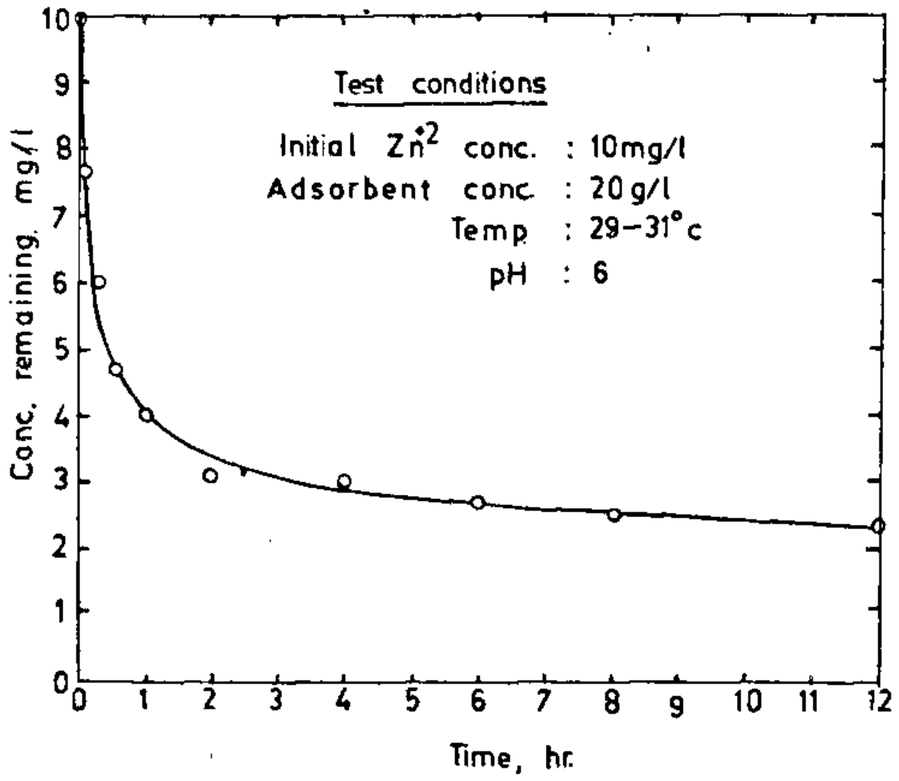

Figure 2. Kinetics of zinc removal by vermiculite.

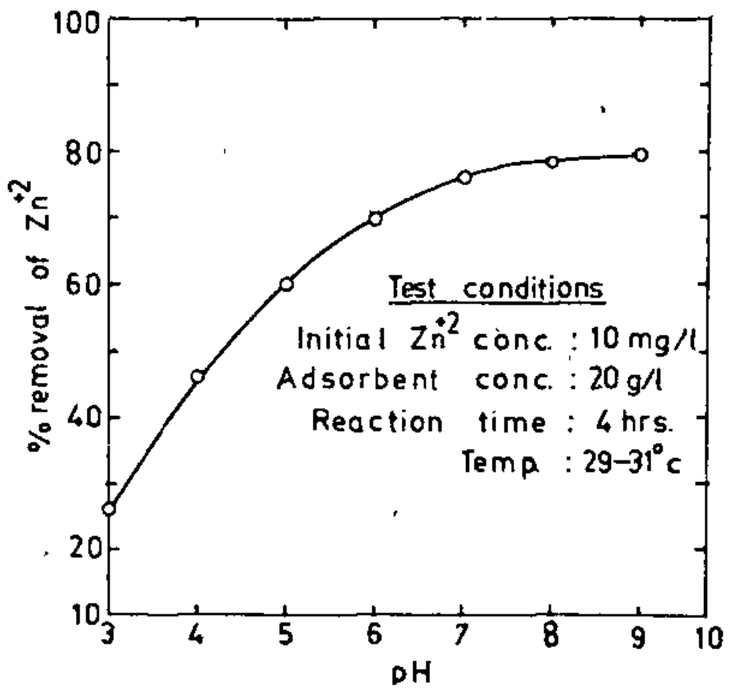

Figure 3. Effect of pH on zinc removal by vermiculite.

