also drawn to forms of the same fungus, which occur in South Africa.

Methods of control should follow preventative lines, which are best attained by proper forest sanitation, such as the destruction of sporophores of the fungus and of diseased wood.

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I also acknowledge the assistance given by various officers of the Forestry Department, and especially Mr. J. D. Keet in collecting specimens of this as well as other Polyporaceæ, as also for notes which frequently accompanied the specimens.

Some specimens of this fungus were verified by Mr. C. G. Lloyd, of Ohio, and him I thank for assistance with the Polyporaceæ generally.

The drawings were kindly made for me by Miss K. A. Lansdell, of this Department (Natal Herbarium, Durban).

EXPLANATION OF ILLUSTRATIONS.

*Fig.* 1.—Highly magnified transverse section through black ironwood to show the delignification and digestion of the wood brought about by this fungus. The dotted regions gave reactions for cellulose with chlorozinc iodide, and the digestion is evident from the cellulose plates projecting into the lumina.

*Fig.* 2.—Section highly magnified, and showing the mycelium of the fungus in the wood of black ironwood, and passing from cell to cell through the pits in the cell walls.

*Plate* 14.—Photographs of sporophores of *Fomes applanatus* from stumps of *Acacia mollisima*. The specimens are in the herbarium of the Government Mycologist at Pretoria, and the numbers are those of that herbarium.

*Plate* 15 *a*.—Photograph of wood of diseased black ironwood, which has already been considerably delignified, and crumbled easily between the fingers.

*Plate* 15 *b*.—Sporophore of *Fomes applanatus* from dead *Podocarpus* sp.

*Plate* 15 *c*.—Abnormal laterally stalked form of *Fomes applanatus* from *Olea laurifolia* (black ironwood).

*Plate* 16.—Spores of *Fomes applanatus*. Highly magnified.

*Plate* 17 *a*.—Nodules of *Fomes applanatus*, which develop into the bracket-shaped sporophore.

*Plate* 17 *b*.—*Polyporus gibbosus* Nees. No. 1703 from Herbarium of Government Mycologist, Pretoria. This fungus is most probably only a form of *Fomes applanatus*.

*Plate* 17 *c*.—Abnormal laterally stalked form of *Fomes applanatus* from dead *Rhus lævigata* (red currant).

(*Read, July* 3, 1917.)

# SOME FACTORS IN THE REPLACEMENT OF THE ANCIENT EAST AFRICAN FOREST BY WOODED PASTURE LAND.

By CHARLES FRANCIS MASSY SWYNNERTON, F.L.S., F.E.S., F.R.H.S.

## 1. INTRODUCTORY.

The observations of which this paper is an incomplete *résumé*, general at first, but more detailed since early 1913, when an investigation of Mr. A. K. Thayer's views on the all-concealing properties of forest led me to some close semi-œcological work and thus to an interest in œcology itself, have extended in all over eighteen years during which I have lived near forest patches. For the last sixteen of them I have lived right on the outskirts of the largest piece of high forest in Southern Rhodesia—Chirinda—and I am including here a brief account of the results of a private attempt of my own at forest protection that has led to a reversal of the process described in the title.

I have not seen this type of forest, as it occurs in East Africa, discussed at all thoroughly—though it very likely often has been, for I have no access to libraries, and my own is very limited.* It is impossible, actually, that the idea of its former continuity should not have occurred to everyone in the least acquainted with the distribution of our forest plants and animals, and it is the evidence afforded by their distribution that still gives the idea its best support. It may be of interest, nevertheless, if I state the evidence of other kinds, in so far as I have observed it, that a single locality can produce, and discuss the main factors that may have affected the distribution and welfare both of this type of forest and of its supplanter.

My observations have been confined to the Melsetter district of Southern Rhodesia, and to the foot-hills and lowlands in Portuguese East Africa that divide that district from the sea; and it is to this small section of our East African floral area that my remarks and conclusions primarily apply. I cannot help feeling that their applicability is, actually, wider, though I do not for an instant flatter myself with the belief that my local and still incomplete observations have given me all the factors that will have contributed to the change referred to in the title of this paper, or even, quite necessarily, the most important of them; and my object in writing is rather to provoke discussion

* I cannot tender this excuse for having overlooked Mr. J. S. Henkel's most interesting account of "Forest Progress in the Drakensberg" until the very day before posting the present paper. It is pleasing to have been able to confirm his observations from another portion of the sub-region. I am sorry I have not seen Prof. Bews's paper referred to by Mr. Henkel, or any other references to the subject, so far as I remember, excepting those actually alluded to in this paper. I hope that this will be accepted as an excuse for any resultant shortcomings.

and the production of evidence from elsewhere than in any way to attempt to dogmatize.

### 2. The Two Types of Wooding referred to.

From where I write, 700 feet above the nearer flats, and 4,000 above sea-level, on the hill that is crowned by Chirinda, I can see an immense tract of country. It includes low veld, stretching away to sea-level and looking like the sea, foot-hills, plateau, and high mountains, the latter with peaks of nearly 9,000 feet. And practically the whole of this great stretch of country, physically and geologically most varied, is to-day under grass, and to the greater part of it can be accurately applied Welwitsch's term of "wooded pasture." The wooding varies from widely-scattered shrubs and small trees and groves to a uniform covering of close-standing trees that is nevertheless mere wooded pasture, not true forest. The species are extraordinarily varied, but nearly pure wooding sometimes occurs in the groves of *Uapaca Kirkiana* and *Brachystegia* on the drier slopes of the mesophytic areas, of *Acacia* near *natalitia* on the dolerite, and of *Copaifera mopane* in areas of smaller rainfall. Grass fires, lit by natives wishful to cultivate, or hunting buck and rats—also nowadays by whites—sweep over it annually.

The type of vegetation is one which, with variations, is common through much of Africa south and north-east of Tanganyika.

One feature in the view remains unmentioned. In rare, isolated, little patches on the flats, or filling kloofs, or, more frequently, crowning hills and looking like the "Rings" on the Sussex downs, are small, dark "forests of gigantic timber," as Livingstone called them in Angola. The nearest of them, a hundred yards away, completes the panoramic view I have described, carrying it round from the south-east to the west again, and, except for its larger size, is sufficiently typical of them all. Its suddenness—its non-blending with the surrounding grass veld—is the feature that most strikes an observer outside. It is like a tall plantation. On entering it, one is struck with its loftiness, its density, and its step-like formation, described already in my paper on the Melsetter trees and shrubs. No contrast could be stronger than that between this type of forest and the wooding of the grass veld, whether we have regard to their outward appearance or to more fundamental characteristics. The trees of the forest are intolerant of fire, the pasture trees are especially adapted to withstand it. The members of the one formation never enter into competition with those of the other—where grass-burning is the practice—yet the soil and moisture conditions inside and outside the forest are exactly the same, excepting in so far as they are modified by the presence of the forest itself.

Sub-divisible, as the effect of altitude, into "mountain" and lowland types, the first with an admixture of Gymnosperms, the second without them but loftier, and varied further with latitude, Chirinda-like forest is found in patches throughout East Africa



from the Cape Province to Elgon and beyond, in the higher rainfall areas; but in parts of the Congo basin and elsewhere in the west it covers the face of the country. A suggestive gradation occurs from this condition, through the forests of British East Africa, which, if isolated, are still large, down to the diminutive dense forests of Southern Rhodesia. Where continuous they are regarded, I believe, as primary. Are they then to be looked on as secondary in the other areas? If so, how, with such laboriously-moving constituent members as, for instance, *Widdringtonia*, have they reached their present widely isolated positions? If not, why are they no longer continuous throughout? It is the last problem, chiefly, which I propose to discuss in this paper.

