The savannas are among the most variable of terrestrial ecosystems and are known to undergo large changes in production, composition and structure (Walker and Noy-Meir, 1982). The savannas of India which occupy the dry subhumid peninsular regions, show strong affinities with the East African savannas. The commonness between these two could be seen in the flora and fauna. The representative vegetation of the two ecosystems are in the form of the tree species, the grasses, the mega-fauna (mainly elephants) and the occurrence of annual fires. Hence a comparison could be done between the two ecosystems analysing the dynamic functioning of the herbaceous layer and the processes, namely primary production, nitrogen dynamics and the effect of fire on the vegetation.

**Primary production of the herbaceous layer**

The aboveground primary production (709.69 g m\(^{-2}\)) and the total production in the present study was in the range of estimates within the savannas of Africa (Strugnell and Pigott, 1978; Deshmukh, 1986; Kinyamario and Imbamba, 1992). Indeed this is justified by the likeness in species composition of the two ecosystems. But there seems to be a difference in the methods used. While the studies in Africa have made use of permanent plots for measuring primary production, it was not possible to do so in the present study. Instead the production estimates are in situ values obtained by temporary protection of plots on a monthly basis and the position of the plots changed every month. This is also closer to the method used by McNaughton (1985) for
determining the actual production in the Serengeti. Here two of the three types of production given by McNaughton (1985) was obtained, namely the 'Apparent production' (production values under grazed conditions) and 'Actual production' (production values from temporarily protected plots). The shortcomings lie in the fact that a permanent plot could not be established in order to have production values from totally protected plots (control).

It has been argued that the standing biomass and primary production of the herbaceous vegetation is affected by grazing. On the contrary McNaughton (1985) considers production to increase due to grazing. This may not be an immediate effect of grazing as Ojasti (1983) has clarified in saying that, depending on the extent of the grazing activity, production may be stimulated and improve the plant cover for other consumers. In the absence of grazing the most of the plant parts remain attached to the plant, thereby sequestering the minerals and lowering the primary production (McNaughton, 1985). The animals by passing through the vegetation or by grazing prevent this accumulation of old tissues and consequently increasing the nutrient status of the regrowing plant tissues (McNaughton, 1979).

One aspect that stands out in the study is the value of consumption (460.01 g m\(^{-2}\)/year or 1.26 g m\(^{-2}\)/day) which is at 64 % of the aboveground production. This value is high in comparison to the values given by Prasad and Sharatchandra (1984) and Sukumar (1989) for a similar ecosystem. On a global level it is comparable only to the Serengeti plains where McNaughton (1985) obtained a value which was 66 % of the aboveground production. Here consumption has been
calculated as the difference of phytomass values inside the plot (protected) and outside (grazed). This follows the method described by Milner and Hughes (1968), where they have given that this method may over-estimate the values due to the increased growth rate inside the cages as a result of microenvironmental changes occurring in them. They have also mentioned that by regularly moving the cages it is possible to determine net primary herbage production accurately. Here instead of the cages, temporary plots (with ropes) were used, hence the change in vegetation inside these could have occurred only as result of exclusion of herbivores, although intake by invertebrate herbivores have not been accounted for. Consequently the values here seem to be more accurate because the value here considers for losses through consumption. Apparently there exists no comparative estimates of consumption for other Indian savanna regions.

Values of primary production from the savanna regions of Northern India are higher than in the present study. The MAB study (Misra, 1983) conducted in the Chandraprabha Santuary near Varanasi though classified under the savanna ecosystem showed different climatic, soil and vegetative characteristics in comparison to the present study site in southern India. Further another study in a dry tropical forest in Mirzapur forest division in northern India also showed different characteristics of climatic and soil conditions (Singh and Singh, 1992). Whereas the present study area had a dry spell of 4 - 5 months, the other sites studied in northern India had the dry season extending up to 7 months.
Methodology has been outlined by many authors to be a reason for variation in the production values. As mentioned earlier many estimates of standing biomass and primary production of the tropical grasslands are available. But understanding and interpreting them have had the difficulties in the varied methods that have been used in and the comprehensiveness of the various studies (Lamotte and Bourlière, 1983). Plant production has been measured through various calculations involving different algorithms, but some standardised methods were discussed by Singh et al. (1975). Productivity measures which have excluded decomposition have been shown to be underestimates by Jones et al. (1992). At the Bandipur National Park for the same species composition with a variation in rainfall the production observed was also different (see Appendix II). The variation in production values due to variation in methodology was reiterated by Kinyamario and Imbamba (1992). But comparisons of the present study with most others in India is possible due to the likeness in the methods and computation techniques used for calculating primary production. It is true that in order to be more comprehensive, data on all the components is necessary, but much is dependent on the perspective in which the study is undertaken.