important role in the adsorption of heavy metals by clay minerals. Figure 3 shows the effect of pH on removal of zinc by vermiculite. At pH 3.0, only 26% of the zinc present was removed; the rate increased with increase in pH, and at pH 9.0 about 80% of the zinc was removed. This type of behaviour is particularly true for the strongly hydrolysable cations[8]. At low pH, the H^+ present in the solution competes with zinc for the active sites on the vermiculite. The enhancement of adsorption with increase in pH, is apparently due to the presence of coordinated OH^- groups. The replacement of an aquo group by a hydroxo group in the coordination sheath of a metal atom may render the complex more hydrophobic by reducing the interaction in the solvent–hydroxo complex. Complex interaction might then in turn enhance the formation of covalent bonds between the metal atom and specific sites on the solid surface by reducing the energy required to displace water molecules from the coordination sheath[9]. It has also been reported[10] that clay minerals generally exhibit strong cation-exchange properties in alkaline solution, strongly binding many hydrolysable metals to their surfaces.

On the basis of this study, we conclude that vermiculite may be extensively used for removal of zinc, one of the pollutants in industrial effluents.

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Savannization of dry tropical forest increases carbon flux relative to storage

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A study of dry tropical forest and savanna derived from it suggests that, although carbon stored in the savanna vegetation was less than half of that in the forest, carbon input through net primary production was similar. The savanna, drawing upon biodiversity resources, was able to maintain the same level of ecosystem productivity as the forest through species replacement. Belowground parts contributed more to carbon storage and flux in savanna than in forest, but carbon stored in soil remained far lower in savanna. Our studies indicate that conversion of dry tropical forest into savanna increases carbon flux relative to storage. This has implications for global carbon budget studies.

GLOBAL carbon dioxide concentrations have substantially increased from the mid-eighteenth century to the present day[1], and CO_2 is expected to reach 600 ppm before the middle of the next century[2]. Deforestation accounts for an annual net release of carbon[3] between

0.9×10^{15} and 2.5×10^{15} g, one third of which could be due to oxidation of soil carbon in the tropics occasioned by changes in land-use patterns[4]. Changes in land use through anthropogenic and climatic forcing result in vegetation conversion, which is likely to influence the balance of storage and flux of carbon in terrestrial ecosystems[5]. Therefore, for predictive global geosphere–biosphere modelling, a knowledge of relative C-storage and C-flux characteristics of converted ecosystems is essential. Most of the tropical Asian savanna has arisen owing to forest conversion[6], and Sagan *et al.*[7] have estimated that around 7×10^6 km^2 of tropical forests have been converted into savanna. Our studies indicate that conversion of dry tropical forest into savanna increases carbon flux in relation to storage.

The present data are the result of two consecutive years of study of three forest and three savanna sites located in the Kaimur range of the Vindhyan hill tract (24° 20′–25° 10′ N, 82° 30′–83° 30′ E) of India. The savanna originated from dry tropical forest three or four decades ago through anthropogenic forcing and is maintained by free-range grazing and lopping. The average annual rainfall exceeds 1000 mm, more than 85 per cent of which is received during the southwest monsoon (late June to early September). November to February is a cool, dry period (winter) and March to mid-June is hot and dry (summer). The soils are nutrient-poor ultisols, derived from Kaimur sandstones (Dhandraul arthoquartzite), and are reddish-brown in colour, sandy loam in texture, shallow, leached, and of moderate water-holding capacity (30–50 per cent)[8]. Total soil nitrogen ranges from 0.214 to 0.236 per cent in forest and from 0.065 to 0.109 per cent in savanna. Mineral N (NO_3-N + NH_4-N) ranges from 1.6 to 9.6 μg g^{-1} in forest and from 2.4 to 5.8 μg g^{-1} in savanna. Phosphate phosphorus ranges from 1.4 to 4.8 μg g^{-1} in forest and from 2 to 4 μg g^{-1} in savanna.