### 3. Present Distribution of High Forest in the Melsetter-Beira Section.

Chirinda is our largest patch on the British side of the border, but, as I have said, it is by no means the only high forest in the country. Small patches are scattered along the Portuguese border and in Portuguese territory south of the Lusitu River, and wooded kloofs often tend to reproduce this type of forest. Further north, the higher mountains, including Chimanimani, boast many forest patches of the "mountain" type, and forest patches crop out along the high Anglo-Portuguese boundary so far north as Umtali and, I am told, beyond. I am not acquainted with the last-named patches, but Mr. L. Cripps told me, when in Chirinda some years ago, that he recognised there species of big trees which also occur in forest on his farm near Umtali. I am not aware that forest of this kind occurs much more than 25 miles west of the border, and, if that be the case, it may be regarded as falling entirely within the area of greater rainfall; but, travelling 30 or 40 miles east, one comes on an extensive forest patch, larger than Chirinda, on the eastern slope of the Sitatonga Hills,* and, far nearer sea-level and relatively nearer the coast, the well-known patches on the Beira Railway and one south of the Buzi River which contains, as well as *Khaya nyasica*, other trees that in growth, foliage and bark I was unable to distinguish from certain trees of Chirinda, though I was unfortunately unable to secure flowers. It is true that further dense forests—the great dwarf rubber forests of the lower veld—cover immense areas, and may well be taken into consideration in connection with the distribution of our forest animals (they are the only place in which I have seen *Papilio ophidocephalus*, also occurring in Chirinda, really abundant, but they seem to me to belong to a very different type from the kind of forest I am discussing here, and probably to be, in part, secondary. At the same time, I am informed that in portions of these forests not visited by myself

*I include the Sitatonga Forest with a slight reservation. I passed through in May, 1900, when I had not yet taken up botany, and when, also, I had not yet seen Chirinda, so that my memory of it may be inaccurate. I believe it to be correctly included here.

(*e.g.*, at Makupi's), patches of Chirinda-like forest occur, and I judge from the statements of natives that other patches of the same kind must occur here and there in the low veld off the beaten tracks.

4. Evidence of Forest Destruction and Probable Former Continuity.

(1) *From more or less direct observation.* I have myself seen a single fire destroy a 10-15 yards depth of forest along a very limited front, and, in the Chimanimani Mountains, seen where much larger areas than this had been cleared by the last season's fire; and I have witnessed in the eighteen years I have resided here a more gradual, yet definite, eating into portions of the outskirts of small forest patches with which I am acquainted, by the annual fires. The evidence of old natives in this connection—at any rate of those who do not live right up beside forest—is apt to be unsatisfactory, as they appear not to observe and remember readily gradual events that concern them little; but one very old man—old even when I first came here—who lived in his youth right beside the Chipungambira patch (near Spungabera), and then moved up beside Chipete, tells me that when he was a lad some specially destructive fires destroyed quite large pieces of each of these forest patches.

In the case of the "Jihu"—a large, rich, mostly Portuguese trap-area south of Chirinda—it is possible that 30 or 50 years hence no one will be able to say from personal observation that true forest ever existed there. Yet in 1906 evidence, in the form of charred tree-bases, the vegetation that immediately succeeds forest, etc., still pointed unmistakably to the recent existence of a good-sized patch on the eastern slope of the rise dividing the Zona and Kurumadzi rivers, and, near the Zona, a patch of fine mahoganies still stood, but some of their late companions were sprawling, charred, on the ground just round them, and were surrounded in turn by the evidences of previous destruction.

As for the matter of former continuity it is suggestive that the final destruction of the first-mentioned forest-patch widened by several miles the gap between surviving patches, while the piece of Chipete said to have been destroyed 60 years or so ago continued that forest towards a still-existing outlying strip of Chirinda.

2. *Indirect Evidence.*—The *position* of the majority of the surviving patches is perhaps suggestive. Three of six patches I can see from where I write definitely crown hills, and two others are on a ridge. This very common position certainly *seems* to point to the probability that fires sweeping from below have gradually eaten up the forest lands till these for the most part occupied only the hills, and have then burned across the "necks," split the forest stretches into patches, each occupying the higher parts of a hill, and then continued to eat these



back by the process already noted. Compare, also, Whyte's description below.

Not that their elevated position is, by any means, all there is in favour of the hill-tops as a last refuge of forest. Sandstone and shale below, they are frequently capped with overlying dolerite and the fertile red loam that belongs to it, and that seems to offer this type of forest the best guarantee of the luscious margin, even in the dry season, which helps it to keep out fire. At the same time, these dolerite caps are in several cases a continuous part of the main masses of our two big trap-areas—are, so to speak, the very slightly outstretched processes of a great *Amœba*—and it is therefore highly suggestive of the first view here mentioned, that it is chiefly these, the culminating points, and not the main masses, that to-day carry forest. Chirinda, Chipete and Maruma are amongst the examples. Again, some of the higher mountain-forests, and considerable slices of Chirinda itself, as well as small patches elsewhere, and some experimental planting of my own, show clearly that this type of forest can flourish perfectly well on the sandstone and shale, although, for indirect reasons, such as the one I have suggested, it has undoubtedly, I think, been the general tendency for the fires to remove it from these areas first.

The *plants and animals* of the forest-patches afford evidence of the usual kind. One has to be cautious in relation to the alternative possibility of migration, and a bird like the Milanji Bulbul (*Phyllastrephus milanjensis*), which inhabits also the wooded kloofs, is under suspicion of having travelled along by easy stages; but it seems significant that trees with no special means of seed-dispersal are found in very widely-separated patches unconnected by water, and that the same applies to animals that, at any rate, one does not suspect even of local migration. Such are the common Robin of Chirinda (*Erithacus Swynnertoni*), formerly found only there and in Chipete, but since discovered by Mr. P. A. Sheppard in forest-patches near Macequece, on the Beira railway, and such shade-loving and unenterprising fliers as the butterflies *Aterica galene* and *Euphœdra neophron*, taken by me in the Sitatonga and Chirinda forests, and seen in others. However, the resemblance between their arthropod inhabitants generally is striking, and one finds such utterly sluggish species as the scarlet millipede of the tree-trunks (*Spirolobus*), and a barely-moving "red spider" (*Trombidium*) in widely-separated patches. Cases like these last seem to me to tell decisively against the theory of migration.

The usual *succession of vegetation* that follows forest also affords good evidence of progressive shrinkage and probable former continuity, and the case of *Chipete* is instructive in this and in other ways. It is a patch of perhaps 40 acres crowning a hill, and separated now from the main body of Chirinda by a wide kloof and several hundred yards of grassy hillside. There is a little wooding in the kloof, and there are three diminutive scraps of it near its head, on the Chipete side, on the sandstone.

That these are not purely new growth, but originally, probably, the remnant of a former general continuity between Chipete and Chirinda is suggested by the presence till, some years ago, of a couple of old decayed trees, by the fact that the destruction of the little patches (in no way worth protecting) has gone on till nearly nothing is left of them but a few square yards of rank green grass and creepers in each place, and by an examination of the surrounding vegetation with the usual local succession in mind. This last suggests the former connection of the three as a single, straight strip of forest, and the latter's yet earlier connection with a Chipete far larger than at present.

An examination of the low, erect, so-called "*Sand-apple*" scrub (*Parinarium curatellæfolium*), which nearly everywhere clothes these hills, bears all this out, and indicates further facts, in a very remarkable way. For, whatever agency—their own once more abundant parents or some animal that distributed the stones—once sowed these little sand-apples broadcast and ubiquitous over the face of the country, has obviously ceased to exist many years ago. Now the sand-apple will just germinate in forest, but it won't live there; so that those areas that were covered with forest at the time the sowing ceased should to-day show no sand-apples. Actually, a most clearly defined bare ring of this kind surrounds Chipete, and others surround Chirinda itself (with much country to its south-west), the group of three little patches referred to above, a piece of ground between these and the former, big Chipete, and—a further link, taking us to within 200 yards of Chirinda—a long, narrow piece of ground with occasional suggestive vegetation between these same little patches and the latter forest. I may say at once that neither differences in the soil, or in its humus or water-contents, nor any other factor except the one I suggest, has proved at all capable of accounting for the sharp demarcation, in these places, between the ground that is crammed with *Parinarium* and that which has none.

In general, the "Sand-apple line" seems to show that the main body of Chipete at the time indicated swept down far nearer to Chirinda than it does at present. It also (contrary to expectation based on the lie of the ground) suggests that the fires worked in between the forests from the *head* of the kloof, along the broad sandstone area that still carries the disappearing connecting-links I have described, and that the latest point of junction between the two forests was at the point indicated by the information received from the old Kaffir, along a ridge characterized by dolerite. This illustrates the fact already referred to, that forest tends to disappear from sandstone first. Further, if the latest point of junction was actually at the spot suggested, Chipete would have formed a *fold* of Chirinda, and its native name, meaning "the fold," would perhaps be explained. Natives questioned as to its origin have always said they do not know—that the name was handed down to them by their forefathers.



A similarity in the species comprising Chipete and the part of Chirinda that was, apparently, last connected with it is suggestive, but not conclusive, for bird-carried species are largely concerned.

