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ACTA FORESTALIA FENNICA. Sisältää etupäässä Suomen metsätaloutta ja sen perusteita käsitteleviä tieteellisiä tutkimuksia. Ilmestyy epäsäännöllisin väliajoin niteinä, joista kukin yleensä käsittää useampia tutkimuksia.

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SWAMP FORESTRY RESEARCH IN FINLAND

LEO HEIKURAINEN

SUOMENKIELINEN SELOSTUS:
SUOMETSÄTIETEEN TUTKIMUSTOIMINTA SUOMESSA

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Introduction

In Finland, one-third of the land area is covered by swamps and, furthermore, some of the mineral soils are troubled by an excess of water. It is therefore easy to understand that the drainage of forest lands is the most important form of forest improvement work in the country. Systematic draining was begun in State forests in 1908, but twenty years passed before it became a practice in private forests. Prior to 1940, when the War interrupted the rapid progress of forest ditching, an area of approximately 800 000 hectares was already under drainage. In the immediate postwar period the work advanced slowly, but by the late 1950's the prewar rate of forest ditching was again reached. At the present the area of swamps drained for improved forest growth exceeds one million hectares and the annual rate of new ditching surpasses 100 000 hectares. By conservative estimation, Finland still has some 3.5 million hectares of swamp suitable for forest ditching, and at the present there exist possibilities for attaining this goal in another forty or fifty years. So large an undertaking naturally necessitates extensive research.

The Formation and Area of Peat Lands

The origin of swamps and the formation of peat has interested research men as early as in the 1700's, but the first significant investigation of the question was not made until the beginning of this century. In 1913 CAJANDER (7) explained the origin of swamps as: (1) the filling in of small bodies of water by vegetation; (2) the generation of peat on flooded areas; or (3) the paludification of forest lands. Even before this he had considered the generation and development of swamps in his publications (6). In these investigations the filling in of small bodies of water was regarded as the main cause for swamp formation. However, BACKMAN (4) demonstrated several years later that in central Ostrobothnia most swamps had developed under forests and only a few of them by the filling-in process. Later investigations (2, 44 and 1) supported BACKMAN's idea of the minor significance of this process. True, the importance of the filling-in process in the formation of swamps depends on the part of the country in question, but in every instance it has been slight when compared with the paludification of forest lands.

It had now been proved that the filling in of small lakes and ponds by vegetation is of minor importance, and since LUKKALA (51) had shown in his studies that most of our swamps have come into being through the paludification of forest lands and that this phenomenon still takes place, it seemed that the problem of swamp formation was solved. In Sweden, however, under conditions corresponding to our climate, somewhat different conclusions were reached. The forest land did not appear to be such a dominant factor in the formation of swamps as indicated by Finnish studies, while the primary swamp formation, which refers to the invasion of peat-forming vegetation on land newly emerged from the sea, was seen to be of more importance. The primary formation of swamps has also received the attention of Finnish scientists (44 and 3), but it was considered unimportant. The matter was left as such until 1956 when HUIKARI (26) in his investigation raised the question again but in new light. On the geologically-young lands most of the swamps (60 %) have come into existence through primary swamp formation and only 35 % has been the result of paludification of forest lands. On geologically-old lands some 40 % of the swamps were shown to have originated through primary formation and about 50 % through forest-land paludification. HUIKARI's investigations also indicated that the transformation of forest lands into swamps by paludification is no longer a common phenomenon, but it may be of local consequence.

The stratigraphy of swamps, the generation of surface formations, etc., are closely related to the origination of swamps, but since they are not considered a part of the science of swamp forestry, they are only mentioned in passing.

Relatively accurate determination of the area of swamps in Finland was made from maps already at the beginning of this century. Since then the area of peat lands has been studied in connection with the National Forest Inventories. The information has been presented by regions and by swamp site types. The inventory material also includes the area of peat lands drained for forestry purposes grouped according to the degree of drainage. Likewise, the distribution of swamps by owner groups appears from the results. In the most recent of the three forest inventories, the depth of the peat layer was also recorded (30 and 31). The material collected gives a firm basis for the planning of practical forest ditching operations in regard to regions, owner groups, and the country as a whole.

Swamp Site Types and Their Suitability for Forest Ditching

The study of peat-land vegetation and the classification of swamp sites on the basis of vegetation began in the 1800's. The first publications appeared in 1870 and 1871 when the founder of Finland's plant geography, J. P. NORRLIN (76 and 77), made a classification of swamps. In 1878 appeared the doctoral

thesis of EDVARD VAINIO in which he used such terms as sprucegrowing *korpi*, forested *räme*, *rahkaräme*, *neva*, and *letto* (96).

The actual swamp site types in their present form were defined by A. K. CAJANDER, who published an investigation in 1906 presenting the principal types, *letto*, *neva*, *räme*, and *korpi*, and also several subtypes, described mainly according to the development of the swamps (5). But he also pointed out that the task had not been an easy one since only a limited number of investigations had been made. After that he proceeded to study the vegetation of peat lands and in 1913 there appeared the publication, »*Studien über die Moore Finnlands*» (7), which was a continuation of his work on the theory of forest site types and which was a pioneering publication on the classification of swamp sites. The swamp site types as introduced by him in this publication are still used for the most part as originally defined. He distinguished approximately 30 different kinds of *neva* types (*Weismoore*), over 10 different *letto* types (*Braunmoore*), nearly 20 *räme* types (*Reisermoore*), and over 10 *korpi* types (*Bruchmoore*). CAJANDER's classification is based on both the ground cover and the growing stock. The main types, *neva*, *letto*, *räme*, and *korpi*, are distinguished mainly by the predominant tree species in the growing stock in the same way as done by NORRLIN and VAINIO, and the finer division into subtypes is made on the basis of the ground cover. The material used by CAJANDER was in some respects rather limited and almost entirely lacking for the localities where the different *letto* types are common. In his publication he indeed stressed the constant need for research on swamp site types.

