A few decades ago the influence of forests on local climate and water resources was a subject of speculation and controversy rather than one of objective scientific discussion. The burden of the proof was with those who believed that forests exert a significant influence on climate and streamflow. Today there is ample experimental evidence that forests do exert such an influence. The burden of the proof now lies with those who maintain that forests have little or no effect on basic resources. The name of H. Burger has an eminent place among those pioneers who have endeavored through research procedure to establish the subject of forest influences and practical watershed management on a more scientific basis.

What has happened during the past few decades is not that the important facts relating to forest influences have all been discovered and catalogued. On the contrary, probably many more reasonable questions can be raised today than ever before. What has taken place is that now the different aspects of forest influences can be more clearly defined and discussed. One phase of forest influences, that of practical watershed management, has achieved a status as a field of applied science. This has come about by the interpretation of experimental data and the acceptance of proven facts as a basis for logical deductions and a clear exchange of ideas.

The present paper is an attempt to give a few examples of accepted concepts on forest influences in different parts of the world, particularly practices that are not generally well known. It is to be expected that the applications of forest influences will vary from country to country, and sometimes within a country if there exists a wide climatic or physiographic difference. For example, in the Mersin Province of Turkey, the Forestry Department has planted large areas to Eucalyptus, one object being to dry out land too wet for the production of cotton.

Another large sand dune area near the Mediterranean coast in Southern Turkey has been planted to trees for the purpose of stabilizing the surface and holding the dunes in their present position. In the mountainous regions, heavy cutting of the indigenous trees followed by unregulated grazing on steep slopes, has created flood source areas that endanger the citrus groves below. Here there is an attempt to regenerate forests and build back the soil to favor hydrologic processes leading to the infiltration and storage of rain water. Thus in Turkey practical application of forest influences are in progress to dry out wet areas, to control sand dunes and to build back mountain soil to regulate streamflow. There is no question in the minds of the local land managers that all of these practices are effective for their different purposes. These simple examples are only a few of the long list that could be compiled, showing how the concepts of forest influences are being applied in broad programs for better land utilization.

"Mitteilungen der Schweizerischen Anstalt für das forstliche Versuchswesen, Bd. 35, Heft 1"
One aspect of forest influences on which there is world wide agreement is the effect of trees in improving the local climate. The term "local climate" as used here, refers to those elements of the overall general climate, such as wind velocity, evaporation, temperature and rainfall, as these are modified locally by vegetation, altitude, topography, direction of exposure, etc. The term "microclimate" has sometimes also been used in this same sense, but the present writer prefers to restrict "microclimate" to the minute climatic environment of the underside of a leaf, or the north side of a tree trunk, where very minor differences in environment can be of major importance in the life of small organisms.

In the Union of South Africa, which is within the temperate zone, extensive afforestation over a period of fifty years on the sandy Cape Flats near Cape Town, has so effectively controlled the wind movements and improved growing conditions that a part of the once critical area can now be used for the production of garden produces and small fruits. The principal factual data available is simply that gardens can now be grown where definitely they were once impossible because of wind and shifting sand. However, this example of creating a productive land area by planting trees, is on a relatively small scale when compared with the extensive utilization of coastal sand dune strips in Japan. Here a very large population thrives on land created from coastal sand dunes. This practice of sand dune stabilization using tree wind breaks has been carried out in the Southern Honshu Prefectures for many centuries. In the Nigata Prefecture and elsewhere on the west coast of Honshu, the capture of dunes for cropland is still very active and can be observed in all the various stages from drifting dunes to well-established fields surrounded by thrifty tree windbreaks.

It is true that tremendous labor effort is expended to build up the soil, but this could not have been done without the modification of the local climate by planting the trees. In this example there are no continuous climatic measurements to demonstrate exactly what effect the trees have exerted on the local climate. From the practical point of view of the Japanese farmers, no such measurements are needed.

Many other countries also have successful examples of sand dune control by tree planting, but none has made use of the reclaimed dunes for cropland to the extent that this has been done in Japan.

In any discussion of the applications of forest influences modifying the local climate mention must be made to the use of trees surrounding tea paddocks for control of mist and to the use of high overstory of trees for both tea and coffee, as well as other special crops. Such practices have been of long established usage where these crops are grown and are applicable particularly to moist higher altitudes of the tropics and subtropics. Detailed continuous measurements demonstrating the actual effects of the trees are not available, but this practical application of forest influences has universal acceptance.