*To sum up*: Chirinda itself, shaped like an hour-glass by the fires that formerly ran in between its twin heights, shows us an early step in forest-splitting. Chipete, only a few hundred yards away, and with highly-suggestive evidence of a former continuity with Chirinda, the next. The other patches of the country show us every gradation in the matter of distance from one another, and I have described an instance above in which a gap was greatly widened by the complete destruction of a forest-patch. The evidence generally is suggestive of former continuity in the section I am particularly concerned with, and of the view that the patches actually represent our most primitive type of forest.

Should we accept this much it is hard not to extend our conclusions. The actual distribution of a number of plants and animals, and the facts touched on in the last paragraph of Section 2, suggest strongly that the idea of a great East African forest that once connected Knysna with Elgon and beyond is not far-fetched. Our Gazaland dense forests are the meeting-place of Nyasan and Southern species, *Podocarpus milanjiana* carries us on beyond to the German and British East African mountains, and cases like *Khaya nyasica* (not much more than a sub-species of *K. senegalensis*) take us round with a swing, *via* Nyasaland, into the forests of the west. Finally, *Pseudocalyx*, *Pœcilostachys*, and other apparent relics of the connection with Madagascar, enable us to picture the forest as existing already in the earlier Tertiaries, when, as the great nummulitic deposits between Chirinda and the sea alone suffice to show, the country's configuration must have been very different, and land must have been under water that to-day carries isolated forest and was once perhaps clothed with it.

### 5. Factors in Forest-distribution.

(*a*) High Primitive Forest.—I have already incidentally indicated the view (1) that the general area in which Chirinda-like forest can occur is strictly limited by conditions of *rainfall;* and (2) that *one* important factor which has brought about its present scattered distribution is *the annual grass-fires*. It has been suggested to me that the rainfall generally is gradually diminishing, and that this may be the factor that is causing the forests "to die out."

Directly, no—or so one would say: for the surviving forests are, for the most part, in far too flourishing a condition to allow one to suppose that any such detrimental influence is at work within them. At the same time, a realization of the exact conditions under which some of them grow suggests that the possibility should not be lightly dismissed. Thus Neave (*Geographical Journal*, February, 1910) writes of the "mitu," or

dense forest-patches, of the high plateau country, the backbone of which forms the water-shed between the basins of the Congo and Zambezi rivers, that "they are commonly on the source or banks of a stream." Many of our kloofs—with streams or probable underground moisture—carry dense bush that is practically a sub-community of our high forest formation, and often contains a considerable sprinkling of true forest forms, as *Khaya, Piptadenia,* the shrub *Tricalysia,* and others I might name. The forest-patches on dolerite, as I have said, often occupy the hill tops, but the red loam in any case probably conserves moisture better than the sandstone. Of the little patches on the latter formation that I have referred to more particularly earlier, it is interesting to note that the elongated one, nearest Chirinda, now no longer carrying forest, follows roughly a shallow kloof, in which a spring has sometimes appeared after great downpours in our older, heavier, rainy seasons, while those nearest Chipete were connected this last season, after a 31.4-inch rain in four days, by quite a stream—on a convex surface with no trace of a previous surface-flow excepting from the lowest of the patches. The survival of one or two other very small patches has obviously been aided by the presence of low, widespread ant-heaps of *Termes bellicosus,* full, of course, of collected humus. So that, on the drier soils, it is in the damper places or above probable subterranean waters that forest most tends to survive. Again, it is the rule—which has its notable exceptions—that the forests have eastern and south-eastern aspects.

Actually, all this is explicable also in relation to fire, and against the other interpretation we must place the present non-afforestation of the vast bulk of the doleritic area with the aspect described, and the ease and success with which forest-trees can be re-established on the drier soils, continuing to take care of themselves if looked after for the first season or two, and then merely protected from fire. Also the fact that considerable pieces of Chirinda are on the sandy soil, yet carry flourishing forest—lower and slightly less dense, it is true, on one of them, yet apparently thoroughly healthy. Chipete, it is true, has latterly rather the appearance of decay, but it is on the dolerite, and I will show below that this appearance is probably due to another reason than drying up. It must be remembered, for the piece of country with which I am specially dealing, that the rainfall is even now heavy right from the coast to the mountains, excepting within particular circumscribed areas. If the inner plateau lands of lighter rainfall, which line the great curve of dotted forest and comprise much of South Africa and most of Rhodesia, ever boasted high forest, and this were destroyed before the advent of fire-using man, one might be disposed to attribute it to a general decay accompanying a falling rainfall. I doubt whether our coast rainfall has yet fallen so low as to act thus as a directly destructive factor, and it is interesting that seeds of forest-trees, sent by myself many years ago to the



lower-rainfall plateau area (at Salisbury) have produced flourishing trees. At the same time, I abundantly realize that my personal observations have been carried out from a centre that is not only blessed with good summer rains, but is exceptionally favoured through the relative cool that accompanies a considerable elevation, and through the usual possession of light winter rains in addition. So I will not generalize.

On the other hand, a reduced rainfall—and even a relatively slightly reduced rainfall—might well have produced a powerful indirect effect. After a good rainy season the heavy green fringe of *Hypoestes* and other tall herbs and shrubs that surrounds our dense forests lets little fire in, and it cannot travel if it gets in. In a very dry year the opposite tends to happen, and there can be little doubt that dry cycles must see a vastly greater destruction of forest than wet ones. Since grass-veld became its neighbour and grass-fires became the order of the year, the Chirinda type of plant formation has depended for its continued existence on the adequate co-operation of herb and shrub and tree. The herbs that belong to it cannot flourish and keep back fire without the coolth and relative moisture that is retained, *when the rainfall gives it,* by the canopy of the trees and shrubs and lianas, and if the trees are deprived of luscious greenness in their herb-fringe and carpet, they are also deprived of their protection against fire. It is even possible that the trees of the formation might inhabit a far wider *general* area than they now do were it not for this indirect result of a smaller rainfall, and the fact, already referred to, that at least one of them flourishes under the latter condition in the Gardens at Salisbury (I do not know, however, what the cultivation has been) may support this hypothesis.

I have already suggested that this indirect factor will be specially powerful where the soil is relatively poor or sandy, and that this may be one reason why forest tends to disappear from soil of this kind first. It may just be worth suggesting further that another indirect factor working in the same direction—a less important one—*may* have been—elephants. At any rate, my recollection of their work in the Sitatonga forest, in which they were somewhat plentiful at the time of my visit, leads me to suspect that the rather poor forest that tends to occur on the poorer sandy soil in Chirinda would be more liable to such damage by elephants as might tend to let fire in. Whether, when they were here in the great numbers described by old natives, their destruction of the "green fringe" actually did more than counterbalance the lessened ferocity of the fires that might have resulted from the general trampling (yet greater drying) of the grass-veld round the forests, can best be settled by observation of forests in which they are still abundant, but I am inclined to think that they may have acted as a slightly accelerating factor in the destruction of forest by fire. A more important accelerating factor will have been the late fires that were in vogue during the native *régime.* According to all

accounts, most of the burning was annually postponed till September and October, when the grass is very dry, and when the forest fringe and carpet is also at its driest, owing both to the hot sun and to the strong, dry winds that are blowing continually from August onwards. These late fires are often exceptionally fierce and destructive. It is also possible that throughout the hot, low veld the rate of destruction may have been comparatively high.

A *retarding* factor may well have been the grass-eaters of our once great ungulate population, and the known facts in this connection even constitute a strong argument against the view that fire has been an important factor at all. We know from old hunters that formerly in the Free State and elsewhere these grass-eaters used to eat the veld bare, and it is the fact, apparently, that in British East Africa to-day, and at any rate in considerable portions of German East Africa, they eat the grass so close that fires do not take place. Our own older natives state that this has happened over particular areas even in the section with which I am more particularly dealing, but that it has not been a general phenomenon, annual fires having taken place through the rest of the country throughout their life-times.

This shows that even with only a native population in the land it has been possible to have periods of grass-fires. I have already referred to a considerable *destruction* of forest that took place through fire 30 years or more before the white man came. Selous records the grass-fires as occurring annually in his hunting days in the Transvaal, Bechuanaland, Matabeleland, and Mashonaland; they have been, apparently, as regular a phenomenon in Northern Rhodesia with buck still plentiful. I do not know, however, whether this applies back to the time at which the whites entered that country. I well remember references to the severity of the annual fires in Nyasaland in early numbers of the *B.C.A. Times;* and I will shortly quote a passage from an account of Alexander Whyte's botanical exploration of Mount Milanji 26 years ago (*Trans. Linn. Soc.*, 1894, vol. iv, Pt. 1, p. 3), that shows them to have been occurring annually before that time with "deplorable" and "devastating" effects on the forest. All this suggests strongly that such a superabundance of antelopes, etc., as will completely stop grass-fires, has been a local and temporary phenomenon, alternating with periods of fire; and, of course, so long as fires take place at all, they will, in dry seasons, destroy forest.