Since CAJANDER's work there have appeared a number of investigations on swamp site classification. KUJALA (43) analyzed the swamps at Kuusamo, an area insufficiently covered by CAJANDER's data. WARÉN (98) published an investigation which was not an actual study on swamp site types but deserves mention for the fact that it has creditably enriched our knowledge of the peat-land vegetation of Finland. PAASIO's work on the vegetation of domed bogs (79) and *neva* bogs (80 and 81) has advanced especially the classification of *neva* bogs by giving further theoretical background and information.

The study of plant associations in *korpi* swamps of Eastern Finland by TUOMIKOSKI (94) is mainly concerned with the problems of plant associations, but the methods introduced are readily applicable to the actual study of swamp site types. Employing these methods, HEIKURAINEN (10) has analyzed the vegetation of eutrophic *räme* swamps, thereby confirming those parts of swamp type classification which had until then received less attention.

CAJANDER's work was also followed by a number of classifications intended for practical use. At first LUKKALA prepared such booklets alone (47 and 54) and later together with KOTILAINEN (62). Not only was simplifying swamp classification the purpose of these booklets, but also new research findings were presented, and thereby the bases of classification were strengthened. Especially

KOTILAINEN's introduction of the different types of *letto* swamps is to be given credit for increasing our knowledge of swamp site types.

Because the swamp types are rather numerous, attempts have been made toward simplified classifications. They have all been intended for use in the field and the one presented by HUIKARI (23) is the most simplified of all. It has also had some application in practice. There ought to be mentioned also the classification by HEIKURAINEN and HUIKARI (20) in which the 28 most common swamp site types and their suitability for forest ditching have been described.

The suitability of swamp site types for forest ditching has been a matter of supreme importance in the research on swamp forests in Finland. The fitness of peat lands for forest growth was a topic of discussion already in the late 1800's, but until the above-mentioned publication on swamps by CAJANDER appeared, there was no solid background for dealing with it. In this investigation, however, CAJANDER presented his opinion that the swamp site types after draining are converted to certain forest site types. He arrived at this conclusion by observing a few old naturally-drained swamps and by inferring that if the same forest site type can occur on different mineral soils, it could also occur on peat soil.

Thus CAJANDER delineated a pattern for the research of the economical fitness of swamp types for forest ditching whereby it was first attempted to determine the kind of ground cover which will become predominant on different swamps after draining and from that indirectly conclude the profitability of ditching by assuming that the production of wood would be the same as on the forest site type characterized by the same ground cover. TANTTU (91) crystallized CAJANDER's idea into a concept of fertility series where the swamp site types fall into different fertility series each of which having a certain forest site type as the end result of draining. TANTTU based this mainly on the changes of ground vegetation in old drained areas, most of them ditched in the 1860's.

Analysis of the tree growth on drained swamps as a criterion for the profitability of ditching was first attempted by MULTAMÄKI (70). He discovered that the growing stock on drained swamps corresponds to that of forest site types when the ground cover on the swamp has become the same as the cover on the firm-land forest site type. So it seemed evident that the idea of the convertibility of swamp site types to forest site types first presented by CAJANDER and later supported by TANTTU was now further strengthened by growth and development studies.

The transformation of swamp site types into forest site types has later, too, interested investigators, and their findings have not given unqualified support to the previous theories. For instance, the numerous investigations by LUKKALA (49, 57 and 66) have indicated that ordinary forest ditching can scarcely ever bring about a plant association which would be of the same sort as those in upland forests. Parallel results based on strong evidence are presented in SA-

RASTO's doctoral dissertation (89) and this idea has by now been widely accepted. KELTIKANGAS (35) did point out when studying the problem that a very efficient draining after a long period of time can cause the ground cover on peat to resemble very closely the ground cover found on mineral forest lands. Further, he has agreed with the idea expressed in Sweden by which the swamps, regardless of the original type, will be converted to the *Myrtillys* type of the mineral-land forests, provided that drainage is sufficiently thorough and is in effect for a great length of time. However, this development may require such a thorough draining and long period of time that practical ditching rarely is sufficient to produce such results.

So it seems that the indirect approach to evaluating a ditching operation, whereby the future forest site type ground cover to be obtained by draining is first determined and then the growing stock and productivity of the drained swamp are equated to those of the forest site, lacks theoretical justification. KELTIKANGAS has demonstrated in his investigation mentioned above that the plant associations arising after ditching are not stable and therefore cannot be compared to the forest site types even in this respect. Moreover, the ground cover reacts slowly to the changes in site factors, thus indicating a degree of drainage already passed, which makes it an insufficient index of the present conditions for tree growth.

In studying the fitness of swamp site types for forest ditching, LUKKALA has approached the problem from a completely different angle. He has simply analyzed the stands on different kinds of swamps after ditching. Similarly, he has given up the direct comparison of drained swamps to forest site types in evaluating ditching in his practical guide booklets mentioned in earlier paragraphs. For the economic aspects of ditching LUKKALA (49) has divided the country into five climatic regions. The division is based partly on the growth of trees after ditching and partly on isotherms.

In the most recent studies on the subject, LUKKALA's principles have been applied. HEIKURAINEN (15 and 18) has expressed the suitability of swamps for forest ditching by a ditching index (10—0), which refers to the yeild after sufficient draining. He has also checked the division into climatic regions on the basis of tree growth and has given index numbers to each swamp site type in each climatic region.

The current classification of swamps according to suitability for forest ditching is based on the ability of the swamps to produce wood after drainage. In other words, it is biological and does not as such show the profitability of ditching. The profitability, however, can always be calculated according to certain rules. The following scientists ought to be mentioned for their work on these questions: TANTTU (92), SAARI (83), KAITERA (32), and KELTIKANGAS (36). It should be recalled, however, that this classification has its basis mainly on rather recent ditchings done twenty to thirty years ago and current information from old areas drained for forestry purposes is inadequate. There are, however, LUKKALA's studies (57) of older drained swamps in which he has observed a certain rhythm in the growth of trees, but there is not enough data to provide a basis for drainage classification.

