

Some recent Danish Experiments in Neolithic Agriculture

By AXEL STEENSBERG

MORE than two hundred years ago the idea was advanced that pre-historic agriculture started by man's cutting down the primeval forest and burning most of the trees and branches in order to sow his corn-seeds in the ashes. The father of this theory was the Finnish agricultural chemist P. A. Gadd, who wrote in the year 1753 his *Ovålduga tankar om jordens svedande och kyttande*. Later on his idea was developed and made more generally understandable, amongst others by Professor Gudmund Hatt. And when the Danish botanist Johannes Iversen in the late thirties found a layer of charcoal in a Seeland bog, he explained it as the result of the neolithic farmer's first reclamation of arable land. It may perhaps be a question if this very first charcoal layer came from a neolithic settler's burning of the wood or not. But Iversen's great knowledge of botany and his development of the technique of pollen-analysis soon taught him to discern in the pollen diagrams the actual layers that were due to different periods of clearance.

At these turning points in the diagrams a sudden decline of pollen from oaks, lime, elm, and ash was followed by a sharp rise in grasses and herbaceous plants, soon also of birch and hazel. At the same time pollen of cereals and weeds appeared for the first time, and plantain especially became extremely common. All this goes to show a typical development such as one might expect after clearance, cereal cultivation, and extensive cattle grazing. Details seemed to show that the clearance was combined with burning.

Burning of woodland and scrub was practised of course long before agriculture started. Apparently it was known already in Interglacial times. And in a recent paper on Slash-and-Burning (Kuml, 1955) I showed that primitive hunters and plant-gathering peoples made use of the crackling flames in order to improve their berry-grounds, to produce better grass for wild animals, or to kill gnats and other insects. In Mongolia the nomads also burned off grasslands in order to improve the vegetation for their herds. Maybe the cultivation of grain started in Western Iran on the border line between the highland steppes and the sloping and wooded mountains, as I have suggested, because seeds of the wild ancestors of barley and wheat were accidentally blown into the burned-off areas of the hunters, and were found to grow abundantly.

In my opinion the term 'Slash-and-Burn' is a good general term for all these modes of improvement. Therefore I do not agree with Professor Ekwall when, in *Man*, 1955, he proposes to use the term "swidden" for the burning and cultivation of wooded land. This term has a special meaning in the Scandinavian languages. It means to clear and burn repeatedly in a sort of rotation. And when prehistoric farmers began to till the soil the wooded areas were so immense that repetition of burning on the same piece of land would hardly be needed in a man's life-time. On the other hand I am not convinced that prehistoric farmers needed to move their sites very often. To judge from modern parallels too much stress has been laid upon the periodic moving of the villages of the early agriculturists.

Much can be learned from the study of Slash-and-Burn agriculture in modern times. But could neolithic man really have cleared large areas of the thick primeval forest with his clumsy flint axes? And what would be the effects of clearance in a North European deciduous wood? We know that mixed oak forests and beech forests were cleared by fire in northern Germany as late as the early eighteenth century. But no living person has seen the results of it. Therefore, at the suggestion of Dr Johannes Iversen, a team of ecologists and archaeologists, led by him, decided to put these questions to the test of field experiment. The others were Dr Troels-Smith, Svend Jørgensen, and myself from the Danish National Museum. We obtained the needed funds from the Carlsberg Foundation and a permission from the forest authorities to clear about two acres of wooded land in the Draved forest in south Jutland. This forest is a mixed oak forest like that of neolithic times, and this was the reason why it was chosen. However, the forest proved to have one drawback. It is situated on a plain surrounded by moors and bogs, and accordingly the height of the water table is rather elevated. In contradiction to this the clearance of neolithic man as well as those of modern Slash-and-Burn agriculturists have usually been placed on sloping grounds.

In order to control the test, only a part of the area was to be burnt, while another part was only cleared. Svend Jørgensen and Dr Troels-Smith took charge of the axe tests. They obtained a number of original neolithic flint axe blades from the National Museum, and a model for the wooden haft was available in the form of the well-known Sigerslev hafted axe, excavated from a Seeland bog. The first tests were made in February 1952 in a temperature of 3 to 4 centigrades. At the second cut one axe was totally broken. Two minutes later the biggest blade was cracked transversally. And after three or four minutes the edge of the third axe was spoilt. The last and smallest axe had the handle split at a too violent stroke. The lesson was: (1) that flint axes have to be treated carefully in frosty weather; (2) that if the haft was not

to be split, it must not hold the blade too tightly, but must leave room for a little sideways play when struck; and (3) that the usual tree-chopping technique, in which one puts one's shoulders and weight into long, powerful blows, would not do. The lumber-jacks, unable to change their habits, damaged several axes. The archaeologists soon discovered that the proper way to use the flint axe was to chip at the tree with short, quick strokes, using mainly the elbow and wrist. Troels-Smith worked with an axe blade which had not been sharpened since neolithic time, and he finished the clearing operation without spoiling it.

