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/E RESEARCH PROGRAMME NO. 27

ENVIRONMENTAL DATA ( TREND )

# ECOSYSTEM STUDY OF TROPICAL DRY - EVERGREEN FOREST

sponsored by

ADVANCED RESEARCH PROJECTS AGENCY ( ARPA ), U. S. DEPARTMENT OF DEFENSE

managed by

EARTH SCIENCES LABORATORY, U.S. ARMY NATICK LABORATORIES ( NLABS )

under ARPA Order 917

conducted by

APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

under U.S. Army Contract DAJB 29 67 C 0122

in collaboration with

DEPARTMENT OF METEOROLOGY, OFFICE OF THE PRIME MINISTER

NATIONAL STATISTICAL OFFICE, OFFICE OF THE PRIME MINISTER

ROYAL FOREST DEPARTMENT, MINISTRY OF AGRICULTURE

DEPARTMENT OF RICE, MINISTRY OF AGRICULTURE

DEPARTMENT OF LAND DEVELOPMENT, MINISTRY OF NATIONAL DEVELOPMENT

DEPARTMENT OF MINERAL RESOURCES, MINISTRY OF NATIONAL DEVELOPMENT

CHULALONGKORN UNIVERSITY

KASETSART UNIVERSITY

MILITARY RESEARCH AND DEVELOPMENT CENTER, MINISTRY OF DEFENCE

SEATO MEDICAL RESEARCH LABORATORY

# ANNUAL REPORT 1969

ASRCT, BANGKOK 1969

COOPERATIVE RESEARCH PROGRAMME NO. 27

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# F O R E W O R D

This summary report covers the progress of ASRCT Cooperative Research Programme No. 27: Tropical environmental data (TREND) for the period 1 January to 31 December 1969.

The research is being conducted under the management of the Earth Sciences Laboratory, U,S. Army Natick Laboratories (NLABS), Natick, Massachusetts, U.S.A. Dr. Lester W. Trueblood is Director of the Earth Sciences Laboratory; Dr. Paul Dalrymple serves as Project Supervisor, Mr. George Simmons Rubin de la Borbolla as Project Manager (succeeding Mr. George Immisch in July 1969), and Mr. Robert Fegley as Deputy Project Manager.

The research programme is being carried out by the Applied Scientific Research Corporation of Thailand through its Environmental and Ecological Research Institute in collaboration with other agencies of the Thai Government: the Department of Meteorology and the National Statistical Office (Office of the Prime Minister); the Royal Forest Department and the Department of Rice (Ministry of Agriculture); the Department of Land Development and the Department of Mineral Resources (Ministry of National Development); the Chulalongkorn University; the Kasetsart University; and the Military Research and Development Center (Ministry of Defence); and with the SEATO Medical Research Laboratory.

TROPICAL ENVIRONMENTAL DATA (TREND)

ANNUAL REPORT 1969

# I. INTRODUCTION

## Background

1. This summary report has been prepared by ASRCT in satisfaction of its reporting obligation under article 7 of U.S. Army Contract DAJB 29 67 C 0122, covering research being carried out pursuant to ARPA Order 917 under the management of U.S. Army Natick Laboratories and in collaboration with other agencies of the Thai Government and other groups. It covers the period of 1 January to December 1969 and contains a brief review of the development of research facilities and selected results and data. More detailed information will appear in scientific reports which will be issued on specific aspects of the programme.

2. During the reporting period the following agencies of the Thai Government have been actively engaged with ASRCT in the research programme: Royal Forest Department and Rice Department, Ministry of Agriculture; Military Research and Development Center, Ministry of Defence; Kasetsart University and Department of Meteorology, Office of the Prime Minister.

3. Continuous consultation has occurred with the Earth Sciences Laboratory of NLABS in the planning and execution of the work reported. The facilities have been provided by the presence in Thailand of NLABS Project Manager, Mr. George Simmons Rubin de la Borbolla and his Deputy, Mr. Robert Fegley. Advice and logistical support from OSD/ARPA Bangkok has been received through Dr. Leonard Wood.

## Objectives

4. The programme is an interdisciplinary study of a dry-evergreen forest environment in the 1500 mm annual rainfall zone about 300 km north-east of Bangkok and 60 km south of Nakhon Ratchasima.

5. The programme is providing a reference framework of data on environmental factors, particularly those which relate to tropical deterio-

ration of materials and to personnel operating in tropical forest environments, and is examining the interaction of meteorological, hydrological, soils, vegetation and other biological factors in such environments. The findings will bear on problems of tropical deterioration of materials; problems of pest and disease control; problems relating to the health and welfare of people living and working in such environments;and problems of forest management, conservations, and regeneration.

6. Analyses of the data will be correlated with those from similar studies in the Panama Canal Zone, in an attempt to determine the degree of analogy between environmental conditions here in Thailand and the validity of tests conducted at the U.S. Army Tropic Test Center, Canal Zone, for the south-east Asian region.

7. The study also provides valuable information on the tropical ecosystem embraced in the study area. The international scientific interest in this work is illustrated by the proposal of the International Biological Programme to designate the study as a major programme within its Terrestrial Productivity Group.

8. A subsidiary objective is to build up capacity within Thai Governmental agencies to carry out such studies, so that long term continuity in the work can be ensured.

Research plan

9. The research plan provides for investigations in the following fields:

   1) Meteorology, particularly in micrometeorology;

   2) Hydrology, with emphasis on ground water;

   3) Soils, particularly physical conditions;

   4) Vegetation, especially taxonomy, seasonal changes, and forest debris (litter) studies;

   5) Microbiology, with emphasis on bacteria and fungi;

   6) Macrofauna.

10. The study involves detailed horizontal and vertical measurements of environmental parameters centred around two instrumented tower about 50 metres high and approximately 450 metres apart, one located in a forest clearing and the other within the forest. Micrometeorology is the principal earth science being studied.

11. Broad study plans were prepared initially for each major aspects of the programme. These have been elaborated into detailed work plans. During the reporting period, all of the early survey phase in various disciplines has mostly been completed, and more analytic studies have occupied the attention of the various research groups.

12. The facilities at the living quarters and experimental sites are now quite satisfactory.

## II. RESEARCH FACILITIES

### Location

13. The study area is within the ASRCT Sakaerat Experiment Station, an area of about 80 square kilometres, which the Government has allocated as a forest reserve for scientific purposes. It is situated at approximately $14^{\circ}30'N$, $101^{\circ}55'E$ and lies on the new strategic highway (Route 304) connecting Nakhon Ratchasima and Chachoengsao, extending to Sattahip Naval Base. It is about 60 km south of Nakhon Ratchasima and is some 300 km by road from Bangkok, access being either by the new highway or by the Friendship Highway.

### Description

14. The study area is about 4 km by 2 km and is on a tilted, slightly dissected sandstone plateau of elevations between 300 to 600 metres. Slope of the plateau is from south-west to north-east. The area includes typical dry-evergreen forest of north-east Thailand, dry dipterocarp forest, clearings at various stages of regeneration, a good variety of soil types, streams, springs, and other features of environmental interest.

Preparation

15. Topographic survey of the study area has been carried out with the assistance of a surveying team from Kasetsart University to provide ground control points for the reference grid for locating specific plots and features. This is being linked to the 1:10,000 scale map prepared by the Royal Thai Survey Department from photogrammetric compilation.

16. Living quarters have been constructed and are accessible from the main road via a three-kilometre all-weather road. A further road of about three kilometres gives access to the tower sites.

17. In the living area, a laboratory and office building, a living and messing unit for scientific observers and technicians, two houses for senior scientists, and houses for the Station Manager and auxiliary staff are in use. There are thirteen major structures. A dam, fed by a spring, provides water supply. During the period of November and December 1969 a team from the Department of Mineral Resources had drilled a well, 300 feet deep, in the area on the opposite side of the road from the power plant; water was not obtainable.

18. Data logging equipment for the micrometeorological system has been in an air-conditioned observing building. This is connected to the station electric supply system by a power line.