The yield studies of trees on drained swamps were mentioned above. Because there has been active research in this field and the results have had a decisive bearing on practical ditching operations, it is justified to give a more comprehensive account of this research.

At first, observations and measurements were made of the growth of trees. After the first domestic yeild tables for forest site types were prepared, it was possible to compare the growth and other stand characteristics between the stands on drained swamps and upland forests. The first study of this kind was made by MULTAMÄKI (70). Because stands, especially at that time, were uneven and most of them young, the comparisons were, of necessity, restricted to the dominant trees. These studies seemed to indicate that the growth of trees on drained swamps corresponds to the growth on mineral soil. Later, the Forest Research Institute has set up a series of about 400 permanent sample plots which cover the whole country and from which valuable results have been obtained through periodical measurements. LUKKALA has reported results in a number of publications (49, 55, 57, and 66). The results that have been published have given proof for the idea that draining can convert struggling swamp forests and even barren swamps into productive forest land where the growth and other characteristics of the stands bear comparison to the stands on mineral soils. These results have gained further support from a recently published study by HEIKURAINEN (18) based on data from swamps drained in the 1930's throughout the country. The growth of the trees was determined in one series of measurements of the diameter and height increments. With rather high certainty it is now known how the trees on different swamp site types and in different parts of the country will grow after ditching. It must be borne in mind, however, that the ditching for the most part has been too recent to permit the study of the trees during a full rotation, which makes our knowledge of further development rather indefinite.

The latest research on the changes in ground vegetation on drained swamps have had new objectives. Now it is being attempted to determine the extent to which the changed vegetation can express the tree growth on drained swamps. After it had been shown in the investigations mentioned above that the ground cover does not change to one such as is found on forest site types, SARASTO (89) has noted that, in addition to the plant associations characterized by grasses and *Vaccinium myrtillys* or *Vaccinium vitis-idaea*, which bear some resemblance to the ground cover of forest site types, drainage can also result in quite stable plant associations dominated by *räme* shrubwood. The use of the ground vegetaion of drained swamps as an indicator of the productivity of site is now under investigation.

Site Factors on Swamps

The ecology of swamp plants has been an object of much research in Finland. It would be impossible to consider all of it within the scope of this paper, so only some of the most important work will be recalled. The creditable and significant investigation by KOTILAINEN (39) marked the beginning of work in this field. He treated the properties of the uppermost peat layer, concentrating especially on the interrelationships between the acidity of the peat and swamp vegetation. It can even be stated that through this and other similar studies the classification of swamp site types has become established on a scientific basis that facilitates the use of the types to indicate the potentialities of the swamp. In other ways, too, KOTILAINEN has made a notable contribution in this field (e.g., 40, 41 and 42).

The study of different peat types is basic to peat research. At the beginning of this century the common practice was to divide all peats into two groups, fen peats and *Sphagnum* peats. Once it had been shown that the properties of peat were in close relation to the plant-remains composition, the analysis of peat types and their properties was started also in Finland. WARÉN (97) was the first to study peat types in Finland and his work has been creditably supplemented by KOTILAINEN (39), LUKKALA (48), and KIVINEN (37), to mention only the most important names. In these investigations our present system of peat identification was established and the foundation laid for the knowledge of the properties of peats. Much has been added to this knowledge by later research. The classification of peats has gained much from the method of microscopic determination of peat types introduced by HEIKURAINEN and HUIKARI (9) and from VAHTERA's (95) study on the nutrient status in forest-ditched swamps. The latter investigation gives attention to the changes in acidity and nutrient contents of peat after draining. Special mention ought to be made of the studies of the decisive influence of the bedrock on the chemical characteristics of peat, made by SALMI (e.g., 86, 87 and 88). Determination of the degree of decomposition of the peat has been treated, for example, by SARASTO (90).

The climate of swamps has also received attention in Finland. The investigations made by HOMÉN (21) at the end of the 1800's have become classics among these studies. It was clearly demonstrated that the characteristics of peat in relation to thermal properties are very special when compared with other types of soils. After HOMÉN the studies of climatic factors on swamps were neglected until MULTAMÄKI (75) published his extensive work dealing with the freezing of spruce seedlings on drained swamps. From this investigation it was obvious that the temperature relations on peat lands are unfavorable when compared with mineral lands. The consideration of this fact in the management of swamp forests was also outlined. The thermal relations of peat lands have been an object of research also among agricultural scientists, and their investigations have revealed many facts which have a direct bearing on swamp forest research (e.g., 99 and 82).

Among site factors, water is of particular significance on swamps. It is quite easy to understand that water has been considered even in the earliest studies of swamps. Not before 1929, however, did the subject receive any serious consideration. At that time LUKKALA (49) attempted to determine the effects of different ditching patterns on the changes in the level of the water table. He studied the problem by varying both the depth of the ditches and the distance between them. The series of experiments and observations made by the Forest Research Institute extending over several decades make the successful study of the question possible. Later LUKKALA has published additional information from these investigations (66). The effect of fellings on the water table has also received his attention (63). MULTAMÄKI (72) has studied the relations between swamp site types and the ground water. Then LUMIALA (67) considered the response of several plant species to the ground water, and in the aforementioned investigation by MULTAMÄKI the changes in the height of the water table obtained by draining received attention. On the basis of these investigations and some others (e.g., 28), the depth of ditches and the width of strip currently in use have been determined.