Woody-plant biomass was measured using allometric equations relating circumference to biomass. Aboveground herbaceous biomass was sampled monthly in 50 cm × 50 cm harvest plots and fine-root biomass (< 5-mm diameter) in 15 cm × 15 cm × 15 cm monoliths. Net aboveground primary productivity (NPP) of woody species in both forest and savanna was estimated allometrically using girth increment[9], and that of herbaceous vegetation through peak–trough analysis of biomass time series (ANP = $\sum_{i=1}^{n} \Delta^+$ live-shoot biomass + $\sum_{i=1}^{n} \Delta^+$ dead-shoot biomass + $\sum_{i=1}^{n} \Delta^+$ litter mass, where n = sampling intervals) using a decision matrix[10]. Peak fine-root biomass was added (assuming turnover of ≤ 1 year, based on our experience from root chambers and analysis of biomass dynamics) to the above estimates to obtain total net production (TNP).

Carbon content of various plant parts, viz. bole branch, foliage, litter, roots and herbaceous shoots, was determined using a Perkin–Elmer 240 CHN elemental analyser. Soil carbon was determined using a Heraeus CHN-O rapid analyser.

The total carbon storage in the forest vegetation averaged 28.68 tonnes of C per hectare (t C ha^{-1}) and that in savanna 12.89 t C ha^{-1} (Table 1). The belowground biomass in the savanna contributed more (37 per cent) to total C storage compared to that in forest (15 per cent). Share of herbaceous vegetation plus fine roots in total stored-vegetation C was only 4 per cent for forest compared to 49 per cent for savanna.

The net carbon input (TNP). in forest and savanna ranged between 4.75 and 8.06 t C ha^{-1} yr^{-1} ($\bar{x}$ = 6.27 t ha^{-1} yr^{-1}) and between 5.49 and 6.45 t C ha^{-1} yr^{-1} ($\bar{x}$ = 5.96 t ha^{-1} yr^{-1}) respectively (Table 2). Thus, although the carbon storage in savanna (mean B/P = 2.18) was half that in forest (mean B/P = 4.54), carbon flux was almost equal to that in forest, resulting in mean P/B ratio of 0.47 for savanna and 0.22 for forest. The contribution of herbaceous vegetation plus

Table 1. Plant carbon mass (t C ha^{-1}) in tropical dry deciduous forest and derived savanna.

Component	Aboveground	Belowground	Total
Forest			
Site 1			
Woody	34.32	4.80	39.12
Herbaceous (+ tree fine roots)	0.14	0.97	1.12
Total	34.46	5.77	40.24
Site 2			
Woody	18.31	2.65	20.97
Herbaceous (+ tree fine roots)	0.13	1.16	1.29
Total	18.44	3.81	22.26
Site 3			
Woody	19.90	2.75	22.65
Herbaceous (+ tree fine roots)	0.10	0.65	0.75
Total	20.00	3.40	23.40
Average for forest			
Woody	24.18	3.41	27.58
Herbaceous (+ tree fine roots)	0.12	0.93	1.05
Total	24.30	4.33	28.68
Savanna			
Site 1			
Woody	7.83	0.91	8.74
Herbaceous (+ tree fine roots)	1.92	3.33	5.25
Total	9.75	4.24	13.99
Site 2			
Woody	4.04	0.64	4.68
Herbaceous (+ tree fine roots)	2.26	4.02	6.28
Total	6.30	4.66	10.96
Site 3			
Woody	5.61	0.88	6.49
Herbaceous (+ tree fine roots)	2.68	4.54	7.22
Total	8.29	5.42	13.71
Average for savanna			
Woody	5.83	0.81	6.64
Herbaceous (+ tree fine roots)	2.29	3.96	6.25
Total	8.11	4.77	12.89

Differences in standing crops of carbon between forest and savanna were significant, $P < 0.001$.

Table 2. Carbon input through net primary production (t C ha^{-1} yr^{-1}) in tropical dry deciduous forest and derived savanna.