When the two archaeologists reached the top of their form they were able in co-operation to fell oak trees more than a foot in diameter within half an hour. Small trees they felled by cutting all around the trunk. But on heavier ones they had to use the slower method of hewing two notches, one at each side, and one a little more elevated than the other in order to control the direction of the fall. In all forest clearance for burning the trunks must fall in the same direction; furthermore, this direction in Draved forest would be north-south, because thus the wood would dry more quickly. The biggest trees were not cut down but killed only by cutting rings through the sapwood.

It was interesting that Troels-Smith, during excavations in a Swiss lake-dwelling, had found trees cut in the same way as in Draved by hewing a notch at each side, and the splints of wood proved to have been flaked out parallel to the trunk by cutting grooves above and beneath until the two grooves met each other near the centre of the trunk. And when Professor Forbes of Amsterdam read in the newspapers about the test of tree-felling at the Museum of English Rural Life in Reading during Dr Iversen's stay in England (1954), he wrote to me and related how he had observed the Borneo Bataks cutting trees in a trial with some Chinese coolies in order to amuse a new Dutch governor. The Bataks used stone axes, the coolies American steel axes. The coolies gained the victory, and what is more interesting, Professor Forbes described their technique of cutting as identical with that of Troels-Smith and Svend Jørgensen when clearing wood in Draved. The experiment of Draved also proved that the beech tree is far the most difficult to fell. But this tree was extremely rare in the forests of neolithic times.

The burning was directed by Professor Kustaa Viljuna of Helsinki in Finland, who is an expert on primitive burning techniques. He is a farmer's son and has worked by Slashing-and-Burning himself. But Iversen, Troels-Smith, and I have attended Finnish burnings of coniferous areas. However, in a deciduous wood the great question is to have the twigs and branches sufficiently dried. If they were cut down the year before, you have to lift

them out of grass and other herbs, which have overgrown them during autumn and spring. The first time, in 1953, the test partially failed because the wood was not dry enough, and not even by using a modern flame-sprayer could we burn it. This instrument produced a flame and could be useful in a coniferous area. But here we needed a great starting heat; later on this could more or less dry out the wood behind the flames, if it should happen to be not quite as dry as it ought to be.

Next year, 1954, the burning was successful. The ignition took place along a 30-feet wide belt by means of torches of birch bark attached to stakes. When the belt was well cleared we pushed the still burning logs forward with long poles in order to set fire to the adjacent area. In this manner we burned off the entangled branches of trees, belt by belt. The fire was controlled and conducted day and night in order to achieve an even and thorough burning of the ground. And in three or four days the job was finished.

Immediately after the burning we were going to sow. Archaeological finds of charred corn and impressions of grain in excavated pottery have attested that in Denmark neolithic man made use of three sorts of wheat: *triticum monococcum* (or Einkorn, also called Small Spelt), *triticum dicoccum* or Emmer, and *triticum compactum* or Club Wheat—and the nodding six-rowed naked barley, *hordeum vulgare*. Most of these primitive cereals are still cultivated at experimental stations and can easily be acquired. Only the *compactum* wheat caused some trouble until at last I got it from the Rinn experimental station in the Austrian Tirol.

The next question was how the grain should be sown? No digging sticks from the neolithic period have been found. And some fine spades, which were found last summer in a south-Jutland bog by Professor Schwabedissen of Kiel, could not be of any use to us. They are well dated to the early neolithic age, but they are universal tools with symmetrical blades, not especially adapted to digging cultivation. They may have been used for clay digging as well. Nearly all peoples who in modern times use the Slash-and-Burning technique use the digging stick. Even in the Alpine regions, where wheat and barley were sown in very small fields, the women put the grains into holes made by the digging stick.