19. The micrometeorological sensors have been installed on two tubular aluminium walk-up towers, each 47.2 m high. The main tower is about 3 km from the living quarters at about 150 m higher elevation in a good stand of dry-evergreen forest with some trees over 30 m high. The second tower is nearer the living quarters and is in a clearing which is gradually being extended to about 450 m diameter. Distance between the two towers is about 450 m and both sites are at an elevation of about 535 m. The other proposed walk-up tower, expected to be used in animal observation, was also installed in dry-evergreen forest 100 metres from the main micrometeorological tower. It is approximately 30 m high and of tubular aluminium. This tower was seldom used.

20. The micrometeorological data acquisition system had been periodically in trouble at the beginning through the middle of 1969, but is now fully operational. Data collection on the "analogue" side covers wind direction, precipitation, dew point, radiation, and pressure. Radiation installation was completed and is now also in fully operational stage. Temperature and wind speed data are collected on the "digital" side of the system.

21. Mesometeorological data collection continued at the eight climatic stations to provide supplementary climatic data. Two base stations were set up in 1967, one at the living quarters and the other at the station of the Faculty of Foresty, Kasetsart University, on the main road. Six other stations were set up in May and June 1968 to cover the various vegetation and topographic features of the study area.

22. Radio communication between Bangkok and Sakaerat is available using 100-watt Collins single-sideband tranceivers. Regular road transit between Bangkok and Sakaerat is maintained on a bi-weekly schedule with additional trips as needed. Scientists and technicians commute as the work schedule requires.

## Bangkok

23. ASRCT has laboratory, workshop, and library facilities available in Bangkok providing a wide variety of scientific and research services. Laboratory space has been set aside for microbiological, faunal, and general analytical studies connected with the TREND programme.

24. The Instrument Repair and Calibration Centre within ASRCT assists in the maintenance of most of the specialized electronic and other equipment installed at Sakaerat.

25. Arrangements have been made for ASRCT to have access to the IBM 360-40 computer at the National Statistical Office for data processing. Time will continue to be available on the NSO 1401 computer and on the 1620 computer at Chulalongkorn University.

26. The facilities of cooperating agencies are also available for the various specialized studies in which they are engaged.

## III. RESEARCH ACCOMPLISHMENTS

27. During the reporting period, all of the broad survey phase describing the environment and the ecosystem has been completed. This includes a detailed soil survey of about 30 square kilometres centred on the study area and a geological reconnaissance of the Sakaerat Experiment Station. It also includes a good deal of vegetation inventory, both to define the general vegetation status of the study area and to provide detailed information about specific sites such as the immediate vicinity of the main tower. Some studies were completed with the preparation of technical reports.

28. The following reports are now documented:

"Selection of site for studies in dry-evergreen tropical forest" by Frank Barnette, Frank Nicholls, Khamdhorn Suvarnakich and Thuan Komkris.

"Detailed soil survey of the north-eastern portion of ASRCT Sakaerat Experiment Station (Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima)" by F. Bos and Vichit Thunduan. (Report No. 1 on Research Project No. 27/1.)

"Structure and floristic composition of forest vegetation at Sakaerat, Pak Thong Chai, Nakhon Ratchasima. I. Variation of floristic composition along a transect through dry-evergreen and dry dipterocarp forests" by Sanga Sabhasri, Aht Boonitee, Choob Khemmark, and Sanit Aksornkoae. (Report No. 2 on Research Project No. 27/1.)

"Inventory of vegetation in one hectare (100 m x 100 m plot) centred on forest tower, ASRCT Sakaerat Experiment Station (Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima)" by Tem Smitinand, Chumsri Chaiyanand, Anand Nalamphun and Thawatchai Santisuk. (Report No. 3 on Research Project No. 27/1.)

"Reconnaissance geological survey of the ASRCT Sakaerat Experiment Station (Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima)" by

Amorn Methikul and Montri Silpalit. (Report No. 4 on Research Project No. 27/1.)

"Mesometeorological network installation and instrumentation at ASRCT Sakaerat Experiment Station (Nakhon Ratchasima)" by Joseph Zabransky. (Report No. 5 on Research Project No. 27/1.)

"Inventory of fauna at ASRCT Sakaerat Experiment Station, Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima" by Prasert Lohavanijaya et al. (Report No. 6 on Research Project No. 27/1.)

"Microbial studies of the surface waters of ASRCT Sakaerat Experiment Station, Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima" by Poonsook Atthasampunna and Malee Sundhagul. (Report No. 7 on Research Project No. 27/1.)

"Primary production in dry-evergreen forest at Sakaerat, Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima. I. Estimation of biomass and distribution amongst various organs" by Sanga Sabhasri, Choob Khemnark, Sanit Aksornkoae and Paderm Ratisoonthorn. (Report No. 1 on Research Project No. 27/2.)

"Micrometeorological instrumentation and installation at ASRCT Sakaerat Experiment Station (Nakhon Ratchasima)" by Joseph Zabransky. (Report No. 1 on Research Project No. 27/3.)

"Preliminary study of evaporation and transpiration in dry-evergreen forest at Sakaerat Experiment Station (Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima)" by Sanga Sabhasri, Kasem Chunkeo and Choompol Ngampongsai. (Report No. 1 on Research Project No. 27/5.)

"The defoliation of teng (Shorea obtusa Wall.) and rang (Pentacme suavis A.DC.) at ASRCT Sakaerat Experiment Station (Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima)" by Anand Nalamphun, Thawatchai Santisuk and Tem Smitinand. (Report No. 1 on Research Project No. 27/8.)

"Deposition of airborne fungi in tropical forest environment" by Malee Sandhagul (in draft).

29. An extensive biomass study was completed during the operation of extending the clearing for the open tower, providing good data for

allometric studies and estimates of biomass per unit area. This work has been widened to include an examination of root biomass and the configuration of the forest root system.

30. A water balance study in the dry-evergreen forest, partitioning precipitation into stemflow and throughfall components and investigating runoff and soil penetration is in progress. This work includes an examination of the movement of plant nutrients.

31. Work has continued on examining soil microbial activity and the activity of microarthropods in the soil. These are important components in the study of secondary productivity in the forest.

32. Mesometeorological data are now available from the eight climatic stations. Micrometeorological data have been reduced in a certain number of tapes, and the system was fully operational at the end of 1969. All radiation channels were recording at the end of reporting period.

## IV. MEASUREMENTS OF PHYSICAL ENVIRONMENT

### Topography

33. Topographical data for Sakaerat Experiment Station and its environs are available from the 1:50,000 contoured maps prepared by the U.S. Army Map Service. The Royal Thai Survey Department has prepared a 1:10,000 map with contours at 10-metre intervals by photogrammetric compilation from newly flown aerial photographs. This is being linked to ground control points by ground survey undertaken by staff of Kasetsart University.

### Geology

34. A reconnaissance survey of the geology of Sakaerat Experiment Station was undertaken by the Department of Mineral Resources, Ministry of National Development, under the leadership of Mr. Amorn Methikul, to guide the planning of hydrological studies. This covered some 30 square kilometres centred on the study area, and particular attention was given to drainage.

35. The survey shows that the entire area of the Station appears to be underlain by sandstone of the Phra Wihan formation of the Khorat group to a minimum depth of 1,025 metres. There is no evidence of major disturbances of the strata.

Soils

36. A detailed soil survey of some 30 square kilometres of the Sakaerat Experiment Station was made by the Department of Land Development, Ministry of National Development. Technical supervision and coordination were provided by Dr. F.R. Moorman, FAO Soils Expert, and Mr. Santhad Rojanasoonthorn, Kasetsart University. The survey teams were led by Mr. Vichit Thunduan, Department of Land Development, and Mr. F. Bos, FAO Associate Soils Expert.

37. The majority of the soils belong to the Red-Yellow Podzolic great soil group; this group occurs in all topographic positions on materials derived from both sandstone and shale. Three soil series are distinguished: Khao Yai series, covering the deep soils occurring in the dry-evergreen forest; Muak Lek series, covering the deep soils on shale-derived material; and Tha Yang series, covering all soils with more than 0.2 per cent of the surface covered by boulders or rock outcrops.