Analyses of root systems have been made partly to determine the optimum ditch interval and ditch depth. Already at the beginning of practical forest-ditching work, many investigators noticed the unique root systems of the trees on peat soil. The effects of draining on these root systems has been of particular interest. The first studies were conducted soon after ditching operations were started. KOKKONEN (38) and MULTAMÄKI (70) described the changes of pine roots due to drainage. The work was directed both toward the morphology of roots and, especially in MULTAMÄKI's study, toward the quantity and quality of roots. Comparisons of the root systems of swamp trees and of trees of the same species on mineral lands have also been carried out. Of them, the work by LAITAKARI merits special notice (45 and 46). Also the roots of other swamp plants have been of interest, particularly in regard to their depth and relation to the water table (69). The development of methods has made it possible to devote more attention to root quantity, depth of occurrence, and also to root mycorrhiza. This in turn can give a more thorough and comprehensive picture of the effects of draining on the tree roots on peat lands. Studies have also been made of the changes in root systems occurring during the growing season (12, 13 and 17). These studies by HEIKURAINEN have received broader utility because corresponding research on mineral lands has already been carried out (33 and 34).

Of the other investigations on the biology of forest ditching, there ought to be mentioned those concentrated on the increase in the thickness of the peat layer. They were initiated by CAJANDER (5) and have been continued in many later studies. BACKMAN's (4) and SAARINEN's (84) work, above all, should be

mentioned. Under this topic can also be listed microbiological research. True, it was begun only recently. Thus far, preliminary experiments have been made to determine the effect of draining and wood-ash fertilization on micro-organisms (24) and studies concerning the composition of the microbe population of different kinds of soils (8 and 78), Furthermore, there are the studies by HUIKARI (25) on the reaction of the seedlings of different tree species to the anaerobic conditions of the peat medium. The studies on heat relations, root systems, and microbiology of swamps suggest that the size of the ditches can be decreased when the ditches are made closer to each other. The development in this direction is clearly visible in practical forest ditching operations.

Techniques of Forest Ditching and the Management of Swamp Forests

The effect of time upon the condition of the ditches has rather early been subjected to investigation. MULTAMÄKI (71) pointed out that pronounced shallowing and narrowing of ditches takes place in only ten to twenty years and the main cause is the subsidence of drained peat. LUKKALA (64 and 65) considered the same problem in later studies and his findings are much like those of MULTAMÄKI. In these studies it was possible to show the extent of peat compression and the resulting shallowing of ditches and also the effect of time on the process. On forest-ditched swamps the sinking of peat had not been studied earlier, even though on areas drained for agricultural purposes quite detailed determinations of the compression had been made by that time. The factors causing the deterioration of ditches have also later been studied and the erosion (85) and the compression of peat have been of special interest. It has been shown statistically that the compression of peat and the shallowing of ditches are mainly functions of the original ditch depth (16).

Investigations directly concerned with the techniques of forest ditching have been made as well. LUKKALA has made time studies of the digging work (59). The rock work involved in the ditching has been treated in lesser studies, but neither has there been any need for more extensive research on the matter. A number of tables on ditch dimensions and wage bases have been prepared for practical use. Naturally, research has gone into the making of these tables. The most extensive and complete ones were made by LUKKALA and TIRKKONEN (60). By using these tables it has been possible to plan and set rates of payment for shovel ditching for the whole country according to uniform and generally accepted norms.

The mechanization of forest ditching which has taken place rather recently has also required wide experimental work. There is need to mention only that whereas at first shovel ditching was the only means of doing the work, the development of the past ten years has resulted in the mechanical plowing of about 80 % of the ditches. In addition, explosives and mechanical excavators are also used in ditching. Mechanization has meant great savings in ditching expenses. The research on further development is still very active. To date only one broader account has appeared about this research (27). However, there have been a number of smaller studies concerned with the structure and properties of forest ditching plows, the use of covered ditches and ditching with explosives.

Some investigators have been interested in the effect of forest ditching on the running off of water. The question has been considered more thoroughly with the effects of agricultural draining and the dredging of rivers on the outflow of water, but the influence of forest ditching on the water economy has also been treated in preliminary studies (68). The effect of varying ditch intervals on water economy has recently been of interest in HUIKARI's investigations (29).

The management of stands in drained areas has been studied in rather early investigations. In 1898 CANNELIN published »*Metsänviljelystä suomailla*», a book dealing with the care of swamp trees, and although the ideas presented in this book may sound rather odd to the foresters of today, they still indicate that already at that time the silvicultural aspects of swamp forests had aroused attention. However, it was not until the 1930's that serious studies of these aspects were begun. Especially the questions related to the forestation of swamps were then the most current topics. Experiments on different methods of artificial forestation were carried out (52 and 74), and it was noticed that the new growth usually is easily established although on some swamp site types the difficulties encountered could be considerable (22). It was also possible to demonstrate that on drained swamps the regeneration even by natural means is usually very successful, more so than on mineral soils, as a rule (58, 63, 73 and 11). And after LUKKALA (56) had shown that the poor growth and form of pines on *räme* swamps was not of inherent character but was due to unfavorable environmental factors, there was no reason to hesitate in the use of natural reproduction on drained swamps.

As the stands on drained swamps have grown, the need for improvement cuttings and also for regeneration cuttings has become urgent and the problems related to tree-species composition of stands timely. When an inventory of the present condition of old drained swamps (18) was carried out, it appeared that in a noticeable part of the stands the production was far below the potential capacity and that the problems of regeneration and other improvement work on these underproductive stands were not the same as encountered in the management of firm-land forests. The research on these problems has been only recent and is still in the preliminary stages (14, 18 and 100).