Therefore we started our sowing using a digging stick. Later on I experimented in making drills with the stick, and also in sowing broadcast and afterwards scratching the grain into the ground with a wooden rake. When using the digging stick, I made 50–70 2–4 cm. deep holes per square metre, that is to say about 15 cm. distance between the holes, and in the case of drilling the distance between the rows was about the same. We learned from this experiment: (1) that the grain is better protected against birds

when put into holes; (2) that it came up more equally distributed when put into holes; (3) that *triticum monococcum* grain is difficult to cover when sown broadcast because of its great surface in proportion to its weight, especially when a great multitude of charcoal is spread upon the ground; (4) that the grain sown in holes and drills had an advantage in the beginning, but just before harvesting no real difference was to be seen between grain sown in holes and that which was broadcast (perhaps the ripening was a little delayed in the case of broadcast seed, which was due to the later sprouting); (5) weeding as well as harvesting is a little easier when the grain has been sown in holes, because the corn stalks are then growing in bundles.

On the 22nd of April 1953, when we did our sowing, the soil was wet and inconvenient for the grain. The summer was rather dry, but the harvest-time wet. A great many ears of corn were broken off just before or during the ripening process; birds and mice had eaten them. Therefore it was difficult to estimate the real output of the harvest. The next year, when we burned a larger area, the sowing was even later because of late spring, the 25th of May to the 9th of June. This year the soil was in a condition for sowing that would please every farmer. And the sprouting developed quite perfectly. By the 27th of June the first seed sown had reached 50 cm. height and the latest 15-25 cm. By the 2nd of August the first seed sown was a little more than one metre high. But the summer of 1954 was one of the wettest Denmark has had in this century, and the harvest was delayed until September. When I harvested the first plot on the 9th of September, the stalks had already been broken off 10 cm. beneath the spikes, even if the corn was hardly quite ripened. And I was harvesting in plain water with rubber boots on my feet.

Estimated per hectare the quantity of seed sown was rather large. In 1860 the normal barley seed per hectare in Jutland was about 130-135 kg. In Draved, 1953, the seed of *hordeum vulgare* was 155 kg. in holes, in 1954 204-310 kg. broadcast, and 50 kg. in holes. And in 1955 the seed of six-row barley was 310 kg. broadcast. From these figures it will easily be seen that you will *save at least half the amount of seed by putting it into holes*. In 1953 the yield of *hordeum vulgare* was only 90 kg. per hectare, less than had been sown, but this poor result was due to the fact that nearly all ears had broken and fallen off before harvesting. In 1954 the harvest was about three times the seed sown, even if the same factor had been acting, breaking down the ears just before harvest. In 1955 the harvest of six-row barley was less than the seed sown. However, this year no new areas had been burned; the seed was sown in the same field as in 1954, i.e. it was the second harvest of a burned area.

The breaking off of the ears must have been due to some local factor, per-

haps to the high water table in Draved, which causes some disease in the stalks. We know from Scania in Sweden that the harvest of rye in olden times was often 16–24 times the seed sown after burning, in comparison with 2–5 times in the normally tilled village fields. According to the luxurious growth of the stalks in Draved we should have expected a yield of the same quantity, if these local factors had not spoiled the harvest.

Small areas were sown in unburned woodland close to the burned areas, in order to compare the two methods of cultivation. These small corn-plots—or “reiter,” as we called them, using a Norwegian term—were hoed by a wooden hoe, and afterwards the seed was either sown in holes or broadcast. In both cases the sprouting was insufficient, and the few stalks growing up suffered severely from lack of natural nutrition in the soil.

What are the factors which cause the difference in growth of the seed in soil treated with fire and soil only tilled by a wooden hoe? Different opinions have been advanced on this point. Earlier it was a general conviction that the ashes of burnt twigs and branches—mainly potash—produced an effective nutriment for the vegetation for a year or two, and afterwards the area had to regenerate for twenty years or more. The Swedish Professor L. G. Romel has spoken of a special *assart effect*, which can be obtained by cutting down all the trees, even without burning. He tells us that Finnish assarters knew a hundred years ago that it was not the ashes that fed their crops so well, it was something produced by an acidifying or “souring” of roots or trees newly felled. Thanks to this assart effect even the supposed “inactive,” tough “mor” (i.e. acid humus) of old and poorly growing northern spruce-woods quickly releases ammonia in great quantity once the so called “mor” has been severed from the old spruce. Samples of such “mor” stored in a laboratory had up to 30 per cent of its total nitrogen available after a year and a half of storage. In comparison the best Danish beech mould would have less than one-half of this percentage. According to Romel this assart effect is believed to have a good deal in common with green manuring. He thinks it has done away with the acid “mor” in the Danish beech forests during the last hundred years, because the Danish foresters cut areas of the woods down totally instead of felling single trees here and there.