38. Some of the remaining soils have been assigned to the Reddish Brown Lateritic soil group, i.e. those on the somewhat richer shales, but their occurrence is incidental and the soils appear to be transitional to the Red-Yellow Podzolic soils. A further group, Low-Humic Gley soils, are found in a few poorly drained depressions.

39. In mapping the soils, action has been taken to distinguish soil variations with respect to depth of soil, surface stoniness, and slope.

40. The physico-chemical properties of soils from the great soil groups of the core area are being examined in the laboratory of the Rice Department, Ministry of Agriculture.

Climate

41. Little information is available from earlier observations to characterize the climate of Sakaerat Experiment Station. The nearest synoptic station is at Nakhon Ratchasima (Khorat) which is 60 km to the north. Details of available earlier records from Khorat and supplementary stations at Prachin Buri, Pak Chong, Sikhiu, Pak Thong Chai, and Kabin Buri were summarized in Semi-Annual Report No. 1.

42. Two base stations for climatic data were established in mid 1967. Six satellite stations were set up in May/June 1968 to sample variations in soil, vegetation topography adjacent to the tower system. Details of these stations are given in Semi-Annual Reports No. 3, No. 4. Observations are being taken by observers from the Department of Meteorology directed by Dr. Kajit Buajitti in collaboration with Mr. Joseph Zabransky.

43. All stations are now in full operational stage. Climatic data were collected continuously throughout the entire year at all eight mesometeorological stations. Observations were carried out by rotating teams of three observers from the Meteorological Department. Aside from occasional recorder chart shortages, there were no malfunctions with the instrumentation.

44. Under the supervision of Dr. Kajit Buajitti, the Meteorological Department has reduced temperature, rainfall, evaporation, and humidity data through December 1969. Summaries of climatic data from October 1967 through June 1969 are in the preparatory stage for reproduction and distribution at ASRCT. A brief report, "Mesometeorological network installation and instrumentation at ASRCT Sakaerat Experiment Station (Nakhon Ratchasima)", was prepared in early 1969. Climatic conditions at the mesometeorological station at the Sakaerat Experiment Station can be generalized. Mean temperature starts at 25.1°C in January and rises to 27.7°C in March at the highest average of 1969. After March, the average temperature decreases throughout the rest of the year to 20.4°C in December, with a yearly average of 25.2°C. The maximum tempera-

ture is 38.0°C in April and the minimum temperature of the year is 10.8°C in December.

45. Beginning in January as the first month the humidity has a mean of 69.3 per cent and decreases sharply to 60.3 per cent in February. The rise of humidity is gradual until the rainy season starts in May when the relative humidity goes up to 76.2 per cent with rapid increase. Throughout the rainy season, the humidity varies with little differences from 80.9 to 85.0 per cent. After the rainy season the humidity drops to 81.6 per cent in November and 70.3 per cent in December, and the yearly average is 75.6 per cent.

46. Rain starts at the very beginning of the year in January but completely stops in February. From March through November the rainfall has been recorded. The fluctuation of rain is slight throughout the rainy season, but the greatest amount of rain is recorded in August at 370.1 mm. The rain decreases suddenly in November and completely stops in December. Total annual rainfall is 1357.2 mm.

47. Evaporation of water each month from January to August is over 100 mm. The most dramatic change is from 118.5 mm in January to 175.6 in February. After the rainy season evaporation decreases sharply in September to 72.6 mm from 108.5 mm in August. Evaporation fluctuates slightly during the period September to November but recovers again in December to over 100 mm. Annual record of evaporation is 1519.8 mm in 1969. Evaporation data are very much affected by wind and the wind effect marks variations due to seasonal humidity variations.

## V. MEASUREMENTS OF BIOLOGICAL FACTORS

### Vegetation

48. Studies made in 1967 and 1968 have been summarized in Semi-Annual Report No. 4 (For period of 1 July to 31 December 1968). Some of these have been continued into 1969.

49. The inventory work started since July 1967 by the Royal Forest Department directed by Mr. Tem Smitinand and his group. Many plots of various dimensions were laid down in the test site in July 1967 until December 1969. This is in order to make the comparative

study on the speciation, frequency of occurrence, density and association of free species among the various types of vegetation. At the time of reporting, technical reports have been drafted under two topics: "Vegetation analysis of dry-evergreen forest" and "Flora of Sakaerat."

50. An inventory of vegetation in one plot of one hectare (100 m x 100 m) centred on the forest tower has been made by the same group, and a report on "Inventory of vegetation in one hectare (100 m x 100 m plot) centred on forest tower, ASRCT Sakaerat Experiment Station (Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima)" has already been issued.

51. In relation to this work, a preliminary attempt has been made to study the effect of fire on the forest flora, since one hypothesis is that the dry dipterocarp forest is a fire disclimax of the dry-evergreen forest. Soil samples from both forest types have been collected and, after baking in an oven to various temperatures and with different time limits, have been potted and kept in a greenhouse with constant watering. Germination of various species has been followed to check the effect of exposure to high temperatures on subsequent germination. The results of the study reveal that, in dry-evergreen forest, some elementary plants (e.g. moss) germinate well in all treatment except in 200°C, 60 minutes treatment. It may be generalized that high temperature affects seed germination since the number of species decreases when the temperature increases.

52. Plant collectors have been assigned to collect herbarium specimens of flowering plants and ferns all year round in the test site and adjacent area. In 1969, Australian and Dutch botanists visited the site and thoroughly collected herbarium specimens, most of which are expected to be listed in the "Flora of Sakaerat". The full account of the Flora of Sakaerat will be accomplished as soon as the specimens will have been properly identified. Identification of plants is a time consuming process, owing to the lack of type descriptions and specimens.

53. The preliminary study on forest fire in dry dipterocarp forest aims to determine the rate of fire spread, and the data on the loss of organic matter and the soil moisture content are fundamental to the study on the watershed control and change in the microclimate. The study started in September 1967. During the dry season of 1969, two circular sample plots were laid down in dry dipterocarp forest. A report on this study has already been drafted.

Macrofungi

54. Observations have been made by the Royal Forest Department team on mushrooms and wood-destroying fungi. The majority of wild mushrooms are found on the humus and litter in the dry-evergreen forest, generally near a trail which permits sunlight penetration. Most of the wood-destroying fungi, i.e. conk or shelf fungi, are found growing on tree trunks, usually on dying standing trees or fallen trees. Such fungi are rarely found in the dry dipterocarp forest.

55. Mushrooms and wood-destroying fungi usually have a moderately wide host range. Polystictus xanthopus Fr. and Lentinus praerigidus Berk., which are common species, grow on several species of tree. Prevalence of macrofungi varies with the season, being found widely in the wet season and diminishing in the dry season. Work on identification continues.

Bacteria

56. A survey of bacteria occurring in air, water, and soil in the Station area has been carried out by an ASRCT team led by Dr. Malee Sundhagul. Specific attention has been given to deposition of airborne bacteria in different vegetation communities and at different heights in the dry-evergreen forest. The report on the deposition of airborne bacteria will be included in final report of the Mycology section.

57. Examination of water samples collected from streams and dams in the study area during the dry and wet seasons indicates that, in general, the water is unfit for drinking. Checks have been made on the water in the dam providing supply to the living quarters and on the rain water store in tanks for drinking. Changes in number of bacteria

correlate inversely with rainfall. The report "Microbial studies of the surface waters of ASRCT Sakaerat Experiment Station, Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima" by Poonsook Atthasampunna and Malee Sundhagul has been issued.

58. Soil bacteria from the dry-evergreen forest, from the dry dipterocarp forest, and from clearings were examined throughout the year. Activity increases with increasing moisture content, and is highest in the wet season. The percentage of spores decreases in the wet season indicating that soil bacteria are in their vegetative form more in the wet season than the dry. An examination of morphological forms indicates that at all sites the dominant type is the short-rod bacteria group.

