Vedic civilization flourished in the land north of the present day Luni. According to them later neotectonic movements made the northern part of the Aravalli Mountains to subside, which paved the way for the River Yamuna to pirate the Saraswati waters and flow eastwards, leading to the extinction of the once mighty Saraswati. However, this account would remain merely an interesting 'story', until it is corroborated by convincing documentation and precise dating of the geological events, like uplift, subsidence, migration of palaeochannels and tying them up with archaeological record and dates. The last chapter of the book describes the synoptic history of Rajasthan from Archaean to Recent.

A large number of maps and photographs supplement the description. Unfortunately, the value of many of the maps is somewhat diminished because only some place names are given without any latitude–longitude and it is difficult to place the maps in a regional framework. Small index maps showing the locations of the detailed maps would have been useful. Similarly localities of most of the photographs are not mentioned. The authors have freely expressed their strong opinions on the contending hypotheses on many issues, but at places they express their views without mentioning the logic behind them. The writing is lucid, though at places they have used some quaint expressions (e.g. 'the lineations are polarized', p. 54; 'inverted zone of basin margin fault', p. 74; 'lithospheric crust', p. 119) which could have been avoided. The index of the book is a source of irritation. The items are arranged in such a haphazard way that it is almost impossible to locate a topic.

In spite of a few shortcomings it is an extremely valuable scientific publication in which researchers from a wide field of geology would find that topics which interest them are discussed in details and with perception. This is a book which no scientist desirous of having an in-depth knowledge of Rajasthan geology can do without.

D. MUKHOPADHYAY

Department of Geology,
University of Calcutta,
35, Ballygunge Circular Road,
Kolkata 700 019, India
e-mail: elfim@vsnl.net

The Forgiveness of Nature: The Story of Grass. Graham Harvey. Vintage. Random House, 20 Vauxhall Bridge Road, London, England. 2002. 372 pp. £ 7.99.

'All flesh is grass', says the *Bible*. The truth of this statement is amply borne out in Graham Harvey's exquisitely written book on the story of grass and grasslands and how these have shaped man's culture and civilization. The title *The Forgiveness of Nature* is taken from an article in praise of the bluegrass that the US Senator John James Ingalls published in the *Kansas Magazine* in the 1870s. It outlines the impact one family, the Hominidae with just one species (*Homo sapiens*) has had on another, the Poacae (or Gramineae) with over 10,000 species, and how the destinies of these two families have become intertwined. Poacae preceded Hominidae by almost 55 million years, yet the association between human beings and grasslands has been 'close and long-lasting'. No other plant family has played such a crucial role in the advance of human civilization. As a Chinese saying goes, the most precious things are not jade or pearls, but the five grains: rice, wheat, millet, sorghum, and maize, which trace their origin to wild grasses. They account for 60% of the calories consumed by people in the developing world, while animal protein and fat are obtained from grazing animals. 'Grass,' according to Harvey, 'is a reminder that we have a history older than our lives.' The book also describes the evolution of the practice of animal husbandry in Great Britain from the Middle Ages to the present, which brought untold wealth and prosperity to the British farmers. Graham Harvey is the Agricultural Story Editor of *The Archers*, and he embellishes his narrative with interesting accounts of the impact of grass on sports such as football, cricket and lawn tennis.

According to an early Greek legend, mankind owes the ability to cultivate crops to the generosity of Persephone's mother Demeter, the goddess of crops who gave some wheat seeds to a priest who then broadcast them across the Earth, thereby sowing the dual blessings of agriculture and civilization. The Euphrates Valley in Iraq is where agriculture began. Grasslands were always associated with freedom and mobility. Pasture in Greek is *nomos*, from which the word nomad was derived. Thus as Harvey points out, 'the nomad is a mobile pastoralist, the owner and breeder of domesticated animals'. Livestock were central to the mobile Neolithic pastoralists, who bred the wild ox or auroch. It is not known how or why nomadic communities ceased their way of life and settled down to a lifetime of tilling the soil. For, contrary to the popular notion, the hunter–gatherer lifestyle is not harsh. 'By the sweat of thy face shalt thou eat bread' might have been the injunction given by God when he banished Adam and Eve from the Garden of Eden – implying that they would have to struggle hard for their survival. But this is not so as far as the Kung Bushmen of the Kalahari desert in South Africa are concerned. They spend less than a quarter of the working week in gathering food. Compared to the subsistence farmer, the hunter–gatherer has time even for leisure!