But the three strongest arguments in favour of fire as a factor are indirect. The first is, the result of protecting forest from fire. I will describe this in Section 6. The second is this: The grasses which covered this country when the treks came in still cover it wherever fires have continued annually, and grazing has not been excessive. Where, on the other hand, grazing has been very close and burning has for long stopped, new grasses are replacing the old ones. The third is the strongest argument of all. It is afforded by the existence to-day, over all this vast



area, of *pyrophytic* trees and shrubs. Such perfect adaptation to a condition of annual fires as we see in these and the differentiation into numerous daughter species, which probable pyrophytes have already undergone, will hardly have come about in less than very many thousands of years. The fact may have an interesting bearing on the antiquity of man in this part of the world, for, now at any rate, no regular fires take place excepting through his agency. In the days when our igneous rocks were forced to the surface things may have been different, and the pyrophytes might have made some beginning. The analogy of the vegetation in areas still actively volcanic should be useful here.* Of course, if such a plant community exists in any place which can be stated confidently never to have undergone a fire-period, the argument goes. Meantime, I am inclined to regard it as conclusive.

It must be remembered, I think, that differences in the numbers and hunting proclivities of the natives and the number of the lions do not exhaust the possible factors that may have produced fluctuation in the ungulate population. The rinderpest, which so reduced the numbers of some of our larger buck, is unlikely to have been the first epidemic that has swept through them. The process of immunization to the effects of *trypanosomiasis* must alone have taken long, and led to great reductions in their numbers, though it may, of course, have been completed before fires began. The immunity, if any, of the older African races of man should have a bearing here.

The actual process of forest destruction is well described in the account of Whyte's exploration of Milanji in 1891, already mentioned: "It is deplorable to witness the devastating effects of the annual bush-fires, from which even this lofty and all but inaccessible retreat is not exempt. During the dry months of August and September these fires, originating from the villages on the lower slopes of the mountain, gradually creep up the precipitous cliffs from tuft to tuft of grass until at last they reach the grassy plateau. Once there the work of destruction is rapid. The fire rages along the table-land and eats its way along the edges of the remaining belts of forest, annually scorching, if not burning, the bark and timber of the outside trees, and killing outright the young seedlings. In exceptionally dry seasons it appears that these fires have even penetrated some of the damp forests, and hundreds of giant cypresses lay prostrate . . generally burnt right through at the base of the tree."

These are the two stages—first scorched, later burnt into or through. The process of destruction in ordinary years is

* Of the plates illustrating Dr. Tempest Anderson's account of the volcanoes of Guatemala (*Geog. Jnl.*, May, 1908), one (Pl. II. "Santa Maria, from the slopes of Cervo Quemado") might represent a scene in the poorer pyrophytic wooding between Melsetter and Umtali. Another (Pl. VII. "Tropical forest on the slopes of Attilan") is exactly Chirinda, without the big trees.

slower than one would perhaps gather from the above account, and the forest may even hold its own completely along considerable fronts for very many years, explaining the fact that in some places the "Sand-apple line" even now nearly touches Chirinda, and conveying sometimes, to the mere traveller or short-term resident, the impression that "the patches of dense-crowded forest trees . . . are seldom or never affected by the annual bush-fires" (S. A. Neave, "Zoological Collections from Northern Rhodesia," P.Z.S., June, 1910). But in a dry year the fire runs in further, and a succession of two or three dry years tends to produce the result described by Whyte. It is quite interesting that the destruction of portions of the Chipete and Chipungambira forests already referred to should, according to my informant, have coincided with "the last great famine"—in, I should judge from my estimate of his age, about 1860.

*Other factors*: *Cultivation*.—I have laid stress on fire because there is very clear evidence of its destructiveness in the recent past, and because it is the only important factor that can be seen at work here to-day. But another factor of possibly high importance must by no means be lost sight of. I have suggested (*Journ. Linn. Soc. Bot.* xl.) that the grass-fires "obtained their original hold on the forest-lands during some period of dense native population." With a better realization of the time required, I would no longer say "original"; but clearing for cultivation, which was in my mind as affording starting-points for fire, may itself have contributed to the destruction. It is very interesting to read Thomas Belt's account of the way in which the whole Pacific slope of Nicaragua has been, apparently, cleared thus by the Indians *without* the aid of fire* in the course (he believes) of thousands of years, the trouble of weeding the grass that soon comes in being in this case the incentive for the continued use of the forests to the neglect of the still fertile savannahs; and Roosevelt records the destruction of much dense forest in East Africa between the Aberdare Range and Mount Kenia" by the Kikuyu tribe in order to give them new soil for cultivation," while "similarly destructive agricultural methods have separated portions of the Elgon and Nandi forests, which were formerly continuous." Miss Lilian Gibbs, in a most interesting paper describing the last of her adventurous explorations (*Jour. Linn. Soc.*, 1914, xlii., no. 285), shows us a relatively early stage; for she describes how the primary forest of Borneo still covers the lowlands north of Kinabalu, where there are no natives, but has elsewhere been destroyed by them for cultivation up to an altitude of 3,500-6,000 feet, and, in the valleys, considerably higher (p. 11).

The clearing of this type of forest is not the rule amongst our natives to-day—I have seen only one small instance of it, in Portuguese territory—but when Chirinda-like forest covered a large proportion of the country, there was more temptation

* Belt does not mention fire.



and (if the population were large) less choice, and this mode of cultivation may have been as much the fashion here as it was in Belt's day in Nicaragua. A recent period of this kind might explain, far better than fire alone, the clearing of certain rich trap-areas, like large parts of the Jihu, since the sand-apple line was fixed—subsequently, that is, to another kind of period during which the disappearance of forest from the poorer or drier soils first was the rule. Not so recent as to have left memories or traditions—for of these I find no trace: and not concluded by the Zulu incursion—for this, an incorporation on this side of the Sabi rather than a conquest, appears to have interfered so little with the life of the people as to have been unlikely to have caused the cessation of such a custom. Yet it might have been coincident with the Arab trade and the better days of the Varozwi.

A fact that perhaps may tell against the importance of the above factor is that some of the most important forests in Africa outside of the solid area occur far up on the route of the southward migration of the races, and where blocking and crowded populations would appear to have occurred in the process.

An instance of the effect of the constant *cutting of saplings* by natives will be given below. Continued long enough by sufficient natives, it would certainly end in the destruction of the portion of forest affected.

*Shade*.—Roosevelt and Heller (*African Game Animals*) suggest as the *raison d'être* for this "massed" type of forest and its sharp demarcation from the surrounding grass-veld that the trees composing it seem capable of growing only "where they are protected from the maximum quantity of sunlight." The need is doubtless felt by certain species—as it is, I believe, by the Cape Stinkwood—and the shrubs and herbs are also, doubtless, largely dependent on shade. *Coffea ligustroides*, planted by me without shade, failed, and shrubs of *Conopharyngia usambarensis*, though they have grown vigorously, show some leaf-crumpling and a flecking with yellow that indicates some chlorophyll-destruction. Seedlings, again, in their first dry season, have certain small requirements, which may be better referred to below. Beyond this, the view does not seem to apply to our big forest trees. Many years ago, in experimenting in shade-trees for coffee and standards for *Landolphia rubber*, I planted forest-trees in the open sunlight, did not irrigate, and, except at first, gave no cultivation. Each is now growing in isolation, surrounded by grass but protected from fire,, and the latter seems to be, at this stage, its sole demand. The failure of one individual (*Chrysophyllum* sp.) has been counterbalanced by the success of another that has come up naturally, in broad sunlight, outside the forest, and *Khaya nyasica*, *Lovoa Swynnertonii*, and *Eckebergia Meyeri* (Meliaceæ), *Teclea Swynnertonii* (Rutaceæ), *Schefflerodendron gazense* (Leguminosæ), *Pygeum africanum* (Rosaceæ), *Chrysophyllum fulvum* (Sapotaceæ), *Strychnos mitis* (Loganiaceæ), *Maba mualala* (Ebenaceæ), *Croton*

*Sylvaticum* (Euphorbiaceæ), and *Celtis dioica* (Uricaceæ), all big trees of Chirinda, are flourishing under the unwonted conditions in spite of a somewhat dry series of years. The same may be said of *Widdringtonia Whytei* of the mountain forests, and I have been told that this tree, amongst others, comes up, and grows up, outside the forests in unburnt portions of German East Africa. My trees named above, like those of the European forests, show clearly their independence of the massed condition for such protection as they may need from excessive sun—and wind—by readily protecting themselves when necessary through lower branching, a stockier growth, and, in one or two cases, denser foliage. The firmer, smaller "sunlight" leaves were naturally assumed early, in ready adaptation to the early need for reducing transpiration.