59. Studies on soil nitrification revealed that the density of nitrifying bacteria was high in the dry-evergreen forest soils and in the grasslands soils. The non-symbiotic nitrogen-fixing bacteria, Azotobacter, have not been detected, probably due to the general high acidity of the soil.

60. Soil profiles studies revealed that the number of microorganisms, both bacteria and microfungi, were high in the surface layers (0-8 cm) where the organic matter was also found to be high. Both microbial count and organic matter content decreased sharply with depth, levelling off at about 30 cm.

Microfungi

61. The same team has carried out a survey of microfungal occurrences in the station area. Collaboration with Dr. Emory G. Simmons of NLABS in identification of microfungi has continued throughout the investigation. Special attention has been given to microfungi occurring on plant materials and to airborne fungi. Some genera are presented. More than 700 strains of microfungi have been isolated. Of these 50 strains have been identified, and their identification confirmed and certified. The cultures are being maintained by ASRCT as reference culture of Thai fungi.

62. Survey have been made on cellulolytic fungi in the soils in dry-evergreen forest soils and in dry dipterocarp forest, and on micro-

fungi growing on certain foreign materials introduced into the station area. Several strains have been found active in colonizing on materials such as electric cord, cable insulation, and tarpaulins. Distribution studies on cellulolytic fungi indicate that members of Aspergillus and Chaetomium are more or less confined in the open dipterocarp forest, Paecilomyces and Cylindrocladium in the dense dry-evergreen forest. Genera which are equally active in both communities were Penicillium, Trichoderma, Gliocladium, Streptomyces, and Myrothecium.

63. Studies on plant-fungi relationship has revealed two results. First, an undescribed fungi of Hyphomycetes group is specifically associated with the culms of a bamboo species, Thrysostachys siamensis. The fungi has been proposed as a new genus, Aerodictiopsis. It is characterized by having well defined and branched conidiophores bearing brown tuberculate dictyospores. Second, the most common fungi associated with roots of a dominant vegetation of the forest, Hopea sp., are Gilocephaloticum sp.

64. A report has been prepared on the surface deposition of airborne microfungi covering diurnal variation, seasonal variation in different vegetation communities, and variation with height in the dry-evergreen forest. Deposits are higher in the morning and evening than during midday and early afternoon. Deposition rates are highest in the period January to April, are more moderate from May to August, and are lowest from September to December. The pattern of annual fluctuation is similar in all vegetation communities; however, rates are lower in the dry dipterocarp and dry-evergreen forest than in the grasslands.

65. Studies are being undertaken to determine the effect of forest fire, which occurs annually in February and March in the open dipterocarp area, upon microbial flora. Determinations were made of microbial density and their activities in term of rate of carbon dioxide evolution. Results indicate that the bacterial and fungi at the surface soil are most affected, more than 90 per cent are destroyed. The rate of carbon dioxide evolution is significantly reduced. However, the microbial population and their activities return to normal within a few months.

66. Soil microfungi most abundant and common to soils throughout the station area are of the genera Penicillium, Aspergillus, and Trichoderma. In the wet season, Penicillium members are of more or less equal occurrence in different vegetation communities, whilst Aspergillus members are more frequent in the drier soil of the dry dipterocarp forest, and Trichoderma members are most frequent near the stream.

67. Identification of fungi collected from Sakaerat Forest has revealed some rare or undescribed forms. Work is being continued in Mycology Laboratory of ASRCT to describe and illustrate them.

68. Some of the fungi isolated and identified have been permanently preserved and deposited with the Centre for Thai National Reference Collections. These will serve as reference cultures for future taxonomic studies of Thai fungi. All of the technical reports of microfungi studies are awaiting submission.

Fauna

69. A considerable volume of data are now available on the occurrence of various faunal taxa at the Sakaerat experimental site. Regular programmes of collection undertaken by staff of the Centre for Thai National Reference Collections under the guidance of Dr. Prasert Lohavanijaya have enabled the faunal occurrences to be catalogued and have provided information on seasonal fluctuations in abundance. More than 70 families of insects are represented in the station area. Work has been continuing in identifying species occurrence amongst a collection of over 1,000 specimens. Records show the existence of at least 14 species of snakes in the area, four of these being very poisonous (Trimeresurus popcorum, green pit viper; Agkistrodon rhodostoma, Malayan pit viper; Naja naja kaothia, Indian cobra; and Dendraspis hannah, king cobra), and four other mildly poisonous. Eleven species of lizards and seven species of amphibians have been recorded. Through the cooperation of the ASRCT-Thailand team of the Migratory Animal Pathological Survey, bird banding and bat banding studies have been done, including examination of ectoparasites. In all, some 103 species of birds have been recorded. Mammalian populations have also been sampled.

Report on "Inventory of Fauna at ASRCT Sakaerat Experiment Station, Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima" by Prasert Lohavanijaya et al. has already been issued.

70. The SEATO Medical Research Laboratory has occasionally screened blood samples taken from mammals for rickettsia and related diseases. The virus of scrub typhus (Rickettsia tsutsugamushi) has been found in 1968 from rats, tree shrews, and the clog-faced fruit bat (Cynopterus brachyotis). Their work is still continuing.

71. The fauna study group has initiated three studies programmes in 1969 in addition to former studies. They are studies on soil microarthropods, insect population, and rat population.

72. The insect population study had started since August 1968 and continuously in progress until 1969. Two light traps, one in the dry dipterocarp forest and the other in the clearing of the micrometeorological tower area, have been in operation. The collections are made two nights a week. The study is a continuation of work for the complete annual cycle. At the period of preparing this report this study programme has been completed. The final phase of data analysis and preparing technical report has been undertaken.

73. During the period January to October 1969, the study on soil microarthropods has been carried out. 160 soil samples, each of about 0.5 litre in volume were taken from 4 plots in the dry dipterocarp forest and from 4 plots in dry-evergreen forest. Each soil sample is processed in heat driven separating funnels for several hours. A moisture measurement was also taken from each sample. At the reporting period, all data are being recorded and tabulated in final stage. The technical report is under preparation.

74. In the third week of June 1969 the fauna study group has placed 450 live traps in the dry dipterocarp forest about 1.5 km from the camp site toward the highway (route 304). The traps are placed in grid system 15 m apart. Banana is used as bait. The operation included two days of pre-baiting and three days of trapping. At the end of trapping period the population of small mammals in this selected area (approximately 210 m x 435 m) is practically wiped out. An effort is being made to determine the population density

of this area with the hope that the result will be an indication of the secondary productivity of the dry dipterocarp forest.

75. In 1969, a strange species of spiders was found in the study area at the Sakaerat Experiment Station by Mr. Sukhum Pongpipatana. The live specimens were collected and taken back to the ASRCT fauna laboratory by Mr. Noel Kobayashi to be identified and for further study. These spiders were identified as the black widow spider (Latrodectus mactans), a well-known species of poisonous spider. The most common place where they are found is in South America, and this is the first instance that they have been reported in Thailand. In September 1969, Mr. Noel Kobayashi received confirmation from the British Museum of Natural History that a spider he caught at Sakaerat experimental site was indeed a black widow. Mr. Noel Kobayashi, afterwards, conducted further study on these spiders in collaboration with fauna staff in CTNRC laboratory, ASRCT, Bangkok. This study has not been completed.

76. Soil microfauna is being examined both in dry-evergreen forest and in dry dipterocarp forest. By the last quarter of 1969 it was still reported that the population of mites (Acarina) was high in comparison with other forms.

77. The ASRCT fauna group has also been working with a bioscience team from Chicago Field Museum, Drs. R.F. Inger and R. Heyer, who, with the aid of a National Science Foundation grant, have been conducting a year long study at the TREND research site. The study centres on the structure and dynamics of animal communities in tropical forests. Collection of reptiles and amphibians through randomly located quadrants (8 m x 8 m) and transects has been continuing through 1969. This comparative study using data from seasonal forests, such as at Sakaerat, and true rain forests, is sought to measure community characteristics of diversity, niche breadth, overlap, and population size. The characteristics found will be related to structural diversity and patterns of temporal variation in the forest ecosystem. At the time of preparing this annual report, the draft of final report in field study by the bioscience team is being submitted.