The study of grasses is known as Agrostology. Grasses trace their origin to the family Liliaceae. They first made their appearance in the fossil record about 55 million years ago, just 10 million years after the demise of the dinosaurs. Grasslands occupy almost a quarter of the Earth's land area extending from Alaska to Antarctica. They are the dominant natural vegetation of the prairies of North America, savannahs of Africa and steppes of Central Asia. They range in size from tiny herbaceous plants to giant woody bamboos of Burma and China, and make up one of the four great terrestrial habitats or biomes, the others being forest, desert and tundra. Ironically, grasslands owe their survival to a certain amount of aridity, for too much rainfall will ensure their replacement by forest trees. Grasses appear to thrive in areas devastated by man. In general, the more fertile the soil, the fewer the grass species it is likely to contain. Their success lies in their power of reproduction and speed at which they colonize new areas. Many people suffer from hay fever in summer when flowers throw up their pollen filling the air. Their flowers, however, are not colourful since they are pollinated by wind and not insects. Despite the fact that flowers of most grasses are hermaphrodite, there are mechanisms to prevent self-fertilization. The stigma can recognize and reject pollen produced by the same flower!

Green plants harness the energy of sunlight absorbed by chlorophyll to build organic compounds from water and carbon dioxide. Grasses transform between

1 and 3% of the light hitting them into chemical energy, but make use of two distinct biochemical processes – the so-called C_3 and C_4 pathways – to achieve this. C_4 grasses found mostly in the tropics are more efficient and faster-growing than the primitive C_3 grasses. Because most grasses grow rapidly, their leaves are able to transport carbohydrates produced by photosynthesis to other parts of the plant, either for continual growth or for storage. A critical aspect of grassland management is the timing of grazing pressure. Ideally, grazing should be scheduled to coincide with the end of the active growth period so that new herbage production is stimulated by the removal of the older growth. The agency responsible for doing this, prior to the arrival of man, was the grazing animal. Thus, the two families Poaceae and Equidae (horses, zebras and asses), according to Harvey, were mutually dependent. When grasslands became widespread only a few mammalian species were able to exploit the resource. One was the horse (*Equus caballus*) which evolved in North America and spread to South America, Europe, Asia, and finally Africa but became extinct in the country of its origin. The Spaniards reintroduced the horse into North America, and changed the way of life of many of the native Indian tribes. The hey day of the Indians living in the plains was brief. Equids were able to exploit the grasslands despite their poor nutritional value and siliceous defences. They did so by evolving a simple stomach, high-crowned molar teeth and passing the food through their digestive system rapidly. This enabled the equids to feed on the run. Grasslands, as Harvey points out, are semi-natural ecosystems that cannot survive without the intervention of grazing animals.

In North America, the prairie represented 'a biological powerhouse, rich in wildlife and with a productivity no modern farming system could match'. In the 1860s, prior to the arrival of the white settlers, it supported more than 60 million American buffalo (*Bison bison*). The buffalo disappeared in the two decades after the American Civil War. 'Kill every buffalo you can' an American officer advised in the 1870s, 'every buffalo dead is an Indian gone'. The buffaloes were wiped out through the voracity of the white hunters. The key to the incredible productivity of the prairies was a combination of species diversity and an ability to accumulate a vast reservoir of nutrients and water in the top few centimetres of the soil. There was no need for fertilizers or irrigation. While the buffalo had grazed and moved on, the introduction of English cattle led to the replacement of palatable species by less palatable ones. Cattle ranching led to over-exploitation of the plains. According to the American writer Richard Manning, 'The habit of fattening cattle on grain is just that, a habit. As a result, we eat fatter meat and the heart-stopping cholesterol it contains. Seventy per cent of the grain crop of American agriculture goes to the livestock that replaced the bison that ate no grain, and one wonders, what is agriculture for?' But the introduction of steel ploughs – courtesy of the John Deere Company – effectively destroyed the productivity of the prairie. The American Prairie became a dust bowl, the consequences of which have been movingly related by John Steinbeck in *The Grapes of Wrath* which won him the Nobel Prize for Literature in 1962.