The moisture that canopy—and especially, as in Chirinda, layers of canopy—directly and indirectly conserves is the real essential: not to the big trees, once started, for they are shade endurers and shade makers rather than shade lovers and sunlight fearers: but to the formation as a whole, in keeping green its defence against fires. Yet neither the advantage in relation to fire, nor defence against drought, can be regarded, I think, as the forest's *raison d'être*, though they may explain its long survival here as against possibly less efficient sub-types of the same formation that may have gone first in the drier areas: for what is essentially the same general type is found elsewhere in the world with fires absent and a rainfall approaching 200 inches. The fact is that, with vegetable reproduction what it is, it is not crowding, but the converse that most needs accounting for, and the latter is probably in most cases due to thinning agencies or conditions of hardship. The sharp demarcation between veld and forest—the "solid wall" of Roosevelt and Heller, "definite line" of Belt, and "abrupt cliff" of my own description (*Jour. Linn. Soc., Bot.* xl.)—is, in the places in which we see it to-day, man's handiwork, direct or indirect; but the difference is in any case between two plant societies, each of which normally supplies conditions that are intolerable to the other, and make invasion and commingling impossible except with outside assistance.

*Duration.*—The various complicating factors I have referred to earlier make it futile to try to estimate the probable duration of the period of destruction. A very crude estimate, based on fire alone and on a higher average rate of destruction than is observable here to-day in the case of unprotected forest-patches, gave the figure of 105,000 years. Even if we should admit the systematic destruction of forest for cultivation during many centuries, the figure would still have to be great. Yet man's association with extinct animals at Broken Hill suggests that this need not, in itself, be a formidable objection to the view that primary forest of the Chirinda type once covered the strip from the mountains to the sea, and was removed chiefly by the two agencies I have suggested—especially by, and for



long only by, fire. Such a tradition as that mentioned, I believe, by Theal, to the effect that the Kaffirs on reaching the Limpopo found savages there who, at that late date, had no knowledge of fire, might tell against it. But even if the tradition be well-founded, it does not seem quite impossible that a type as low as are the present Vaalpens of that valley might have remained without fire for an immense time even with fire-using Bushmen and Hottentots in the country.

It seems impossible to say whether the retarding factors I have referred to earlier will have been more than counterbalanced by accelerating factors. A single, really prolonged period of drought might have seen *immense* forest-obstruction. Again, a slow and gradual start from a few small centres is possible, or, on the other hand, the fires may have come in along the whole dry western front, the forests of the inland plateau country, if they existed so late, having been burned off first. It might also be argued that the dense forests are mainly a mountain phenomenon, and that it is unnecessary to assume that, at this latitude, they may have extended to the coast. A once more or less continuous strip of forest on the mountains and eastern foot-hills would explain distribution, and have needed less time for its destruction. Against this we must put the fact that the South Melsetter and Mossurise forest-patches, though occurring at from 3,000 to 4,000 feet, are essentially of a lowland type, that such patches occur also in the lowlands and not far from the sea, and that dense, high forest is similarly found in the lowlands in British East Africa.

(*b*) PYROPHYTIC FOREST.—The trees that are associated with the annually-burning grass-veld are fully as intolerant of dense-forest conditions as are the grasses themselves. Adaptations of the bark enable them (once well established) to meet the fires with nothing worse than a loss of leaves and their seedlings survive both fires and winter drought in a marvellous way; but the latter, in contrast to the true forest seedlings which will keep alive for years in the undergrowth awaiting light in order to grow up, cannot long survive damp and shade. I have numbers of times seen masses of *Uapaca* seedlings in particular, dropped in the forest by Kafirs or baboons, germinate, yet fail every time to persist. It is correct, therefore, to say that the factors that have reduced the dense forest areas have also brought about the present wide distribution of the trees of the pasture-lands.

*Derivation.*—Dr. W. L. Thompson has said to me that he has been much impressed with the probability that the one type has arisen from the other by the fact that the same genus so often possesses representatives both in the forest and in the pasture. *Ochna, Eckebergia, Rhoicissus, Parinarium, Eugenia, Vangueria, Strychnos, Vitex, Bridelia, Ficus,* are amongst the instances of this quite striking fact. If (as I think we must) we regard regular fires as a relatively recent phenomenon and the present "wooded-pasture" trees as belonging to a later, specialized, definitely pyrophytic type, it certainly seems not entirely unlikely that if we could go back far enough we should find that they are, each

one, eventually thus derived from a forest-inhabiting ancestor. But the present wide distribution in Africa of many of them suggests that for these we should need to go back very far indeed, and that the replacement of any particular great piece of forest has probably proceeded (as it does under our eyes to-day) far more by immigration and spread of already-specialized forms than by the transformation of its own trees. It is likely enough also that some of the forms came in, already ombrophobous, from an equivalent to our present grass-veld that may already have existed in drier areas long before fire, in the hands of man, became an important factor. This would entail a less violent re-adaptation than is presupposed in the transformation of a forest-tree into a pyrophyte and, especially, of its seedling into a seasonal xerophyte, and the indirect palæontological evidence, such as there is of it, seems to point to the existence of open country in early Tertiary times. Against the view that such country may have existed *in potential forest areas* before man and his fires commenced to destroy, may be placed an argument which anyone who has lived long in this country—in this part of it at any rate—will have seen growing up under his eyes. The fact is that land from which fire is excluded tends to go back to dense bush. Even the more open grass-veld here is full of stumps that seldom get further than a one season's shoot.* The very fires that have rendered their existence on that ground possible, by driving the forest off it, keep them from growing up until, some year, a poor burn, it may be, or no burn, allows of a second season's growth being superadded to the first and gives a more fire-resisting bark to the latter—just as the shade that secures the survival of the forest seedlings may also keep *them* back till the sun, some year, gets in. Keep the fire from such a piece of ground—or burn too soon—for several years, and these shoots grow up and eventually in places become so dense as to reduce the grass and the severity of the fires and to allow semi-forest types as *Markhamia lanata* and *Albizzia chirindensis* to spring up amongst them as I shall describe below, and eventually to replace them. The result, when this occurs so far from high forest as not to obtain seeds from it, is a form of dense thicket, that is not uncommon in this section. I am not at all sure that very large parts, at any rate, of the great rubber-forests of the Portuguese lowlands may not be of this type. I was much struck, when there, by the frequent intermingling seen of the trees usually found in pasture with the shrubs and climbers of the denser growth and the smothering by these that was actually in progress.

The semi-forest types referred to just now, and especially such a one as *Rauwolfia inebrians*, at home even in Chirinda yet capable of holding its own outside with only a little protection from fire, may represent the sort of form through which our

* *Cf.*, also, Neave ("A Naturalist's Travels on the Congo-Zambezi Watershed," *Geog. Jnl.*, Feb. 1910, p. 138"): "The tree-stumps . . . have to undergo a very keen struggle to survive the annual bush fires."



more specialized modern pyrophytes have descended. The *Rauwolfia* appears to owe its dispersal mainly to birds, and it seems to me highly significant—but I do not know whether an examination of other African forest areas would give a corresponding result—that those forest-trees which possess congeners in the fire-swept pastures are, for the most part, the ones which produce edible fruits: all but one in the list above are of this category. The seeds of these, dropped into every conceivable sort of station outside, would occasionally hit off conditions which would be, in varying degree, supportable, and the transformation might thus come about by easier stages than seeds dropped on the outskirts of a disappearing forest, and bound in a year or two to face the full severity of the fires, could hope for. That the migration has not been from the veld to the forest seems rather to be suggested by the present uniformly inhospitable conditions in such forests as Chirinda, though with elephants still abundant in them, or natives making clearings, this may not have been the case to the same extent in the past.