## VI. PRODUCTIVITY STUDIES

78. These studies aim at providing data on net primary production and on secondary production in the several vegetation communities in the station area, with major attention on the dry-evergreen forest.

### Biomass

79. Continuing from a major study of biomass in the dry-evergreen forest started in 1968, the study has been extended to root biomass. Data are being collected and processed. The preparation of technical report is being undertaken. Other biomass studies have been summarized in Semi-Annual Report No. 4.

### Litter

80. Studies on rates of accumulation and disintegration of litter on the forest floor has been continued in 1969. The study was confined to one year of observation at first from March 1968 to February 1969, and was extended for another year from March 1969. The litter has been collected monthly from the original ten sampling sites. Each sampling site consists of the same 12 one square-metre wooden plots, while an additional plot is provided as a treated one. The study will give preliminary findings of the year-round litter fall and loss by decomposition. The result will appear in the terminal report which is being prepared. Details for the past work was reported in Semi-Annual Report No. 4. These studies were conducted by teams from the Royal Forest Department and from the Faculty of Forestry, Kasetsart University.

81. The report of the study on the natural defoliation of 'teng' (Shorea obtusa) and 'rang' (Pentacme suavis) in the dry dipterocarp forest has already been published. Another two species in course of study, 'krat' (Dipterocarpus intricatus) and 'daeng' (Xylia kerrii) were rigged up during October 1969. Weekly data collection has been undertaken until the completion of defoliation (March 1970).

82. These studies are closely linked with studies on soil microbiological activity being made by the ASRCT team under Dr. Malee Sundhagul and studies on soil microarthropod activity by another ASRCT team under

Dr. Prasert Lohavanijaya. They are also linked to the work on cellulose-decomposing fungi which has already been referred to above. Studies on microbial decomposition of litter indicated that the rate of litter decomposition was higher in the dry-evergreen forest than in the dry dipterocarp forest. Similar results were obtained in an examination of the decomposition of cellulose materials buried in the top layers of the forest soils. Studies on microbial activity in the forest floor in terms of carbon dioxide evolution showed a higher rate of evolution in the dry dipterocarp forest and in the grasslands than in the dry-evergreen forest.

Termite mound

83. Since termite activity may be an important factor influencing the soil condition and forest productivity, some studies have been carried out on this aspect at Sakaerat Experiment Station by a team from the Kasetsart University. In order to identify termite mound activities under a dry-evergreen forest floor, preliminary study plots of 50 x 50 m were made in the forest area of the main tower and tower No. 3. The area of study plot at tower No. 3 was extended with 37 x 46 m to the north in order to cover overall area for a map showing the typical extent of termite mounds of various classes, such as incipient, youthful, rounded, flat top, and old trace. In addition, a microtopographic map of 10 centimetre contour interval was made to locate termite mounds, stones, and stand positions.

84. It has been discovered during mapping 32 termite mounds at forest tower area and 51 termite mounds at tower No. 3 area that most termite mounds are in the rounded or flat top stage; however, there are some in incipient and youthful stages. This study is still being conducted.

85. Future work will include an intensive study of representative mounds from various age classes. Observation on the development and growth of trees in relation to termite activities will be made.

86. The temperature gradient of the termite mound is also being investigated. The ASRCT soil research team led by Mr. Pongpit Piyapongse has periodically observed and recorded some temperature data since 1968. At the end of 1969, this team has put up some instruments to study temperature gradient of the termite mounds more intensively. At the time of preparing this annual report, the study is still continuing.

## VII. MICROMETEOROLOGICAL STUDIES

87. Micrometeorological studies using the two complex tower installations are to be the principal earth science investigations at the Sakaerat Experiment Station and the core of the studies under the TREND programme. Observations are directed towards determining vertical differences (profile curvatures) in the parameters measured, microclimatic conditions associated with vegetation levels, and energy exchanges between the ground and the canopy, the canopy and the sky, and at the soil-air interface. Comparisons will be made between the data from the two towers to define significant correlations.

88. The programme is being carried out under the general guidance of Dr. Heinz Lettau of the Department of Meteorology, University of Wisconsin, and directed by Mr. Joseph Zabransky. Observers and technicians from the Department of Meteorology and from ASRCT are involved in system installation and operation. The 360-40 computer at the National Statistical Office is being used for data analysis. Mr. Somsakdi Supharatana is currently studying for the M.S. degree in micrometeorology under Dr. Heinz Lettau at the University of Wisconsin in preparation for future micrometeorological study.

Summary

89 The year 1969 was the first full year of operation for the micrometeorological programme. Installation is complete and all equipment is operating except for the dew point sensors. A serious problem with the magnetic tape recorders plagued the data acquisition programme for nearly half a year and overshadowed significant

progress in reduction of temperature and wind speed data. The year ended with three and a half months of full data collection, free of trouble, aside from the absence of the dew point sensors. The difficulties which were encountered during the year solidified periodic, routine checks into an austere programme of constant scrutiny on all vital system components.

## Maintenance problems

### Instrumentation

90. The dew point system has been the biggest problem to the data collection programme to date. The year started with its absence. The sensors were returned in March and they began to fail within a month after reinstallation. By August most had failed and were shipped back to the United States again for an investigation of the engineering design. Although the dew point sensors had not returned by the end of the year, word was received that the cause of problem lay in the inadequacy of the RTV sealing compound around the thermister and thermocooler.

91. The sensors are expected to be returned in early 1970 and it is still hoped that one rainy season can be salvaged with their use. It is quite unfortunate that two dry season were passed over because of the dew point sensor malfunction.

92. Most other problems with sensors were quite incidental; an occasional faulty potentiometer in a rain gauge or wind direction sensor, and worn bearings in the wind speed or wind direction transmitters were the only troubles. The fact that the wind speed bearings were low in stock early in the year, and the wind speed standard spent 6 months in the United States undergoing standard calibration comparisons, meant that comparisons could not be made in the field, a highly unsatisfactory situation for the entire year.

93. The quartz thermometry system has proved quite successful. This not only means the sensors withstood the vigorous environment, but the quality of data also continued to be consistently good. This was not, however, totally unexpected since the system had demonstrated reliability in the past.

Data acquisition system

94. All difficulties with the data acquisition system were dwarfed by the problem with the magnetic tape recorders during the year. Although trouble appeared as early as February, it was not detected until late April while checking a backlog of data tapes at the National Statistical Office. The data tapes could not be read on the IBM 360. Nearly two months were spent checking out the entire system with only one single positive fact resulting—the tape recorder was at fault and had to be returned to the United States. A recorder on loan was sent to Thailand as a temporary replacement. In the meantime the second original recorder ("analogue" recorder) showed a similar problem.

95. The "repaired and modified" recorder was returned in August; it still did not work and was promptly returned to the United States. It was returned again in October with a couple of defective parts. These parts were replaced and the recorder has since operated well. The "analogue" recorder was modified in situ but continued to malfunction. The repaired and temporary recorders were retained for operation and the "analogue" recorder has been sent back to the United States for an overhaul. The trouble with the recorders remains a mystery.

96. Problems occurred in many of the other units in the system, but could be considered minor compared to the significance of the recorder trouble. The majority of these lesser problems appeared during the early part of the year and could be attributed, in part, to the numerous power failures and unregulated voltage fluctuation towards the end of 1968. There were some transistor failures also resulting from overheating in the temperature-wind speed system as well as in the digital clock. The heating problem has been solved by using both air conditioners at all times. The a.c. voltage for the system and towers is now regulated and power failures rarely occur.

97. Because of the curtailment of data collection in 1969, efforts have been made to make the last year of operation (September 1969 - September 1970) as fruitful as possible. All units in the data acquisition system will undergo more frequent checks than recommended

by the manufacturer. The magnetic tape recorders will undergo thorough checks after every tape change. Sensors will also be kept under more careful scrutiny. Most of this is now made possible since the programme has, at long last, received the services of a project electronics engineer. Supervision and surveillance are expected to be nearly 100 per cent for the remainder of the programme.

