ S and 76°24′20″ W. The northeast corner is at 00°40′45″ S and 76°23′08″ W.

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