Component	Aboveground	Belowground	TNP
Forest			
Site 1			
Woody	5.70	0.37	6.07
Herbaceous (+ tree fine roots)	0.38	1.61	1.99
Total	6.08	1.98	8.06
Site 2			
Woody	3.83	0.16	3.99
Herbaceous (+ tree fine roots)	0.36	1.68	2.04
Total	4.19	1.84	6.04
Site 3			
Woody	3.34	0.18	3.52
Herbaceous (+ tree fine roots)	0.30	0.93	1.23
Total	3.64	1.11	4.75
Average for forest			
Woody	4.29	0.23	4.52
Herbaceous (+ tree fine roots)	0.34	1.41	1.75
Total	4.63	1.64	6.27
Savanna			
Site 1			
Woody	0.96	0.08	1.04
Herbaceous (+ tree fine roots)	2.71	1.74	4.45
Total	3.67	1.82	5.49
Site 2			
Woody	0.87	0.10	0.97
Herbaceous (+ tree fine roots)	2.94	2.02	4.96
Total	3.81	2.12	5.93
Site 3			
Woody	0.77	0.06	0.83
Herbaceous (+ tree fine roots)	3.24	2.38	5.62
Total	4.01	2.44	6.45
Average for savanna			
Woody	0.86	0.08	0.94
Herbaceous (+ tree fine roots)	2.96	2.05	5.01
Total	3.82	2.13	5.96

Differences in carbon-input values between forest and savanna were significant, $P < 0.001$.

fine roots to TNP averaged 84 per cent for savanna and only 28 per cent for forest. Evidently, drawing upon the local biodiversity resources, the converted savanna system maintained the same level of ecosystem functioning (productivity) as the forest through fast-growing species of shorter life span which replaced the longer-lived, slow-growing species of the forest at a cost of reduced C conservation in the biomass. Thus a low standing crop of C (i.e. small structure) in the savanna, in which functional importance shifts from woody canopy to herbaceous ground stratum where C_4 grasses assume predominance, was associated with high C flux. On the other hand, a high standing crop of C (i.e. larger structure) in the dry forest from which the savanna is derived, was associated with lower C flux.

Moore[11] has suggested that there is a larger sink for carbon in the tropical grasslands than has previously been suspected. This has implications for global carbon budget studies. In the present study also the share of belowground parts in TNP in savanna was greater (36 per cent) compared to forest (26 per cent). However, this increased belowground input was not reflected in soil carbon status. Organic C in savanna soil averaged 1.16 per cent, only 53 per cent of that of forest soils (2.18 per cent). High temperatures and rapid, pulsed release of nutrients in impoverished soil to support flushes of growth in tropical grasslands result in higher rates of decomposition, negating the potential effect of increased carbon flux to roots. Other studies have indicated 20–40 per cent loss in soil carbon due to conversion of forest to permanent agriculture and pasture[12,13].

We conclude that conversion of dry tropical forest into savanna increases carbon flux relative to storage and that savanna is a poor carbon-conserving system. Since the dominant vegetation in tropical savanna is of the C_4 type, CO_2 fertilization, as expected in future, may increase photosynthetic C fixation only marginally[14,15]. Increased C:N ratio in organic matter due to CO_2 fertilization[16] could potentially lead to better carbon conservation on account of reduced decomposition[17]. Nevertheless, higher temperatures would still cause rapid C turnover. If climate change increases the intensity of monsoon circulation, resulting in steady, wet monsoon[18] and moister subsoil, woodiness (and hence C conservation) may increase[19]. However, higher production and increased temperatures could subsequently lead to more fire, and therefore decreased woodiness. Human and livestock population increases in future are likely to alter forest/savanna boundaries further. It will therefore be important to consider the forest/savanna patch dynamics in global carbon modelling.

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Effect of indole-3-acetic acid and kinetin on non-cyclic electron transport in intact leaf discs and isolated chloroplasts of *Cephalandra indica* L.