## Data reduction

### Automatic data acquisition system

98. During the first seven months of the year there was no significant data reduction since the temperature-wind speed reduction programme was not debugged and operative until August. Raw data print-outs were used to check all data tapes before reduction began and are still used to check tapes from our "analogue" recorder. The reduction programme for the "analogue" tapes is expected to be complete by mid-1970.

99. Tape check-out progress was slow in the first half of the year due to the lack of a firm contract between ASRCT and the National Statistical Office. A contract was consummated in June and subsequent data tape checks and reductions were done more regularly, but the contract still did not allow TREND any specific computer time during regular operating hours.

100. At the end of the year, the following data tape check-out and reduction totals were complete: 137 tapes were checked out, but only 42 tapes could be reduced, all of which were temperature-wind speed tapes. Of the tapes reduced, 32 covered the period September 1968 to January 1969. The other 10 tapes covered the period September to December 1969. Of the 137 tapes checked, 101 were "digital" or temperature-wind speed tapes, and the remaining 36 were "analogue" tapes. Of 101 "digital" tapes checked, 76 came from the first year of operation (September 1968 - August 1969), 44 per cent of these being IBM 360 compatible. Of the 36 "analogue" tapes checked, 32 were from the first year of operation, 38 per cent of these being IBM 360 compatible.

101. In the both "digital" and "analogue" cases, over half of the tapes were not reducible on the IBM 360 system as a result of the tape recorder problem. It is hoped that these questionable tapes will be reduced on another type of computer in the United States, thus preventing a large data loss.

Analogue strip chart

102. Only radiation data were recorded on the strip chart recorders. Both the single channel pen and the twelve channel multipoint recorders were used frequently during the year to obtain more readily reducible data since the reduction programme for the "analogue" magnetic data tape was not yet available. Radiation data reduced included filtered and total global shortwave, reflected shortwave, filtered and total direct shortwave, illumination, and UV information.

## Data analysis

103. Preliminary data analysis was carried out with both the radiation data and the reduced temperature-wind speed data. A report on the early results from the radiation study was begun at the end of the year. A report on the temperature-wind speed analysis will be forthcomming in 1970. A report on the micrometeorological instrumentation and installation was prepared, however, early in 1969. Mr. Manit Auvuchanonda, physicist, has been primarily involved in the radiation analysis. Lieutenant Ruay Voranawin, climatologist, has been assisting in the graphical analysis of the temperature and wind speed data.

104. Temperature and wind speed data which were analyzed represent the period of September - December 1968. Analysis of air temperature is directed towards determining diurnal variations of profiles from wet to dry season, variations of maximum and minimum temperatures at particular levels from wet to dry season, and the change in temperature amplitude at particular levels between clear and cloudy day in the wet season and from wet to dry season.

105. The current objective of the soil temperature analysis is to determine diurnal variations of profiles from wet to dry season, compare temperature amplitude damping between the surface of soil and the one metre depth on clear and cloudy days, and from wet to dry season.

106. Wind speed analysis is aimed at obtaining an estimate of the diurnal variation of wind speed, determining the vertical variation of wind speed, particularly within the forest, and estimating a value for forest canopy roughness.

107. Radiation analysis has involved calculating values for forest and albedo (the ratio of reflected shortwave solar radiation to the incident solar radiation upon a chosen surface times 100) from season to season, computing values for atmospheric turbidity and precipitable water content from spectral radiometric measurements, computing diffuse radiation from measured values of direct and global radiation, comparing measured illumination to values calculated from spectral radiometric measurements.

108. Former details in micrometeorological study were summarized in Semi-Annual Report No. 4.

## Solar radiation measurement

109. The work on solar radiation measurements conducted by Mr. Manit Auvuchanonda has begun since the early of 1969 by using 2 sets of sensors consisting of the Eppley pyranometers and the CSIRO Funk net radiometers. In a set on the top of the forest tower, three pyrheliometers equipped with rotating filter wheel with broad band-pass filters WG-7, GG-14, OG-1, RG-2, RG-8 and narrow band-pass filters NB-1, NB-2, NB-3 are used to measure the direct radiation. Two pyranometers with the hemispheric WG-7 filters (clear glass) are used to measure the total shortwave radiation falling on a horizontal plane and being reflected by the forest canopy. The filters may also be replaced by the hemispheric broad band-pass Schott filters of GG-14, OG-1, RG-2, and RG-8 to measure the global radiation at well-defined bandwidths. With the purpose of studying the solar spectral radiation, five pyranometers, equipped with

hemispheric narrow band-pass filters A-2, A-3, A-4, A-5, A-6, are used to measure five intervals of spectral solar radiation from the wavelength of about 330 mm up to 3000 mm. The Eppley UV photometer and illuminometer, consisting of sensing photocells, are employed to measure the ultraviolet radiation at the wavelength of 280-380 mm and the daylight illumination. Two more Funk polyethylene radiometers, used as unidirectional sensors, measure the total incoming and outgoing solar and terrestrial radiation to enable the calculation of the net radiation.

110. At the base of the forest tower, another set of sensors were installed in the same configuration as in the top of the tower except three of the pyrheliometers are absent. At the clearing floor, only one pyranometer with NG-7 filter was installed inversely to measure the solar radiation reflected by the grass.

111. The radiation values as measured by the sensors are recorded by both the analogue unit of the data acquisition system and two Leeds and Northrup strip chart recorders, one of which is a 12 channel model and the other is a single channel model. By using the banana plug panel, signals from any selected sensors can be recorded by the recorders, but cannot be recorded at the same time by the data acquisition system. Unfortunately, the radiation data were recorded by the analogue unit for most of the time in the first half of the year, with only 4 or 5 days in a month. The results came out with the problem in analogue unit of the data acquisition system, and all data are still unable to be reduced. Therefore, the results appearing in the report are those reduced from the data obtained by using two strip chart recorders in the second half of the year.

## Results

112. In the period April-December, the monthly average value of the Angstrom atmospheric turbidity ($B_m$) over the dry-evergreen forest was calculated, and the following results were found: the $B_m$ value started at 0.160 in April and dropped to 0.075 in May. During June-August period $B_m$ was fairly constant around 0.065 and decreased to 0.057 in September. The $B_m$ value increased again to

0.074 in October and finally decreased to 0.067 in December. Although the variation of $B_m$ was not greatly noticed, the daily average value ($B_d$), however, varied greatly from day to day, i.e. the $B_d$ variation of 20 per cent of $B_d$ was found in May and 30 per cent of $B_m$ in October.

113. The monthly average value of the precipitable water (W) of about 4 cm was found with the maximum value of 6 cm in September during May-October period. This value increased from 1.8 cm in April and finally decreased to 2 cm in November and December.

114. The monthly average value of the total direct solar radiation (I) has not been reduced to the mean solar distance value. This value at the solar altitude of $50^{\circ}$ was approximately 1.21 cal/cm$^2$min in May and increased during the rainy months to about 1.28 cal/cm$^2$min in September. The value then decreased to about 1.22 cal/cm$^2$min and 1.27 cal/cm$^2$min in October and November, and increased again to 1.30 cal/cm$^2$min in December. At the sun's altitude, the maximum daily average value of direct solar radiation was observed to be about 1.345 cal/cm$^2$min on 12 December 1969.

115. The variations of the global shortwave radiation (GSW), on clear days, with the solar declination ($S_o$) was found to be very pronounced. The measurements showed that in February ($S_o = 14^{\circ}$) the maximum value of the GSW was 1.35 cal/cm$^2$min, and as the sun declination increased to $+ 18^{\circ}$ in May, the GSW reached 1.48 cal/cm$^2$ min and then decreased to only 1.20 cal/cm$^2$min in December. The total value of about 500 cal/cm$^2$ day was found on a very clear day of 5 December 1969.

116. The daily maximum value of the illumination above the forest canopy varied from 135 klx in May to about 131 klx in July and August and decreased to 106 klx in December. Calculation from the radiometric data obtained by using the RG 8 filter, when compared to the direct measurement values, revealed that the calculated values of the illumination are about 90 per cent of measured values.