Recent developments in forest ditching techniques have lowered the costs to such an extent as to facilitate the fertilization of ditched areas. The studies on fertilization, however, have been begun much earlier. Already in 1928 the Forest Research Institute initiated the first series of experiments using lime. The idea was to kill the sphagnum and also to lower the acidity of the peat and thereby improve the soil conditions for tree growth (53). Although the results did not fulfill the expectations in all respects, the first experiments did serve as a beginning for the expanding research on fertilization. The spreading of sand on swamps was also tested at about the same time. The first fertilization with wood ash was done in 1932. The effect of ash has been excellent, which is evident in the improved growth of trees, in favorable changes in ground cover, and in the increase of microbial activity (24). The experiments on phosphorous, nitrogen, and potassium fertilizers were begun somewhat later. The first were started in 1946 and the results have already been encouraging. Especially the addition of potassium and phosphorus on a number of swamp site types has proved to have a favorable effect on growth (66). The Forest Research Institute currently has a broad series of fertilization experiments where the number of sample plots rises over a thousand and from which the results even at present seem sufficient to answer practical fertilizing questions.

Conclusion

This review of the research in swamp forestry is a rather brief one. The number of publications mentioned is less than a hundred, whereas the total number of publications dealing with problems in the field can be counted in the hundreds. Furthermore, the approach is possibly subjective; another author would perhaps have given different emphasis to different aspects. It is my wish, however, that the review has been able to give at least some picture of the great amount of research upon which the science of swamp forests rests in Finland. It has also been my intention to point out that in our country the research in the field has from the beginning been definitely aimed toward the support and direction of practical work particulary in preparation of useful references (50, 61, 93 and 19). A clear proof of the success of these attempts is provided by the ditching work carried out in Finland which has covered large areas and noticeably increased the productivity of our forests. Much forest ditching still lies ahead, however, which means that there is a continuous and growing need for scientific research in the field of swamp forestry.

Literature

1. AARIO, LEO, 1932. Pflanzentopographische und paläogeographische Mooruntersuchungen in N-Satakunta. Selostus: Suotutkimuksia Pohjois-Satakunnasta. Comm. Inst. Forest. Fenn. 17.1.
2. AUER, VÄINÖ, 1923. Suotutkimuksia Kuusamon ja Kuolajärven vaara-alueilta. Referat: Moorforschungen in den Vaaragebieten von Kuusamo und Kuolajärvi. Comm. Inst. Forest. Fenn. 6.1.
3. —»— 1924. Eräitä vastaisia tehtäviä suotutkimuksen alalla Suomessa. Referat: Über einige künftige Aufgaben der Moorforschung in Finnland. Comm. Inst. Forest. Fenn. 8.
4. BACKMAN, A. L., 1919. Torvmarksundersökningar i Mellersta Österbotten. AFF 12.1.
5. CAJANDER, A. K., 1906. Maamme soista ja niiden metsätaloudellisesta merkityksestä. Suomen Metsänhoitoyhdistyksen julk. 1906/23.
6. —»— 1907. Suot, niiden synty ja kehitys. Oma Maa I.
7. —»— 1913. Studien über die Moore Finnlands. AFF 2.3.
8. GYLLENBERG, HELGE, HANIOJA, PAULI ja VARTIOVAARA, UNTO, 1954. Havaintoja eräitten viljelemättömien maatyyppien mikrobiston koostumuksesta. Summary: Observations on the composition of the microbial population in some virgin soils. AFF 62.2.
9. HEIKURAINEN, LEO ja HUIKARI, OLAVI, 1952. Turvelajien mikroskooppinen määrittäminen. Summary: The microscopic determination of peat types. Comm. Inst. Forest. Fenn. 40.5.
10. HEIKURAINEN, LEO, 1953. Die kiefernbewachsenen eutrophen Moore Nord-Finnlands. Eine Moortypenstudie aus dem Gebiet des Kivalo-Höhenzuges. Selostus: Pohjois-Suomen mäntyäkasvavat eutrofiset suot. Kivalovaarojen alueella suoritettu suotyyppitutkimus. Ann. Bot. Soc. »Vanamo», Tom. 26. N:o 2.
11. —»— 1954. Rämemänniköiden uudistamisesta paljaaksihakkausta käyttäen. Referat: Über natürliche Verjüngung von Reisermoorkiefernbeständen unter Anvendung von Kahlschlag. AFF 61.27.
12. —»— 1955. Über Veränderungen in den Wurzelverhältnissen der Kiefernbestände auf Moorböden im Laufe des Jahres. Selostus: Rämemännikön juuriston vuodenajoittaisista muutoksista. AFF 65.2.
13. —»— 1955 b. Rämemännikön juuriston rakenne ja kuivatuksen vaikutus siihen. Referat: Der Wurzelaufbau der Kiefernbestände auf Reisermoorböden und seine Beeinflussung durch die Entwässerung. AFF 65.3.
14. —»— 1956. Ojitusalueiden metsien hoito. Metsäkäsikirja I.
15. —»— 1957. Lettoräme ja sen metsäojituskelpoisuus. Summary: Eutrophic pine bogs and their suitability for draining. SF 93.2.
16. —»— 1957. Metsäojien syvyyden ja pintaleveyden muuttuminen sekä ojien kunnon säilyminen. Summary: Changes in depth and top width of forest ditches and the maintaining of their repair. AFF 65.5.
17. —»— 1958. Sekametsiköiden juuristoista ojitetulla suolla. Referat: Der Wurzelaufbau in Mischwäldern auf entwässerten Moorböden. AFF 67.2.
18. HEIKURAINEN, LEO, 1959. Tutkimus metsäojitusalueiden tilasta ja puustosta. Referat: Über waldbaulich entwässerte Flächen und ihre Waldbestände in Finnland. AFF 69.1.
19. —»— 1960. Metsäojitus ja sen perusteet. Helsinki-Porvoo.
20. —»— ja HUIKARI, OLAVI, 1960. Käytännön suotyypit ja niiden metsäojituskelpoisuus. Tapio.
21. HOMÉN, THEODOR, 1897. Der tägliche Wärmeumsatz im Boden und die Wärmestrahlung zwischen Himmel und Erde. Leipzig.
22. HUIKARI, OLAVI, 1951. Havaintoja ojitettujen rimpinevojen taimettumista ehkäisevistä tekijöistä. Suo N:o 1.
23. —»— 1952. Suotyypin määritys maa- ja metsätaloudellista käyttöarvoa silmällä pitäen. Summary: On the determination of mire types, especially considering their drainage value for agriculture and forestry. SF 75.
24. —»— 1953. Tutkimuksia ojituksen ja tuhkalannoituksen vaikutuksesta eräiden soiden pieneliöstöön. Summary: Studies on the effect of drainage and ash fertilization upon the microbes of some swamps. Comm. Inst. Forest. Fenn. 42.2.
25. —»— 1954. Experiments on the effect of anaerobic media upon birch, pine and spruce seedlings. Selostus: Kokeita kasvualustan anaerobisuuden vaikutuksesta koivun, männyn ja kuusen taimiin. Comm. Inst. Forest. Fenn. 42.5.
26. —»— 1956. Primäärisen soistumisen osuudesta Suomen soiden synnyssä. Referat: Untersuchungen über den Anteil der primären Versumpfung an der Entstehung der finnischen Moore. Comm. Inst. Forest. Fenn. 46.
27. —»— 1958. Metsäojituksen koneellistamisesta. Referat: Über die Mechanisierung der Waldentwässerung. Comm. Inst. Forest. Fenn. 49.7.
28. —»— 1959. Kenttämittaustuloksia turpeiden vedenläpäisevyydestä. Referat: Feldmessungsergebnisse über die Wasserdurchlässigkeit von Torfen. Comm. Inst. Forest. Fenn. 51.1.
29. —»— 1959. Metsäojitettujen turvemaiden vesitaloudesta. Referat: Über den Wasserhaushalt Waldentwässerter Torfböden. Comm. Inst. Forest. Fenn. 51.2.
30. ILVESSALO, YRJÖ, 1956. Suomen metsät vuosista 1921—24 vuosiin 1951—53. Kolmeen valtakunnan metsien inventointiin perustuva tutkimus. Summary: The forests of Finland from 1921—24 to 1951—53. Comm. Inst. Forest. Fenn. 47.1.
31. —»— 1957. Suomen metsät päävesistöalueittain. Valtakunnan metsien inventoinnin tuloksia. Summary: The forests of Finland by the main water system areas. Comm. Inst. Forest. Fenn. 47.4.
32. KAITERA, PENTTI, 1946. Hyödyn arvioinnista yhteisissä maankuivatusyrityksissä. Suomen Maanm.yhd. Aikakauskirja N:o 11—12.
33. KALELA, ERKKI, 1949. Männiköiden ja kuusikoiden juurisuhteista. I. Summary: On the horizontal roots in pine and spruce stand. I. AFF 57.2.
34. —»— 1955. Über Veränderungen in den Wurzelverhältnissen der Kiefernbestände im Laufe der Vegetationsperiode. Selostus: Männikön juurisuhteiden kasvukautisesta vaihtelusta. AFF 65.1.
35. KELTIKANGAS, VALTER, 1945. Ojitettujen soitten puuntuottokyky eli viljavuus metsätyyppiteorian valossa. Referat: Bördigheten eller virkesproduktionsförmågan å dikade torvmarker i skogstypsteorins belysning. Summary: The fertily of drained bogs as shown by their tree producting capacity, considered in relation to the theory of forest types. AFF 53.1.
36. —»— 1950. Suotyyppien liiketaloudellisesta ojituskelpoisuusjärjestyksestä. Referat: Über die betriebswirtschaftliche Reihenfolge der Moortypen in der Waldentwässerung. AFF 58.4.