In direct contrast to the general agreement as to the effect of trees on the local climate, there is a wide diversity of opinion as to the effects of trees on streamflow from small catchments. The difference of opinions is understandable because the specific effect of trees on streamflow can be both beneficial or detrimental, and both effects can be operating at the same time, depending on the climate, soil, topography, geology, sea
son of the year and other considerations. This apparent paradox is easily clarified by simply taking into consideration only one water cycle component at a time.

There is experimental data that demonstrates that trees are imperative to the production of high quality and quantity of usable water from small drainage basins. There is also evidence that trees will dry up streamflow from small catchments. Examples of trees drying up streamflow are reported in the sub-tropical regions with a continental climate, such as is found in the Transvaal and adjoining regions. Here, with 20-25 inches of rainfall, the natural vegetation is short grass and scrub thorn with a few broad leaf trees in the depressions near water courses. Under these conditions the establishment of tree plantations on the drainage of a weakly flowing stream or spring head can be expected to dry up the flow after a few years. The flow returns again after the trees are cut. In this case the trees simply use more moisture than the present climate affords, while the native grasses and thorn scrub are practically dormant a good part of the year and operate on a lower water economy. Under other situations such as a coastal zone subject to moist monsoons the planting of trees even with the same rainfall could be expected to have other effects.

It is obvious that trees use water for their growth, but at the same time, throughout most of the world, forestry is considered to be an integral part of catchment management.

The modern concept of managing forested catchments is to take advantage of all the recognised beneficial effects of the forest in maintaining soil conditions for infiltration and storage of rainfall, and at the same time to reduce transpiration losses by judicious harvesting of forest products. This is done by directing silvicultural practices toward water production.

Similar experiments carried out in both Northwest Japan and in the Appalachian mountains of the Southeastern United States have shown that the complete cutting of the dense hardwood forest without disturbing the natural forest soil has resulted in considerable increase in streamflow. As the tree growth returns, the annual increase in streamflow drops off, but it is still a significant amount fifteen years after cutting. In both localities there is no serious field moisture deficiency and the soils are quite permeable though not deep, except at the lower slopes and along drainage channels. The amount of streamflow increase that would result from cutting a similar forest catchment but under different soil and climatic conditions, would have to be estimated for each situation.

In addition to directing silvicultural practices to the interests of water production, other alternatives in catchment management have been put to practical use. One of these is the complete change from forest to grassland. However, it must not be assumed that all types of grass will transpire less water than trees. In any case, to carry out the practice successfully within a natural forest region presents major difficulties of maintenance.

Centuries ago, the Japanese were obliged by necessity to solve the problem of replacing forest by grass on steep slopes. Because of the great scarcity of level land for rice paddies, all the organic manures for mixing into the soil and all forage for livestock had
to be produced on steep mountain slopes originally covered by dense forest. Today these grassed slopes, particularly in Southern Honshu, extend to the tops of exceedingly steep mountain ranges, and some slopes have been in grass for 400 years, probably even longer. At a distance these grassed slopes appear to be potential erosion and flood source areas, but on closer inspection there is no active erosion. The reason is that livestock is not permitted on the slopes. The forage, which is mainly coarse Miscanthus grass, is all carefully cut by hand and rolled down the slopes in loosely tied bales. It is then transported by carts, or on the backs of donkeys, or carried by the farmers themselves along established paths and roadways. It was learned long ago that by preventing trampling by livestock, and by handcutting the herbaceous cover, there was no surface storm water or soil erosion. The real secret here is the large amount of hand labour available to carry out the bi-annual cutting operations. In most temperate climates the labor costs in keeping steep slopes in grass and preventing the invasion of woody species, would probably be prohibitive. The fact remains, however, that the Japanese have learned to maintain satisfactory watershed conditions on steep mountain slopes by keeping them in dense grass which is cut by hand, and by eliminating trampling and grazing by livestock.

In many other countries grass is also maintained on steep slopes but wherever overtrampling or overgrazing occurs, watershed conditions have deteriorated rapidly. The Japanese mountain grasslands on the other hand appear to have remained effective for water control, and constitute a unique type of catchment management in a natural forest region.