117. The albedo of the grass at the clearing floor was found to depend on the physical properties of the grass (fresh and dry). Even though the albedo of the dry grass was higher than that of the fresh grass, the minimum value varied only in the range of 15-18

per cent during the April-December period. The albedo of the forest canopy, however, seemed to vary in a wider range. Its minimum value was about 10.5 per cent from April to June and increased to 12.5 in late August and 14 per cent in December. The high value of 14 per cent in December may be interpreted as the result of low solar declination and the reflected radiation by the tower.

118. Although the results of the spectral radiation, UV, and long-wave radiation do not appear in the report, these data have also been recorded and are available for reduction. The radiation study programme as proposed by Mr. Joseph Zabransky will be continued throughout the year 1970 so that the verification of the above results will be possible.

## VIII. ENERGY AND HYDROLOGIC BALANCE

119. It is hoped that when all of the more detailed studies in micrometeorology and plant sciences develop, it will be possible to examine the several components of the energy balance in the dry-evergreen forest, including solar radiation inputs, and an examination of transpiration (water vapour) and carbon dioxide gradients in a vertical plane at the forest tower. At this stage some work has already been completed, but some is still being conducted.

120. A team from the Faculty of Forestry, Kasetsart University, under the guidance of Dr. Sanga Sabhasri and ASRCT soil research team, led by Mr. Pongpit Piyapongse with advice from Dr. Paul Zinke of the Department of Forestry, University of California at Berkeley, are examining several aspects of the hydrological balance in both dry-evergreen forest and dry dipterocarp forest.

### Evapotranspiration

121. After completion of the preliminary study of transpiration and water loss in dry-evergreen forest, the study of water losses as affected by stand composition in dry-evergreen forest was undertaken. The study aimed to find the relation of water loss and different plant covers and bare surface soil. To do this, samples

of the soil at A and B horizons of open ground, old clearing, and forest sites were collected once a day at 0900 hours. The moisture content was determined gravimetrically. The decrease of moisture in soil was determined as water loss. The results of the study revealed that mean rates of loss in the open, old clearing, and forest sites were 4.74 mm, 4.06 mm and 4.05 mm per day respectively. The annual loss was 1745.84 mm in open surface ground, 1452.23 mm in the old clearing, and 1334.98 mm for forest site. It can be seen easily that the highest loss of water occurred in the open, the second highest was in the old clearing, and the least loss was found in the forest. This programme of study needs another year for the investigation.

122. The Kasetsart University team has also been conducting surface runoff study in dry-evergreen forest of the Sakaerat experimental site through 1969. The objective of the study is to determine rainwater losses in situ by surface runoff, the process on which water runs over the soil surface to rivers or creeks. The investigation will provide reasonable data for calculating water balance in the area. Six plots of 1 x 2 m were laid out in the dry-evergreen forest area in the vicinity of the towers, and the amount of surface runoff from the plots has been collected in containers placed at the lower end of each plot. Data are now being analyzed and will be presented in the final report.

Interception, throughfall, and stemflow

123. Interception, throughfall, and stemflow have long been recognized as affecting water balance in watershed areas and soil erosion control. These three aspects also play important roles in microclimate change, plant growth, and soil microorganism activities. This study aims to determine the amount of interception, throughfall, and stemflow as a basis for the study of the change of microclimate, water balance, and plant nutrient cycle.

124. The collars of forty-one sampling trees were fitted in order to determine stemflow. Throughfall is indicated by through-check gauges located under the canopy. Interception is being determined by subtracting grass rainfall by stemflow and throughfall. From

the tabulated data of the three aspects in 1969. It can be said that the three aspects are quite related to the amount of rainfall. This study needs one more year for the investigation and is now in the stage of continuation. The investigations are being extended to cover the effect of the litter layer on moisture retention and to examine soil moisture using forms of lysimetry. Chemical analyses of water collected in these investigations will be used in tracing the nutrient cycle in the forest.

Water losses from bare soil surface

125. A new experiment is being added into the soil study programme conducted by the ASRCT soil research team. The purpose of this study of water losses is to determine the rate of water losses from bare soil surface in the dry dipterocarp forest, compared with the one under small bamboo plants cover after the rainy season. The results of this study will permit an evaluation of the effects of wind movement, soil and air temperature, sunshine duration, and solar radiation on moisture content of the bare soil surface. The neutron surface soil moisture probe was used to determine the soil moisture content volumetrically at 2-hour intervals, starting from 0700 through 1700 hours. The results are now being compiled.

Soil moisture measurements

126. The complete one-year cycle of the routine soil moisture measurement plus few spot-checks were completed by the end of December 1969. The routine soil moisture measurement using the neutron probes has been carried out daily at the two soil plots (clearing and forest area of the dry-evergreen forest) and bi-weekly at the plots as suggested by Dr. Paul Zinke in studying the underground water flow which has begun since the early period of 1969. Two more sites were added into the programme in July 1969, one in the vicinity of the noise measuring van and another in the dry dipterocarp forest. The inventory of the soil moisture content of each month is now available. The data for underground water flow study were reduced and tabulated and being sent periodically to Dr. Paul

Zinke in the United States. The soil moisture profiles of clearing floor in the vicinity of the clearing tower and under forest canopy near the forest micrometeorological tower showed distinct difference in the amounts of soil moisture content. The correlation between soil moisture and other related factors will be presented in a technical report now being prepared.

Comparative soil moisture profile study

127. During July-December period, the ASRCT soil research team had been conducting comparative soil moisture profile study. The plots had been laid in different forest environment of the study area. The measurements of soil moisture content were done weekly at four different plots in clearing of dry-evergreen forest, under forest canopy of the dry-evergreen forest, in grasslands, and in dry dipterocarp forest. The study has been aiming to reveal the different soil moisture profiles in different soil series. Unfortunately, the neutron depth moisture gauge had been out of order for the period October to November, and the data were missing for the two months. However, the surface moisture variation of different soils has been recorded.

Soil sample analysis

128. Samples of the major soil series of the core area at Sakaerat experimental site namely Khao Yai, Muak Lek and Tha Yang, were analyzed for cation exchange capacity. The results obtained indicated that all soil samples contained rather low amounts of exchange capacity. The results obtained indicated that all soil samples contained rather low amounts of exchangeable cations. The average exchangeable $Ca^{++}$ ranging from 3.15-0.9, $Mg^{++}$ 2.55-0.47, $Na^{+}$ 0.44-0.02, $K^{+}$ 0.17-0.03 meg/100. The soil textural classes of the core area ranged from loam to clay loam. Termite activities play an important role in the soil texture changes. They brought up the finer materials from subsoils to the surface layer. The organic matter content ranged from 2-5 per cent. The mineral contents of the parent material are mainly silica, iron oxide, and some titanium.

## Water sample analysis

129. Water samples from the dam site at Sakaerat Experiment Station were occasionally analyzed for total salt content. The results indicated no harmful amounts of salts presence. There is a sharp difference in iron content between dry and wet season.

## Condensation pit

130. Three condensation pits (1m x 1m x 1m) were dug during the last quarter of 1968 and the study of condensation rate was operational until April 1969. Plastic sheets, flasks, and cylinders were used as experimental tools. The study was conducted in the clearing area of the dry-evergreen forest in the clearing tower vicinity. The average rate of condensation is about 1 litre per day, which is sufficient for one person to survive.

## Geological well logging

131. A deep well log from the drilling by the artesian well crew of the Department of Natural Resources at Sakaerat is now being prepared by the soil research group. Surface soils and rocks description will be done to depths of about 46 m. The inter-fingering of blue clay at a depth of about 15 m was noticed.

132. It is hoped that the soil research team could possibly undertake some additional studies to the main programme of soil moisture measurement. The plan for future studies includes the study programmes for surface runoff, soil specific physical properties, and termite mound soil analysis. Soil monolith collection is also being considered. All soil studies programmes for 1968-1969 are now being terminated and technical reports have been prepared.