**Nitrogen dynamics of the herbaceous layer**

The amount of nitrogen available to the plants at any given moment in terrestrial ecosystems is often limited and accounts for only a fraction of the total nitrogen in the soil (Olof Tamm, 1991). Much of the availability depends on the mineralization potential of the soil and on the additions and losses of nitrogen from and to the ecosystem. The
inputs of nitrogen in the savanna ecosystems may be mainly due to precipitation and fixation, while the losses usually may be greater via leaching, denitrification, erosion, fire and export through animal grazing (Bate, 1981). The more important among them which help in recycling minerals are mainly fire and grazing of animals and especially so in the savanna ecosystems. The immediate effect of fire was that it facilitated the release of nutrients stored in the plant tissues (Gillon, 1983) and has been a major cause of lower fertility in the savanna soils as compared to the forest where there is a thick layer of litter.

The active turnover of vegetal matter seems to be aiding in better availability of essential minerals for the plants due to breakdown of tissues. But nitrogen in the vegetation seemed to be exceptionally low. A major proportion of the N in the vegetation was due to the uptake by Themeda triandra. This grass species known to be resistant to grazing could be lowering the N in the vegetation, probably as an antiherbivore measure. The nitrogen production in the soil of the Ainurmarigudi Reserve Forest was seen to occur in pulses. Despite the alternate high and low production of N in the soil, the overall N produced seemed to satiate the needs of the plant. The first stratum (0-15 cm) of the soil is subjected to drastic changes in moisture and temperature conditions. It was clear from the study that the N produced in the soil was mostly in response to soil moisture availability. But a major proportion of the N produced was when the plants were in their initial growth phase, when even the uptake was high. Little variation in the soil organic matter and total nitrogen in the top soil was observed in burning experiments and in the protected plot (Brookman-Amissah et al., 1980). This is probably indicative of the
conservative nature of the vegetation which is satiated by the N production in the soil.

There is still a long way to reach a good global understanding of the functioning of the grass layer. From Figure 5.5 in chapter 5, it can be seen that a great difference exist between ecosystems in terms of primary production and uptake of N. A better approach would be to develop a computerized framework for simulating grassland N dynamics and to assess it by comparing with the various N compartments.

Effect of fire on the vegetation

The structure of the savanna woodland is therefore primarily determined by competition between the woody and grass plants for resources and modified by components such as herbivores and phenomena like fire (Walker and Noy-Meir, 1982). The observations made in the present study was supportive of the fact that the dry deciduous forest at Ainurmarigudi was tending to become open and showing a reduction in the tree density due to the frequent (annual) occurrence of fire. Trollope (1982) has stated that in general fire favours the development and maintenance of predominantly grassland vegetation by destroying juvenile trees and shrubs. A comparison between two plots having a different fire regime showed that the seedling establishment of the trees are high in the more fire prone plot. In the absence of fire the seedlings and saplings are exposed to attack by herbivores. On the other side where the fire was seen to be less frequent it can be seen that there is thicket formation which
General discussion

harbour semi-evergreen forest species. Fire has been known to control the tree/grass mosaics (Phillips, 1974; Goldammer, 1990). Though the forest tends to close up and become dense, this was brought about by invasion of shrubs and weeds, which retard sunlight required by regenerating trees (Sukumar, 1989). They also outcompete the grasses by shading off the soil surface and thereby reducing the surface of grazing area. Generally it was observed that the mature tall trees are generally out of the reach of fires due to the absence of grass under the canopy (Walker and Noy-Meir, 1982). But being a forest with a relatively open canopy even during the peak of growth period of the trees, it was seen that the grasses grow even under tree canopies. As grasses are more common in the open area, grazing is higher thereby resulting in high consumption. Thus in a combination of effects the herbivores and the frequent fires are open up the vegetation towards a more grassy layer, as observed in the African savanna ecosystems (Buechner and Dawkins, 1961; Lemon, 1968) with a reduction in the number of tree individuals and diversity (Brookman-Amissah et al., 1980).

In order to maintain the grass for the grazers and the optimal tree community to suit the browsers it is necessary to maintain an equilibrium between the two. A shift towards either extreme would affect the herbivores which are obligate grazers or obligate browsers. The transition of the forest to a grassy open vegetation is in itself detrimental. When the dead grass accumulates in the absence of fire, subsequent occurrence of fire generally takes abusive and uncontrollable forms often reaching high temperatures and killing great number of plants and animals (Gillon, 1983).
General discussion

The approach here was broad in order to assess the problems related to the understanding the savanna functioning. It is clear that a short term study does not answer much questions, but certainly is a starting point for a more comprehensive work to be initiated and consequently useful to propose strategies for a scientific management of the National Park.