*The Influence of Man and other Animals on this Type of Wooding.*—I have referred to fire as a factor that may repress, temporarily, the growth even of pyrophytic trees. It has not, in the past, been the only repressive factor. It is a matter of comment amongst our Kafirs generally, and also amongst white residents, that the country north and west of Chirinda has been becoming wooded with pyrophytes at a great rate in recent years, and *Parinarium curatellæfolium* has been making great strides in the district generally. I consulted, independently, two aged natives. Each said that in his youth the country in question was as bare as the strip to its north still is, or barer. Asked to account for the change, one said that even *Uapaca Kirkiana* (now the dominant tree and a help in famine) was then too scarce to supply the local population, and that parties of natives used to go regularly a dozen miles, to the Buzi, to collect the fruits. He presumed that the seeds thus carried must have resulted in some of the present groves. This explanation is by no means capable of accounting for all the facts even in relation to this one species, and the old man was puzzled to explain the similar increase on the part of *Brachystegia*, the fruits of which genus have no such interest for the natives; but I mention his statement because it suggests how great a factor for rapid dispersal the natives may in some cases be.

My other informant—an old doctor—from whom I had long previously obtained much of the information with regard to the medicinal uses of plants that I included in my paper on the trees and shrubs, stated that, for the most part, neither the *Parinarium* scrub nor the present groves of other species were new. He had seen them as a child, *but*—the plants that have now made trees were then regularly browsed back to the ground by the great herds of buck that grazed our veld before the white man came.

As a partial explanation this seems to me good, and others have confirmed it. It does not account for everything, for, if

some of the now older groves were actually as small in the old men's youth as they stated, then they had already, as a fact, increased somewht *before* the white man came. It is probable that the increase in the numbers and virility of the local native population which will have accompanied the settling beside Mount Chirinda of the great invading Chief Umzila with his warlike Zulu following will itself have started the process of preservation from the buck—at any rate in the immediate neighbourhood of the main kraal, and some details I have gleaned from old men, but have not space to discuss here, support this view. But the wooding has undoubtedly made its *great*, and general, spurt since the white man's arrival, and this may have been due to the factor suggested as well as to the tamer fires that result from the white man's earlier burning. It is not necessary for most of the species to suppose that the present trees are entirely, or even mainly, old stumps grown up, for the main groves are admitted to have been represented by clumps even in the old men's youth (Umzila placed his first kraal beside such a clump; it now covers a hundred acres), and, the natural reproduction being good, it has merely required the removal of the antelopes to allow it to become effective—the fires permitting. But, for *Parinarium*, as I have shown in my "Melsetter" paper, natural reproduction offers no adequate explanation and old Mi'a'owe's explanation, added to that connected with fire, holds good in its entirety.

Man's influence on the vegetation is a difficult, if interesting, thing to assess with any exactitude. In this locality the black man troubles the large trees of the forest but little—unless one happens to contain a bees' nest, in which case its felling merely anticipates its death from the decay already begun; but when present in great numbers or where the forests are very small, he seriously hinders reproduction by destroying the younger growth. I have been told that Umzila's people, arriving in an otherwise nearly woodless land and commencing building operations, felled an immense amount of small forest growth and destroyed some small patches, not containing many large trees, in a single day. The mere trapping of bluebucks, against which animals Gungunyana (Umzila's successor) is said to have at one time instituted quite a campaign, must have entailed a continuous destruction of saplings for the trap fences. The process was apparently insufficiently severe, or (better) insufficiently prolonged, to cause the decay and disappearance of any portion of Chirinda, but I am inclined to attribute the present rather decayed appearance of the older portions of Chipete to the fact that several kraals, including the Chief Mapungwana's, have always been located just to its east, and that all the young growth was regularly cut down until I commenced to protect it. There is consequently a gap of very many years between the older trees and the next oldest growth and this gap shows up when the former pass maturity.

The natives' influence on the more open wooding would seem



to be, on the whole, repressive. He shifts his gardens every few years, and wherever he makes a new one he first lops off the branches, piles them round the base of the trunks, and, firing them, destroys a patch of bush. Some of the trees of the wooded pastures bear favourite fruits, or support edible caterpillars. Improvident of the goose that lays his golden eggs, he frequently chops these down to collect the "eggs" more easily. He is a far more efficient disperser of the seeds of edible fruits than is the white man, but he fails to keep down the buck that eat down the seedlings. He even reinforces them—with goats.

The white man, on the other hand, chops down some of the mature forest-trees but prohibits the cutting of younger growth. He protects the forest from the annual fires, and tries, if anything, to extend it.* But he also conserves the relatively useless pasture-trees that are making his agriculture expensive and will gradually reduce his grazing. Jealous of his proprietary rights he forbids the native to cut them; an effective and blood-thirsty hunter, he destroys the buck that kept them down; his earlier fires let them make a start, and his sheep and cattle (more frequently kept than goats) definitely encourage them by replacing only the grazing antelopes and keeping down chiefly the trees' competitor and fire-bringer, the grass. And so, if he is not so near a town or mine as to be able to chop all down and sell it, his land reverts to wooding—of a very poor kind, whether you look at it from the point of view of direct utility (as compared with what can be obtained from a quite small plantation of better-class timber), or from that of its influence on soil conservation and the springs. The latter is probably *nil*, or worse.

### 6. Reconquest by Forest.

I am nowadays commencing to see a definite, if incipient, advance on the part of a considerable line of forest as the result of having protected Chipete and my section of Chirinda from the fires for fifteen years past, and the process is worth describing.

The sub-community represented by the *outskirts* plants has made the first and *great* advance. The green fringe of *Hypoestes aristata* has pushed in places as much as 40 or 50 yards into the grass and is supplanting it, the luxuriant climbers *Dioscorea Schimperiana* and *Helinus mystacinus* are in places wandering out and smothering it, and the large shrubs *Vernonia podocoma* and *Vangueria apiculata* and small, laburnum-like *Calpurnia lasiogyne* are following up this advance and making a thicket. Most prominent of all, however, is the semi-tolerant species *Albizzia fastigiata chirindensis*. While the fires lasted, this tree hugged the forest, but now it is thrusting out boldly into the grass-veld—individually up to eighty and a hundred yards, and closer growth, already forming clumps and little woods, up to thirty and forty

* At Chirinda I think we recognise our obligations towards the forest. But it must be admitted that the above has not been the attitude of the white man in all countries.

yards. The forest proper is slowly bringing up the rear, as the shade advances, with a small but quite definite advance of from three to five yards, the out-leaning trunks of *Calpurnia* and other outskirts species that used to be on its outside being now that distance inside it, and in a more or less decaying condition. Only in one place, a broad indentation of Chipete, has the forest advanced as yet in a really sensational manner—90 yards at the deepest spot. It has been enabled to do this under cover of the shade of thorn-trees—also *Bridelia*, *Catha* and *Erythrina*—that had come in with the invading grass-veld and grown up, and with the liana *Toddalia acuminata* as its advance guard and shade-connecter. It is curious to see the above trees—old trees, and, some of them, as the Bridelias and *Erythrina humeana*, marking former limits during the process of forest-destruction—standing far inside the forest, the thorn trees mostly already dead. But an occasional forest seedling is to be seen beyond even the general slower advance of Chirinda, pushing up amongst the outskirts plants; and *Teclea* in special numbers, but a few other species too, are coming up under the shade of the *Albizzia* clumps and even—aided, doubtless, by the layer of humus that has already formed in such positions—that of isolated thorn-trees growing in the unburnt grass-veld. This suggests that far greater progress on the part of the forest itself will be visible at the end of a second fifteen years than is to be seen now, and it seems likely that a final cessation of grass-fires would, other things remaining as favourable as at present, result in the course of ages in the re-taking by the forest of its lost ground, just as Belt claimed would happen in Nicaragua were the felling there for cultivation to be abandoned. The process would be slow, but less slow, I believe, than the destruction has been, for *Hypoestes* and *Albizzia* are energetic and far-pushing pioneers. Also the shade and humus of the forest's rivals, the trees of the veld, would be freely used by it for their supplanting.