## Translocation and water uptakes by trees

133. The Kasetsart University team in collaboration with Dr. J.R. Bently and Mr. G. Conrad of the U.S. Forest Service has undertaken preliminary work on the rate of water uptake by trees in the dry-evergreen forest. Translocation study has been done on insertion of $P^{32}$ and detecting the accumulation both at Sakaerat Experiment

Station and at Kasetsart University Forestry camp. The investigation has also been done on the water absorbtion from the base of tree trunks at different positions to find out where the proper point of injection should be located. It revealed that water insertion in the tree trunk during dry season of certain type of tree has the higher rate of absorbtion. Thus, it is suggested that insertion should be made in different directions on the same tree. In addition, root anatomy and root characteristics have been worked out for twelve species at the Forestry Laboratory, Kasetsart University.

## APPENDIX

## LIST OF PROFESSIONAL PERSONNEL CLOSELY ASSOCIATED WITH COOPERATIVE RESEARCH PROGRAMME NO. 27 (TREND) DURING REPORTING PERIOD

1. Administrative and overall direction

| | | |
|---|---|---|
| Research Director-General, Environmental and Ecological Research Institute, ASRCT | *(1) | (Vacant) |
| NLABS Project Manager | | George Immisch, M.S. (Illinois) succeeded by George Simmons Rubin de la Borbolla, B.S., M.S. (Western Michigan) |
| NLABS Deputy Project Manager | | Robert Fegley, B.S. (Florida) |
| Project Coordinator | +(6) | Pramual Unhanand, B.Sc., M.F. (Michigan) |
| Administrative Officer, EERI, ASRCT | +(1) | Mr. Sern Mungkandi |
| Manager, Sakaerat Experiment Station, EERI, ASRCT | *(1) | Thuan Komkris, B.Sc. (Philippines) |
| Manager of Technical Services, ASRCT | (1) | G/C Sorn Satrabhaya, B.S.C.E. (Philippines); succeeded by AVM. Pramote Cheuynak, B.Eng. (Chulalongkorn) |

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(1) ASRCT

(6) Royal Forest Department, Ministry of Agriculture

## 2. Meteorological studies

| | | |
|---|---|---|
| Research Officer | | Mr. Joseph Zabransky, B.S., M.S. (University of Wisconsin) |
| Cooperating Research Officer | +(2) | Capt. Kajit Buajitti, B.Sc. (Navy Academy), M.S. (Florida State), Ph.D. (New York) |
| Research Associate | *(1) | Mr. Manit Auvuchanonda, B.S., M.S. (Chulalongkorn) |
| Experimental Officer | *(1) | Somsakdi Supharatana, B.Sc. (Chulalongkorn) |
| Project Engineer | *(1) | Mr. Praput Muangmuensuk, M.Sc. (University of Osaka) |
| Cooperating Engineer | +(2) | Ensign Virawongse V. Bunnag, M.Sc. (Electrical Engineering) |
| Head of Electrotechnology Unit | +(1) | Capt. Prabhai Keonil, B.Sc. (RTAF Academy) |
| Technician, IRCC | *(1) | M/Sgt. Tada Nakawiweg Cert. PMEL (Lowry Air Force Base) |
| | *(1) | M/Sgt. Saneh Boonluam Cert. PMEL (Lowry Air Force Base) |
| | *(1) | M/Sgt. Wuthigrai Koneshalard Cert. PMEL (Lowry Air Force Base) |
| | *(1) | Sanan Sitdhijai, Diploma (Bangkok Technical Institute) |

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(1) ASRCT

(2) Department of Meteorology, Office of the Prime Minister

3. Hydrological studies

Nil

4. Soils studies

| | | |
|---|---|---|
| Cooperating Research Associate | +(3) | Pongpit Piyapongse, B.Sc. (Agr.) (Kasetsart), M.S. (Agr.), M.S. (Soils) (Oklahoma) |
| Experimental Officers | *(1) | Weera Sakultab, B.Sc. (Kasetsart) |
| | *(1) | Irb Kheoruenromne, B.Sc. (Kasetsart) |

5. Vegetation studies

| | | |
|---|---|---|
| Coordinator | +(6) | Pramual Unhanand, B.Sc., M.F. (Michigan) |
| Cooperating Research Officers | +(5) | Sanga Sabhasri, B.S., M.S. (Oregon State), Ph.D. (Washington) |
| | +(6) | Tem Smitinand, F.L.S. Ph.D. Hon. (Kasetsart) |
| Cooperating Research Associates | +(5) | Aht Boonnitee, B.Sc. (Agr.) (Kasetsart), M.S. (Oregon State) |
| | +(6) | Chumsri Chaiyanand, B.Sc. (Chulalongkorn), M.Sc. (Aberdeen) |

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(1) ASRCT

(3) Department of Rice, Ministry of Agriculture

(5) Kasetsart University

(6) Royal Forest Department, Ministry of Agriculture

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|---|---|---|
| | +(5) | Kasem Chunkeo, B.Sc. (For.) (Kasetsart), M.C. (Colorado State) |
| Experimental Officers | *(1) | Sally Reynolds, B.Sc., M.Sc. (Rangoon) |
| | *(1) | Thawatchai Santisuk, B.Sc. (For.) (Kasetsart) |
| Cooperating Experimental Officers | +(5) | Niwat Ruengpanich, B.Sc. (For.) (Kasetsart) |
| | +(5) | Sanit Aksornkoae, B.Sc. (For.) (Kasetsart) |
| | +(5) | Choompol Ngampongsai, B.Sc. (For.) (Kasetsart) |
| | +(5) | Panit Thaicharoen, B.Sc. (Agr.) (Kasetsart) |
| | +(6) | Anand Nalamphun, B.Sc. (For.) (Kasetsart) |
| | +(5) | Prabhand Koeysomboon, B.Sc. (Agr.) (Kasetsart) |
| | +(6) | Leena Phuphatanaphongse, B.Sc. (Chulalongkorn) |

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(1) ASRCT

(5) Kasetsart University

(6) Royal Forest Department, Ministry of Agriculture

| | | |
|---|---|---|
| Cooperating Experimental Officers | +(6) | Dhani Phanichapol, B.Sc. (For.) (Kasetsart), M.Sc. (Delhi) |
| | +(6) | Chamlong Pengkrai, B.Sc. (For.) (Kasetsart) |
| 6. Microbiological studies | | |
| Research Officers | *(1) | Sman Vardhanabhuti, M.E. (Chulalongkorn), Ph.D. (Duke) |
| | (1) | Malee Sundhagul, B.Sc. (Chulalongkorn), M.A. (Texas), Ph.D. (Illinois) |
| Research Associate | *(1) | Sriwan Chomchalow, B.Sc. (Agr.) (Kasetsart), M.S. (Illinois) |
| Experimental Officers | *(1) | Poonsook Atthasampunna, B.Sc. (Chulalongkorn), M.Sc. (Tennessee) |
| | (1) | Jiraporn Chouvalit, B.Sc. (Medical Sciences) |
| | (1) | Puangpen Smanmathurapoj, B.Sc. (Chulalongkorn) |
| | *(1) | Bermin Weilbacher, B.Sc. (Hawaii) |
| | *(1) | Chaiyuth Klinsukont, B.Sc. (Chulalongkorn) |
| | *(1) | Wanchern Potarcharoen, B.Sc. (Agr.) (Kasetsart) |

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(1) ASRCT

(6) Royal Forest Department, Ministry of Agriculture

7. Faunal studies

| | | |
|---|---|---|
| Research Officer | (1) | Prasert Lohavanijaya, B.Sc. (Chulalongkorn), M.S., Ph.D. (New Hampshire) |
| Experimental Officers | (1) | Kitti Thonglongya, B.Sc. (Chulalongkorn) |
| | *(1) | Noel Kobayashi, B.S. (Redlands) |
| | (1) | Lakkhana Boonliang, B.Sc. (Chulalongkorn) |
| | (1) | Sukhum Pongpipatna, B.Sc. (Chulalongkorn) |
| | (1) | Supachai Sittilerd, B.Sc. (Chulalongkorn) |
| | (1) | Sunee Krutanuj, B.Sc. (Chulalongkorn) |

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