37. Kivinen, Erkki, 1933. Suokasvien ja niiden kasvualustan kasvinravintosuhteista. Referat: Untersuchungen über den Gehalt an Pflanzennährstoffen in Moorpflanzen und an ihren Standorten. Acta Agralia Fenn. 27.
38. Kokkonen, P., 1923. Beobachtungen über das Wurzelsystem der Kiefer in Moorböden. AFF 25.11.
39. Kotilainen, Mauno J., 1927. Untersuchungen über die Beziehungen zwischen der Pflanzendecke der Moore und der Beschaffenheit, besonders der Reaktion des Torfbodens. Eine pflanzenökologische Studie mit Rücksicht auf die praktische Bewertung der Ergebnisse. Wiss. Veröff. Finn. Moorkulturver. 7.
40. —»— 1932. Luontainen kasvipeite maaperän happamuuden tunnuksena. Suomen Laiduntalous 4.
41. —»— 1933. Zur frage der pH-Amplitude einiger Moorpflanzen. Kritische Bemerkungen. Wiss. Veröff. Finn. Moorkulturver. 13.
42. —»— 1951. Über die Verbreitung der meso-eutrophen Moorpflanzen in Nordfinnland. Wiss. Veröff. Finn. Moorkulturver. 19.
43. Kujala, Viljo, 1921. Havaintoja Kuusamon ja sen eteläpuolisten kuusimetsäalueiden metsä- ja suotyypeistä. Referat: Beobachtungen über die Wald- und Moortypen von Kuusamo und der südlich von dort gelegenen Fichtenwaldgebiete. AFF 18.5.
44. —»— 1924. Keski-Pohjanmaan soiden synnystä. Referat: Ein Beitrag zur Kenntnis der Entstehung der Moore in Mittelösterbotten. Comm. Inst. Forest. Fenn. 8.
45. Laitakari, Erkki, 1927. Männyn juuristo. Morfologinen tutkimus. Summary: The root system of Pine (*Pinus silvestris*). A morphological investigation. AFF 33.1.
46. —»— 1934. Koivun juuristo. Summary: The root system of birch. AFF 41.2.
47. Lukkala, O. J., 1929. Soiden ojituskelpoisuuden määrääminen metsätaloutta varten. Tapio.
48. —»— 1929. Über den Aziditätsgrad der Moore und die Wirkung der Entwässerung auf denselben. Selostus: Soiden happamuusasteesta ja ojituksen vaikutuksesta siihen. Comm. Inst. Forest. Fenn. 13.
49. —»— 1929. Tutkimuksia soiden metsätaloudellisesta ojituskelpoisuudesta, erityisesti kuivatuksen tehokkuutta silmälläpitäen. Referat: Untersuchungen über die waldwirtschaftliche Entwässerungsfähigkeit der Moore, mit besonderer Rücksicht auf den Trocknungseffekt. Comm. Inst. Forest. Fenn. 15.1.
50. —»— 1931. Metsäojituksen oppikirja. Tapio.
51. —»— 1933. Tapahtuuko nykyisin metsämaan soistumista. Referat: Vollzieht sich gegenwärtig Versumpfung von Waldboden. Comm. Inst. Forest. Fenn. 19.1.
52. —»— 1934. Ojitettujen soiden keinollisesta metsittämisestä. Metsätietoa I.
53. —»— 1935. Soiden kalkitsemisesta. Metsätietoa I.
54. —»— 1935 and 1939. Soiden metsäojituskelpoisuus. Tapio.
55. —»— 1936. Neljännesvuosisadan kokemuksia Jaakkoinsuon koeojitusalueelta. Metsätietoa II.
56. —»— 1936. Rämemäntyjen siementen laadusta. Referat: Über die Beschaffenheit der Moorkiefernsamen. Comm. Inst. Forest. Fenn. 22.3.
57. —»— 1937. Nälkävuosien suonkuivausten tuloksia. Referat: Ergebnisse der in den Hungerjahren angelegten Moorentwässerungen. Comm. Inst. Forest. Fenn. 24.3.
58. —»— 1938. Ojitettujen soiden metsittämisestä. SF 46.
59. —»— 1939. Metsäojien kaivun työaikatutkimuksia. Referat: Arbeitszeituntersuchungen zu der Aushebung von Waldgräben. Comm. Inst. Forest. Fenn. 28.3.
60. —»— ja Tirkkonen, O. O. J., 1939 and 1960. Metsäojien hinnoitustaulut. Tapio.
61. —»— 1940. Metsämiehen suo-oppi. Tapio.
62. —»— ja Kotilainen, Mauno J., 1945 and 1951. Soiden ojituskelpoisuus. Tapio.