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Indole-3-acetic acid (IAA) and kinetin have been found to accelerate photosynthetic non-cyclic electron transport in light reaction, whereby the artificial electron acceptor 2, 6-dichlorophenolindophenol (DCPIP) is reduced at a faster rate by accepting electrons. The rate of reduction of DCPIP by IAA treatment is, however, higher than that affected by kinetin. Reducing power of chloroplasts is remarkably higher when these are isolated from leaf discs pretreated with hormones compared to the system when isolated chloroplasts are subjected to hormone treatments *in vitro*.

INDOLE-3-acetic acid (IAA) and kinetin are two major plant growth regulators. IAA has a remarkable role in apical dominance, cell enlargement, cell division, ethylene formation and it also acts on some enzymes. Besides these effects, IAA promotes photosynthesis in a wide range of species[1–3], influences movement of nutrients within plants[4] and stimulates the transport of hydrogen ions across membranes[5]. The possible role of various cytokinins in the regulation of photosynthesis includes the reduction of the lag phase in the production of grana and promotion of synthesis of photosynthetic enzymes and plastidial ribosomal RNA[6, 7]. However, the phytohormones have been shown to affect mainly the enzymatic dark reactions of photosynthesis, but virtually little information is available on the effects of IAA and kinetin on photosynthetic electron transport in light reaction. In the present work, IAA and kinetin action on photosynthetic non-cyclic electron transport in the leaves of *Cephalandra indica* L. was studied. To test whether there is any difference in sensitivity between intact and isolated systems towards hormones, both intact leaf discs and isolated chloroplasts were chosen as the experimental materials.

Fresh and healthy leaves of *Cephalandra indica* L. were surface-sterilized with 0.1% mercuric chloride and washed thoroughly with distilled water. For experiment with intact system, discs measuring 8 mm in diameter were cut from such leaves. Leaf discs weighing about 1 g were floated in different concentrations of IAA and kinetin solutions in petri dishes together with a water control and kept in dark for 1 h, then washed thoroughly with distilled water. For the isolation of chloroplasts, leaf discs were homogenized with chilled sucrose-phosphate buffer (0.5 M, pH 6.0), centrifuged at 2000 *g* for 5 min[8]. Supernatant was taken and centrifuged again at 5000 *g* for 15 min. Residue-containing, partially intact chloroplasts were taken and suspended in the extraction buffer. The volume of the chloroplast suspension was made up to 5 ml by the addition of the same buffer from which 1 ml was taken in test tube and diluted to 4 ml. After mixing the suspension with 0.5 ml of 0.03% 2,6-dichlorophenolindophenol (DCPIP), the tubes were kept under continuous illumination for 10 min provided by two white fluorescent tubes (Philips TL 40 W/33) giving photon density of 150 μE $m^{-2}s^{-1}$ (400–700 nm) at the material level. Chlorophyll content of 4.5 ml reaction mixture containing either treated or untreated chloroplast suspension was about 0.18 mg. After light exposure, the change in optical density of DCPIP undergoing decolorization was measured in Spectronic 20 colorimeter. The control containing chloroplast suspension was kept in dark and used to denote the initial optical density of the dye.

For experiment with isolated system, chloroplast suspension was prepared from untreated leaves in a similar way as mentioned before. One ml aliquot was taken in each test tube, diluted suitably, mixed with different concentrations of hormones and kept in dark for 1 h. Another set of controls was made using mixtures of different hormones taken separately with DCPIP but without chloroplast suspension and kept both in light and dark. It was noted, however, that there was no reduction of the dye without chloroplast suspension. Following dark incubation, 0.5 ml of 0.03% DCPIP was added to each tube and exposed to light as before. Change in optical density was measured and result was expressed in μmol DCPIP reduced per mg chlorophyll per h. Disappearance of blue colour of DCPIP to different degrees indicated the rate of non-cyclic electron flow, i.e. hill activity. Chlorophyll content was measured from 1 ml aliquot of chloroplast suspension[9].

The results show that both the hormones increased the non-cyclic electron transport in both the systems (Figure 1). The salient features of the changes brought about by IAA and kinetin were essentially similar in