Not merely along the general advance, either; for new forest centres would be created under them by fruit-eating birds and would accelerate the closing-up process as they came into bearing. This has begun to happen already, for *Haronga madagascariensis*, a tree of the dense-wooded kloofs, is, over a certain area of ground near Chirinda, coming up thickly under *Eugenia latifolia* and small *Parinariums* in the unburnt grass-veld, and, growing rapidly and overtopping them, is killing its nurse-trees and itself coming into bearing and being visited by numbers of bulbuls. The kloofs generally would help greatly in the re-afforesting of the mountains. Those of a portion of the northern slope of Chirinda that is covered with *Uapaca* and *Brachystegia* wooding, but has been little burnt of late had previously had their pyrophobe trees reduced by the fires to a mere thin line along their bottoms. Yet now they are climbing out again, and—*Eckebergia Meyeri*, *Pygeum africanum*, *Teclea Swynnertonii*, *Sapium Mannianum* and *Eugenia ovariensis*, but especially, and in numbers, the pioneers *Haronga*, *Albizzia*, and, to a less extent,



*Bersama*—they are entering into successful warfare with the pyrophytes of the lower slopes, while the big climbers *Landolphia*, *Choristylis*, *Canthium*, *Rhoicissus*, *Uvaria*, *Secamone*, and *Lygodium subalatum* are flinging themselves out over *Brachystegias* and *Uapacas*, and already smothering some of them. That the pyrophobes should be capable of growing up under trees so exclusive and hard on the ground as the last two *genera* has interested me immensely, and prompted the suggestion I shall state below; but our forest-trees are obviously good fighters. It is possible that few trees have so drying an effect on the ground as Eucalypts—they have quite dried out a small swamp that used to provide me with *Anopheles*. Yet, in my close-planted gum shelter-belts, forest trees and shrubs, as well as several importations, have come up everywhere and grown freely. They include the fine trees *Trichilia chirindensis*, *Eckebergia Meyeri*, *Pygeum africanum*, *Maba mualala*, *Croton sylvaticum*, *Sapium Mannianum*, and *Celtis dioica*.

The prompt advance of forest that follows the cessation of fires is an argument in favour of the latter as the agent of its destruction. The circumstances under which the seeds of forest-trees germinate and succeed outside the forest enable one to gauge their actual needs. I have seen seedlings that have sprung up in numbers on the outskirts and flourished in broad sunshine, while the rain lasted, dry up and disappear as the dry season progressed. Here the ground was bare of fallen leaves, or practically so, and baked dry. On the other hand *Khaya*, *Trichilia*, *Pygeum*, *Rauwolfia*, *Teclea*, *Croton*, *Ehretia*, *Schefflerodendron*, and *Landolphia* sown in ploughed ground survived their first dry season well without shade, the fact that they were covered up, together with the moisture retained by the ploughed ground, and its penetrability, evidently fulfilling all needs. To-day they form a well-grown grove. *Albizzia chirindensis*, again, gives very little shade when one would expect it to be much wanted, for it drops its leaves in June and early July. Yet it seems a successful nurse tree. There is always a fair amount of good humus layer under it, and this, apparently, is able alone to carry a fair proportion of the seedlings it shelters through their first dry season. In general, I should say that one never finds a forest-seedling surviving the latter when some slight layer is not present, unless it finds tilled ground. The seeds slip or are washed down between the undecomposed leaves, and are sheltered by these; and the layer generally, helped by shade when present, tends to retain much moisture between the falls of rain, and also provides a penetrable bed for the seedling's roots, with the result that it has begun to be established by the time the dry season comes. If, now, the humus is such as to ensure the continuance of a sufficient moisture supply, the plant does not fear sunlight. If not, it burns unless shaded. Thus moisture, rather than shade, is the real necessity in their first season, for, at any rate, a great many of the finer and commoner trees of this type of forest, though it is seldom that the

former is sufficient, outside the forest, to enable them to dispense with the latter. *Inside* the forest the tendency of shade is to keep them back, and of sunlight to bring them on. In cultivation, they would probably nearly always need either initial shade or tilth—or water.

The effect of a large antelope population on advancing forest can best be noted where the former still exists. Buck mostly avoid forest. The little "blue-buck" (*C. monticola* inhabits it, and bushbuck lie up in it, but feed outside. The stomach, examined by myself, of an individual that thus haunted the forest, contained recognisable remains only of plants of the grass-veld outside.

*A Suggestion.*—May it not prove possible, for certain purposes, to utilize our already-established pasture-trees as nurse trees in artificial afforestation, at any rate under favourable conditions of rainfall, situation, etc.? I do not know whether it has been attempted. I have myself, as a very small experiment, planted gums (*G. botryoides*) in a *Uapaca* grove under conditions apparently unfavourable to them—a high and dry spur, with mixed shale and sandstone right on the surface and no preparation beyond holes that would just take the roots—and they have over-topped and are killing the *Uapacas;* but gums, not needing shade, and being worse than useless for the purpose that this sort of planting might be particularly used for, are not so much to the point as the other observations I have described.

The pasture-trees make good shelter for stock, and contain a few really useful species, and one would be sorry to sacrifice the gorgeous spring tints of the *Brachystegias*—a landmark in the year; but the type of forest is, all the same, a relatively useless one, and, where not near mines and towns, is tending to swamp the pasture. I have referred to its probable inefficiency in the matter of water-conservation. The humus is more or less burnt off annually, the canopy is commonly so thin and broken that it fails adequately to protect the ground from the sun and check evaporation, or greatly to lower the temperature, and the wooding is so open below and around that the drying winds blow through unchecked. Mr. Hutchins, if I remember rightly, suggested many years ago that the moisture exhaled from the leaves probably greatly exceeded that retained by the shading, and this, for most of the species, seems likely enough. It is doubtful, again, whether, on a steep slope, the thinning of the grass that takes place under a close grove does not lead to greater waste than is prevented by the roots of the trees—at any rate where the fallen leaves are burnt. Finally the drying-up of the springs of a slope in which I am interested has gone on coincidentally with its becoming more and more completely clothed with this type of wooding. I do not connect the two phenomena necessarily, but I doubt whether it would have happened to at all the same extent under pine or Chirinda-like forest. I have several times heard the cutting of this open wooding denounced as likely to "dry up the springs" or "diminish the rainfall,"



but in view of all I have just said, I do not feel that it need be regretted if it should be possible to convert an occasional hillside of it into useful forest.

The value, as nurse-trees, of a drying type of wooding may well be questioned. Yet the observations I have given suggest that it may serve, and the impression left with the observer is that it only requires the continued exclusion of fires and an abundant seed-sowing to extend over the whole slope I have mentioned the operation that is already taking place in the kloofs, and on part of the hilltop. Obviously the growth obtained from such planting could not be expected to be so even or the returns at all so early as from ploughed ground, and it would be worth attempting only in a case like the above, in which not early returns, but the rescue of springs at as cheap a cost as possible was the primary consideration.

*Albizzia* or *Erythrina* or some other useful tree might be used as a shade connecter and wherever natural wooding was absent, being either sown at stake or put in as live posts; and a later sowing made at stake, at stations roughly hoed in the grass, with the better native forest trees as (in these parts) *Khaya and Pygeum.* To get its full moisture-conserving effect from this type of forest, and to guard it against fire, one would doubtless have to follow nature and include some of the shrubs, if not of the lower-canopy trees, in one's sowing, and later, in order to bind the humus on the steeper slopes and add a shade-layer, to introduce forest-grasses at intervals. They would soon spread and meet. Actually, this forest never makes *much* humus, though masses of leaves fall, and there being no white ants and no fire to destroy it, one expects to see accumulation in the course of years. On scraping off the top layer of undecomposed leaves, one finds such quantities of small roots feeding right at the surface that one's immediate impression is that the forest is eating up its humus as fast as it deposits it. Pines would quite likely be better if *Pinus halepensis,* for instance, were found to succeed under the conditions, but the Chirinda type seems very effective in preventing wash and in preserving coolness and moisture and a perpetual flow from its springs, though they sometimes get low in a drought.

If I should be successful, personally, in aiding the reafforestation, begun by nature, of the slope referred to, or the forest-advance itself, in the manner I have just suggested, it is possible that I may yet offer the Association a paper on "The Replacement of Wooded Pasture-land by High Forest!"

*In conclusion,* it may be said, I think, that this type of forest, while primarily dependent on rainfall, has elastic requirements even in that respect. Miss Gibbs gives the range 61-158 inches for another sub-type of the same general formation, and here we may put the minimum as low, I think, as 40 inches: possibly a good deal lower were it not for the more wholesale damage that would then be done by fires. Above a certain figure, varying doubtless with various factors, and with no

strongly-marked dry season, it would appear that this forest gives place, after its destruction for cultivation and the subsequent abandonment of the ground, to secondary forest more or less dense, which becomes largely replaced in time by the original forest. Below that figure, and with a sufficiently strongly-marked dry season, annual fires take place outside the forest, and the latter, as it is destroyed by them or by cultivation, is replaced by grass land, of fire-bearing grasses, intermingled throughout great areas with a secondary type of wooding which is also pyrophytic. This is very different, apparently, from the secondary type in the other class of area, and to be regarded as intervening between it and the primary type; for an equivalent to what is elsewhere the secondary type occurs here as a third stage, should fires cease. The latter is at first partly a matter of the denser massing of the pyrophytic trees themselves, but it is chiefly composed, eventually, of shade-bearing species that belong neither to the true forest nor to the pyrophytes. Where these thickets, or the secondary pyrophytic bush, are near enough to true forest to receive seeds from it, they are eventually swamped and replaced by it—fires still not taking place.