63. Lukkala, O. J., 1946. Korpimetsien luontainen uudistaminen. Referat: Die natürliche Verjüngung der Bruchwälder. Comm. Inst. Forest. Fenn. 34.3.
64. —»— 1948. Metsäojien kunnossapito. Referat: Die Instandhaltung der Waldgräben. Comm. Inst. Forest. Fenn. 36.1.
65. —»— 1949. Soiden turvekerroksen painuminen ojituksen vaikutuksesta. Referat: Über die Setzung des Moortorfes als Folge der Entwässerung. Comm. Inst. Forest. Fenn. 37.1.
66. —»— 1951. Kokemuksia Jaakkoinsuon koeojitusalueelta. Summary: Experiences from Jaakkoinsuo experimental drainage area. Comm. Inst. Forest. Fenn. 39.6.
67. Lumiala, O. V., 1944. Über die Beziehung einiger Moorpflanzen zu der Grundwasserhöhe. Bull. Comm. Géol. Finl. 132.
68. Metsänheimo, U., 1937. Metsäojituksen vaikutuksesta vesitalouteen. SF 42.
69. Metsävainio, Kaarlo, 1931. Untersuchungen über das Wurzelsystem der Moorpflanzen. Selostus: Tutkimuksia suokasvien juuristoista. Ann. Bot. Soc. »Vanamo» 1.1.
70. Multamäki, S. E., 1923. Tutkimuksia ojitettujen turvemaiden metsänkasvusta. Referat: Untersuchungen über das Waldwachstum entwässerten Torfböden. AFF 27.1.
71. —»— 1934. Metsäojien mittojen ja muodon muuttumisesta. Referat: Über die Grössen- und Formveränderungen der Waldgräben. AFF 40.
72. —»— 1936. Über den Grundwasserstand in versumpften Waldböden vor und nach der Entwässerung. Hydrol. Konf. der Baltischen Staaten. Mitt. 4 A, Finnland.
73. —»— 1937. Kuusen uudistumisesta vesiperäisillä mailla. Yksit.metsänh.yhd. vuosikirja 10.
74. —»— 1939. Kuusen kylvöstä ja istutuksesta metsitettävillä soilla. Referat: Über Fichtensaat und -pflanzung auf zu bewaldenden Mooren. AFF 47.3.
75. —»— 1942. Kuusen taimien paleltuminen ja sen vaikutus ojitettujen soiden metsittymiseen. Referat: Das Erfrieren der Fichtenpflanzen in seiner Wirkung auf die Bewaldung der entwässerten Moore. AFF 51.1.
76. Norrlin, J. P., 1870. Bidrag till Sydöstra Tavastlands flora. Referat: Beiträge zur Flora des sydöstlichen Tavastlands. AFF 23, (1923).
77. —»— 1871. Über die Vegetation von Onega Karelien und die naturgeschichtliche Grenze Finnlands sowie Skandinavien im Osten. Referat: Om Onega-Karelens vegetation och Finlands jämte Skandinaviens naturhistoriska gräns i Öster. AFF 23. (1923).
78. Paarlahti, Kimmo ja Vartiovaara, Unto, 1958. Havaintoja luonnontilaisten soiden pieneliöstöstä. Summary: Observations concerning the microbial populations in in virgin and drained bogs. Comm. Inst. Forest. Fenn. 50.4.
79. Paasio, Ilmari, 1933. Über die Vegetation der Hochmoore Finnlands. Selostus: Suomen keidassoiden kasvillisuudesta. AFF 39.3.
80. —»— 1936. Suomen nevasoiden tyyppijärjestelmää koskevia tutkimuksia. Referat: Untersuchungen über das Typensystem der Weissmoore Finnlands. AFF 44.3.
81. —»— 1941. Zur pflanzensoziologischen Grundlage der Weissmoortypen. Selostus: Nevatyyppien kasvisosiologisista perusteista. AFF 49.3.
82. Pessi, Yrjö, 1956. Studies on the effect of the admixture of mineral soil upon the thermal conditions of cultivated peat land. Selostus: Tutkimuksia kivennäismaan sekoituksen vaikutuksesta suoviljelyksen lämpöoloihin.Valt. maatalouskoetoiminnan julk. N:o 147.
83. Saari, Eino, 1942. Metsäojitusten yksityistaloudellisen edullisuuden määrääminen. Referat: Die Abschätzung der privatwirtschaftlichen Einträglichkeit der forstlichen Entwässerungen. AFF 50.16.
84. Saarinen, E. K. E., 1933. Soiden pintaturpeen korkeuskasvusta. Referat: Über das Höhenwachstum des Oberflächentorfes auf den Mooren. Comm. Inst. Forest. Fenn. 19.2.