Another interesting fact is that after the burning the lack of nitrates favours a vegetation of nitrogen-plants such as broom, alder, and others. This effect is specially notable. And in further India alder was actually planted, as the ashes from this tree were considered particularly valuable. Generally speaking, it was important not to burn the soil “to death,” destroying all the bacterial cultures and the lower animal life. On the other hand the flames had to be kept down to the ground surface. It was a question

of not allowing excessive heat. But the intensity of the action of the fire depended to a high degree on the object of the burning and on the type of soil and vegetation of the site. In France marl was burnt and in England clay, as the fire was thought to release mineral fertilizing substances. Finnish sources state that it was most desirable to "kytta" on clay subsoil. In Esthonia burning should preferably take place above good loose soil with a high humus content, but there should not be too much grass in the undergrowth. Where, as in Siegen, Germany, the trees were desired to shoot up quickly again, the roots must not be destroyed. Too severe burning would also prevent the growth of grass, and if too large an area were thoroughly burnt off, the trees were prevented from sowing their seed and the wood thereby from regenerating. Therefore there was a risk that the area might become a heath-land. The same was true if the topsoil was burned to death.

Quite recently the agricultural chemist Sigurd Larsen told me that he had been experimenting on the effects of heat in relation to soil fertility in modern farming. In constantly tilled and fertilized soils, such as plant-nurseries, the effect of heating may be especially of a sterilizing nature. Of course the competition of weeds will also be less for a short time. And this was striking the first year after burning wood in Draved. Two other factors may be of great importance in Slash-and-Burn culture: (1) the emancipation of nutrients of the soil, and (2) an alteration of the reaction of the soil in a more alkalic direction.

In relation to the first point it has been proved by several experiments that when the soil has been heated, the amount of dissoluble manganese increases for a short time. Sigurd Larsen has been more interested in the phosphate content. The content of inorganic phosphate in the soil seems to be stable under a heating up to 100 centigrades, but if you heat the soil to higher degrees it seems that the reception of phosphate by the vegetation increases notably. However, exhaustion of the soil will soon follow.

In relation to the second point, the alteration of the soil reaction, the treatment should be more effective the more acid the natural soil condition is, because wood-ashes are especially rich in potash (calcium-carbonate). According to this, virgin forest should be the most suitable for Slash-and-Burn cultivation, better at least than a modern Danish beech forest. But in some cases the effect may be the opposite of what was intended. Oats, for example, grow best by a relatively low and a relatively high basic reaction. They have two optima of reaction. Other plants may require different conditions. But the potash will soon be washed out, and this factor, in addition to the exhaustion of the soil for phosphate, may be the chief explanation of the very quick impoverishment of Slash-and-Burn areas.

In Draved the growth of the crops was very rich the first year after burning the wood, and the rather acid forest soil may be one of the reasons for this. However, the same factor may have stimulated diseases which caused the spikes to break off and fall to the ground just before harvest. And whatever the beneficial factors were which caused the luxuriant growth of the cereals just after the burning, they were short-lived. In the second year the burned area produced much smaller crops.

Now, three years after the burning, Dr Iversen is watching the developments of the early recovery of natural plant growth. The burnt and the unburnt areas are developing quite differently. In the area cleared of trees but unburnt, events are following an expected course. The ground vegetation consists mainly of the same species which grew there before the wood was cleared away, though the open sunlight stimulates their growth. And ferns, sedges, and grasses flourish more than before. On the other hand, the burnt ground has suffered quite a revolution. Ferns are coming back here too, but most of the old vegetation, having shallower roots, was killed by the fire. Instead we have quite a garden of new plants. Plantain has made its appearance, as was learnt formerly from the pollen diagrams. But spores of mosses too, wind-blown, have found their way into the clearing, and Iversen has tried to find out if mosses were increasing also in the neolithic period. It seems that there really was a sharp rise in general moss growth immediately after the clearances reflected in the pollen diagrams.

In Draved we have pastured goats and calves on some parts of unburnt area as well as on the burnt. But it is too early to say anything definite about the results of the experiments, which are still going on, after the burning and sowing. Quite provisionally I have tried to draw some conclusions from the experiments in Draved forest. Deliberately I have done it rather vaguely, because much work has still to be done before the results can be published.

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