As Andrew Sugden points out in *Turf Wars*, the ability of grasses to survive such adverse conditions as fire, drought, trampling and chewing by hoofed mammals, and to reproduce sexually as well as spread vegetatively has been 'exploited by generations of groundsmen and gardeners in the pursuit of leisure and sport'. Turf management has become a high-tech affair today. The nature of the turf may determine the outcome of the game. No wonder football and cricket clubs in the UK spend enormous sums of money to maintain ideal playing grounds. However, in football there is some conflict of interest between players who would like to have a pitch shaved close to the ground, and ground staff who are reluctant to mow the grass too short, for without sufficient leaf area, the grass will stop growing and become weaker.

Harvey highlights the gradual decline of the natural fertility of pasture following the adoption of intensive agriculture, aided by the use of chemical fertilizers. In 1856 the English manufacturer of fertilizers, John Bennet Lewis enlisted the help of the scientist Joseph Henry Gilbert in setting up an experiment – the Park Grass Experiment – to study the changes in productivity of grasses under different regimes of fertilizer. The experiment still goes on at Rothamsted, 'making it the longest-running ecological study in history'. The study demonstrated the reduction in species diversity following the application of chemical fertilizers, especially nitrogenous ones. Plots receiving artificial nitrogen at higher levels quickly assumed the monotonous characteristics of single-species vegetation, which is almost unknown in the wild.

Much has happened to the landscape in England since the Middle Ages when cultivated lands were like islands in a sea of forest. Nevertheless, wherever there was grass, sheep grazed. The demand for English wool was such that the sheep population outnumbered the human population by as much as six to one. Sheep farming became a profitable enterprise, and wool transformed the society and led to the emergence of the affluent middle classes. Long before the use of nitrogenous fertilizer, farmers in England and Wales would often drown their pastures by diverting river water. This enabled them to enhance the fertility of the pasture land. They also tried 'sewage irrigation', a practice that is still being adopted extensively in China. Leguminous plants such as clover have the ability to 'fix' nitrogen from the atmosphere using symbiotic bacteria. Hence the phrase, 'in clover' – an allusion to cattle feeding luxuriously in fields of clover – a state of luxury! Grasslands return nutrients to the soil, especially when they are rich in clover. Cows feeding on grass and other coarse vegetation produce milk rich in omega-3 fatty acids that can prevent heart attacks.

Intensive agriculture has led to the reduction in the diversity of soil organisms. Charles Darwin understood the importance of earthworms in enriching soil fertility. His last book was on earthworms and was published in 1880. But a revolution in agricultural practice had preceded it in 1840 with the publication of the monograph, *Chemistry in its application to Agriculture and Physiology* by the distinguished German Chemist, Justus von Liebig. This marked the beginning of the science of agricultural chemistry. Liebig advocated the replacement of the amount of major plant nutrients such as nitrogen (N), phosphorus (P) and potassium (K) that were removed in a crop at harvest. Although this led to higher yields, it also drove the wild flowers off the fields, reduced the number of insect-eating birds, and the landscape fell silent. One man who understood the links between grasslands and rural prosperity

was George Stapledon, who advocated a return to mixed farming or the rotation of grass leys and arable crops. In the 1930s, he was able to restore the productivity of derelict hill pastures in Wales. He also recognized the importance of grasslands for a healthy way of life. Even an occasional contact with Nature is known to reduce stress, anxiety and aggression in man. He believed – or hoped – that small farms could ensure both profit and pleasure to farmers and city dwellers. To him, small was indeed beautiful. But Stapledon was no match for the powerful agrochemical companies who had inherited the earth. Farmers have become increasingly dependent on chemical fertilizers to restore soil fertility and control diseases. Economic prosperity has come with an ecological price-tag. It is time we asked nature for forgiveness.

CHARLES SANTIAPILLAI

Department of Zoology,
University of Peradeniya,
Sri Lanka
e-mail: csanti@slt.lk

Edited and published by P. Balaram and S. Ramaseshan, Current Science Association, Bangalore 560 080.
Typeset by R D Typesetters, Bangalore (Ph: 3405672). Printed by Lotus Printers, Bangalore (Ph: 3209909).