85. Saarinen, E, K. E., 1935. Metsäojien syöpymisestä. Referat: Über die Erosion der Waldgräben. Comm. Inst. Forest. Fenn. 20.7.
86. Salmi, Martti, 1950. Turpeiden hivenaineista. Geologinen tutkimuslaitos. Geoteknillisiä julkaisuja N:o 51.
87. —»— 1955. Prospecting for bog-covered ore by means of peat investigations. Bull. Comm. Géol. Finl. 169.
88. —»— 1956. Peat and bog plants as indicators of ore minerals in Vihanti ore field in western Finland. Bull. Comm. Géol. Finl. 175.
89. Sarasto, Juhani, 1957. Metsän kasvattamiseksi ojitettujen soiden aluskasvillisuuden rakenteesta ja kehityksestä Suomen eteläpuoliskossa. Referat: Über Struktur und Entwicklung der Bodenvegetation auf für Walderziehung entwässerten Mooren in der südlichen Hälfte Finnlands. AFF 65.7.
90. —»— 1960. Turpeen maatuneisuuden määrittämisestä. V. Postin maatumisasteen ja Pjavtshenkon maatumisprosentin vertailu. Referat: Zur Bestimmung der Zersetzung des Torfes. Ein Vergleich des Zersetzungsgrades v. Posts mit dem Zersetzungsprosent Pjavtshenkos. AFF 71.2.
91. Tanttu, Antti, 1915. Tutkimuksia ojitettujen soiden metsittymisestä. Referat: Studien über die Aufforstungsfähigkeit der entwässerten Moore. AFF 5.2.
92. —»— 1941. Metsäojituksen edullisuus. Tapio.
93. —»— 1943. Metsäojittajan opas. Tapio.
94. Tuomikoski, R., 1942. Untersuchungen über die Untervegetation der Bruchmoore in Ostfinnland. I. Zur Methodik der pflanzensoziologischen Systematik. Selostus: Tutkimuksia korpien aluskasvillisuudesta Itä-Suomessa. I. Kasvisosiologisen systematiikan metodiikkaa. Ann. Bot. Soc. »Vanamo» 17.1.
95. Vahtera, Erkki, 1955. Metsänkasvatusta varten ojitettujen soitten ravinnepitoisuuksista. Referat: Über die Nährstoffgehalte der für Walderziehung entwässerten Moore. Comm. Inst. Forest. Fenn. 45.
96. Vainio, Edvard, 1878. Kasviston suhteista Pohjois-Suomen ja Venäjän-Karjalan rajaseudulla.
97. Warén, Harry, 1924. Untersuchungen über die botanische Entwicklung der Moore, mit Berücksichtigung der chemischen Zusammensetzung des Torfes. Wiss. Veröff. Finn. Moorkulturver. 5.
98. —»— 1926. Untersuchungen über sphagnumreiche Pflanzengesellschaften der Moore Finnlands, unter Berücksichtigung der soziologischen Bedeutung der einzelnen Arten. Acta Soc. et Fl.Fenn. 55.8.
99. Vesikivi, Antti, 1941. Savimaalla ja vijellyllä suomaalla sekä ojitetulla ja ojittamattomalla rahkarämeellä suoritettujen ilman lämpötilahavaintojen tuloksia. Referat: Ergebnisse von Lufttemperaturbeobachtungen auf Tonboden und bebautem Moorboden sowie auf entwässertem und unentwässertem Sphagnum fuscum — Reisermoor. Wiss. Veröff. Finn. Moorkulturver. 18.
100. Yli-Vakkuri, Paavo, 1958. Tutkimuksia ojitettujen turvemaiden kulotuksesta. Referat: Untersuchungen über das Absengen als waldbauliche Massnahme auf entwässerten Torfböden. AFF 67.4.

AFF = Acta Forestalia Fennica
SF = Silva Fennica

SUOMENKIELINEN SELOSTUS:
SUOMETSÄTIETEEN TUTKIMUSTOIMINTA SUOMESSA

Soiden metsätaloudellista hyväksikäyttöä kohtaan on maamme rajojen ulkopuolella alettu tuntea lisääntyvää mielenkiintoa. Monissa maissa tämän alan tutkimustoiminta on kuitenkin aivan alussa. Omassa maassamme on suometsätieteellä jo puolivuosisatainen taival takanaan. On näinollen ymmärrettävää, että maamme suometsätieteellä on kansainvälisessä yhteistyössä paljon annettavaa. Jotta ulkolainen asiasta kiinnostunut tutkija saisi suppeassa muodossa käsityksen siitä, mitä meillä on tutkittu ja viitteitä siitä, missä vaiheessa suometsätieteen tutkimustoiminta maassamme nykyisin on, on kirjoittaja rohjennut esittää tämän katsauksen. Suomenkielisenä on julkaisu esitetty monisteena.