One other point is perhaps of some importance. Our *retreating* forests of to-day are surrounded by graduated zones, varying in width with circumstances, that might be called *denudation-zones,* should we accept wash as the chief factor in the impoverishment that follows forest—though native cultivation and burning contribute strongly—or, better, perhaps, *humus-zones*. When the forest was still unbroken, but was already retreating before the fires, these zones would have existed as continuous lines or concentric rings along or round the whole forest area, and even the inner lines would still have been continuous for some little time after the forest became broken through, while the outer zones may be regarded as still connected to-day. As the fragments became more numerous and widely-spaced, various complicating factors will have arisen. Members of a particular zone will have persisted far longer in some circumstances than in others; the inner zones will not only have surrounded forest-patches, but have survived them for a time as islands, or, should the forest have advanced again, have disappeared through being swallowed up in it, and changes, through silting, etc., in the distribution of the richer elements of the soil will have led to much displacement. Allowing for all this, I believe that a fuller realization of the former continuity of forest and the consequent extension of the zonal idea to embrace these sub-divisions of some of the altitudinal zones, dependent not merely on altitude but on degrees of soil-impoverishment following the destruction of forest sub-divisions, will give us the correct basis for a study of distribution, as well as for our more local œcological studies, faunal and floral. Thus it is highly suggestive that in the Chirinda region our connections with Kilimanjaro, both in birds and plants, extend to several of



the inner grass zones, and—to take a more local point—it is interesting to find that animals—the "blue-buck" (*C. monticola*), the elephant-shrew (*Petrodromus tetradactylus*)—many butterflies, and such birds as *Anthreptes hypodilus,* which on Chirinda's northern outskirts venture only a few yards outside the forest, and might well be regarded as purely forest, or at most (like the *Anthreptes*) outskirts animals, range to the south of Chirinda over a grass-jungle tract (the Jihu) that is nearly 20 miles wide. The fact is that the innermost humus zones, narrowed to the north by the circumstance that the forest has for hundreds of years held its own there while the slope outside it became denuded, to the south still cover the large extent of country mentioned.

There is this difference between these zones and those that are dependent on altitude: that, while the inner higher altitudinal zones have doubtless spread out during periods of glaciation, mountain forest replacing lowland forest and itself in places being squeezed out of the country, yet it has been able to regain the lost ground when milder conditions returned. But its replacement by the grass-veld zones, or whatever civilized man may yet substitute for the latter—let us hope not desert!—will probably be, for the greater part of the area concerned, final—till man disappears.

*Addendum.*—Mr. J. M. Sim's paper—of great practical interest—on "The Modification of South African Rainfall"* reached me to-day, and, as it bears directly on some of the points I have discussed, I add this note. He proves the disappearance of great forests in the Cape at, I judge, a vastly more rapid rate than may be seen here, but this, I take it, has been in the main the result of the white man's presence. He shows also that, in the Cape, drought conditions, brought about by man, have distinctly to be reckoned with as a direct factor in forest destruction, and though such conditions have not, I believe, acted thus here, yet they may have done so in our lesser rainfall areas to the west—*if the results were not anticipated by fire,* which they probably commonly would be where fire was already annual and the forest unprotected from it. Mr. Sim's remarks on the stag-horning of isolated trees also show clearly that my statement as to the apparent independence of the massed condition enjoyed by our forest trees does not apply to the same type of tree under a much reduced or modified rainfall. Here I know of one or two splendid isolated mahoganies, last survivors of their patches, but now protected from fire, that are in perfect health in spite of their isolation.

I doubt, myself—rashly, for I have no personal acquaintance with them—whether Mr. Sim is quite right in supposing that the Hottentots were kinder to the forests than the Kaffirs have been—excepting where the Kaffirs have also felled or ring-barked for cultivation. Hunting is quite as great an incentive

* *Rept. S.A. Ass. for Adv. of Science,* Maritzburg (1916).

to grass-burning as the wish to cultivate, and here (especially, of course, in the less settled parts) great ring fires are lit annually by the natives for the express purpose of hemming in the contained game, which either breaks through and is shot at or speared—or is burnt. I have known both koodoos and sables to be caught and killed by the flames, in one case quite a number; and these fires, as also fires lit for purposes of rat-hunting, often involve considerable pieces of country. I should expect that hunting man will have used this method ever since he knew the use of fire and found himself in grass-veld.

The paper on the Melsetter trees and shrubs, read in 1916, and several times referred to here, remains unpublished owing to my indisposition. In it I suggested the terms "pyrophyte" and "pyrophobe," here used, for trees adapted to withstand fire, and not so adapted, respectively, and gave in detail the succession of pyrophyte associations that here follows the destruction of forest.

(*Read, July* 4, 1917.)

## NOTE ON THE MICRO-TITRATION OF ARSENIC.

By Henry Hamilton Green, D.Sc., F.C.S.

(*Abstract.*)

(*Printed in Annual Report of Director of Veterinary Research, Pretoria.*)

The difficulty of determining small quantities of arsenic in physiological material with any real approach to percentage accuracy is emphasized, and it is pointed out that for quantities ranging from a milligram or two down to one-twentieth of a milligram a micro-titration method is much more serviceable than the commonly used Marsh mirrors or Gutzeit papers. A method is described in which the arsenic is brought over as arsine in the conventional way, collected in dilute silver nitrate, and titrated directly with $\frac{N}{495}$ iodine (1 c.c. = one-tenth of a milligram $As_2O_3$) after addition of a little bicarbonate and sufficient potassium iodide to keep all excess silver salt in solution. Comparison is made with the reports of referees in the most recent trials of the methods favoured (for food-stuffs) by the Association of Official Agricultural Chemists in America, and it is maintained that micro-titration is more reliable and more rapid than colorimetric determination; that it requires less personal attention to detail, and is applicable in a great many cases where most chemists now adopt a modified Gutzeit method.

(*Read, July* 4, 1917.)

## THE VITAMINE CONTENT OF MAIZE AND MAIZE-MILLING PRODUCTS, AND THE AMBIGUITY OF ITS CORRELATION WITH THE PHOSPHORIC OXIDE CONTENT.

By Henry Hamilton Green, D.Sc., F.C.S.

(*Abstract.*)

(*Printed in the Annual Report of Director of Veterinary Research, Pretoria.*)

The examination of maize-milling products by dietetic experiments, using the pigeon as discriminant, indicates that the distribution of vitamine in the maize kernel follows the distribution of phosphoric oxide whenever any given sample of grain is taken into consideration. This parallelism, however, does not hold between different samples of grain, and in a series of samples of whole maize varying in $P_2O_5$ content from 0.35 per cent. to 0.71 per cent. no difference in vitamine content could be detected by pigeon analysis. In these samples the "indicator limit" of phosphoric oxide, for milled meals on the border-line of efficiency, would vary from 0.23 per cent. to 0.46 per cent. It is therefore impossible to use phosphoric oxide in milled products as indicator of vitamine efficiency unless the phosphoric oxide content of the original mother-grain is known. This information is rarely available, and the determination of $P_2O_5$ as a general analytical guide to efficiency, as advocated by Voegtlin, Sullivan, and Myers, is therefore ruled out of court. Their standard of 0.5 per cent. $P_2O_5$ for maize flour would condemn more samples than it passed, and would condemn the majority of perfectly efficient South African meals. Simple microscopic examination of a meal, to gauge the extent of milling, would be a safer guide than the $P_2O_5$ standard.

By taking "average pigeon requirements" as standard for comparison, and stating this as 100, it is possible to assign "vitamine indices" to any given diet. On this basis whole maize works out at about 160 to 180—*i.e.*, contains over 60 per cent. more vitamine than is actually required in metabolism—and whole maize can therefore stand depletion of vitamine (or $P_2O_5$) to the extent of about one-third before deficiency is likely to be manifested. The following vitamine indices represent determinations on an average series of milling products to an estimated accuracy of about 10 per cent. either way:—

| | Whole | Fine | | | Hominy | |
|---|---|---|---|---|---|---|
| Product: | Maize. | Meal. | Seconds. | Bran. | Chop. | Samp. |
| Vitamine Index | 160 | 120 | 170 | 180 | 380 | 30 |

The actual value in any given case depends, of course, upon the mode of milling. The average fine meal is not deficient. The more highly milled high-class table products and breakfast foods (Fanko, etc.), are almost invariably highly deficient, and