Another interesting example of unusual watershed management is being carried out in the highlands of Kenya, British East Africa. Here, dense stands of bamboo are being cut down and replaced by pine. This procedure is based on the results of soil moisture studies which showed that the bamboo required more water than the pine plantations. In addition, the land is cultivated for potatoes and cabbages for two years between the rows of young trees. Thus part of the drainage area operates each year with reduced transpiration which increases the total water capital from which ground water recharge can draw on.

Still another application of the same general concept of reducing transpiration from a forested drainage is seen in the Cape Province of the Union of South Africa. Here 60 foot strips adjoining all drainage channels are left bare of trees, the reason being that riparian trees are thought to transpire proportionally more water (figure 1).

Probably the most extreme type of catchment management practised today can be seen as one sails past Gibraltar. On the sloping rock faces behind the city lie sizable completely cemented catchments, from which in theory all the rainfall is led immediately to protected reservoirs. Completely sealed catchments are practical only in special situations. They are employed in the Mediterranean region and the Near East, in Australia and some tropical coastal regions of low rainfall. In some instances, as at Gibraltar, the purpose of the sealed catchment is to collect storm water and lead it to the reservoir before it is lost in rock fissures. In general, however, the idea back of sealed catchments is to reduce water losses through evaporation and transpiration.
Strips along drainage channels are not reafforested to reduce water losses by transpiration

(Photo H. B. Rycroft)
The above examples show that in the application of forest influences to municipal watershed management, there is no one formula that has universal application. In some instances the maximum quantity of water is of less importance than the available supply during only a few months of the year. Whether or not large impounding reservoirs are available can also determine the direction of watershed management. Similarly, whether precipitation occurs mainly as snow or rain can be the determining issue. Thus the critical assignment in watershed management is to determine what is required of a specific catchment area and to devise a management formula that is most likely to produce desired results.

As we encounter more complex applications of forest influences to climate and water resources, additional questions will be raised as to the direction and extent of the influence exerted. Such questions, to be realistic, should be in terms of the several related sciences of climatology, hydrology and pedology. They should be directed towards a specific locality and should concern a specific forest influences effect, and should be expressed in terms of a single water cycle component. When questions are statet in this manner, it is possible to discuss them and give a reasonable answer, if it is known. In some cases certain tests must be carried out before an answer is given. For example, infiltration, water transmission, and water storage within the soil profile are not difficult to measure and are basic to solving many watershed management problems. Some questions on the other hand require more than simple tests such as given above. To answer such questions is of course the place of research today, for which the methodology and techniques have become well known through a sizable literature in many languages.

Additional forest influences research today probably should be directed more towards specific water cycle components and towards answering specific local questions. The general concepts of forest influences have already been reasonably well explored and as this paper has attempted to show, these general concepts are now being applied throughout the world.

Die Beeinflusung des Wasserregimes durch Wald
in weltweiter Anwendung

(Zusammenfassung)

Dieser Aufsatz weist darauf hin, wie durch die Forschung der letzten Dezennien unser Wissen um die Auswirkung des Waldes auf den Wasserhaushalt eines Gebietes auf eine wissenschaftliche Grundlage gestellt wurde. Als Früchte dieser Forschung werden zahlreiche Beispiele aus verschiedenen Kontinenten aufgeführt, wie die Drainierung vernässter Gebiete durch Eucalyptuskulturen, die Stabilisierung von Dünen durch Aufforstung, die Verbesserung des Lokalklimas durch Windschutzstreifen usw. Weitere Beispiele belegen, wie das Problem der Abflußregulierung und Wasserversorgung den lokalen Verhältnissen entsprechend grundsätzlich verschiedene Lösungen erfordert; je nach klimatischen und pedologischen Verhältnissen werden ganz verschiedene Eingriffe
in den Wald als zweckmäßig erachtet (Aufforstung, Durchforstung, Umwandlung oder Kahlschlag). Dementsprechend wird darauf hingewiesen, daß die künftige Erforschung dieser immer komplexer werdenden Probleme mehr spezifische Fragestellungen erfordert.

L’influence de la forêt sur le régime des eaux
à travers les continents

(Résumé)

Cette communication montre dans quelle mesure les recherches entreprises au cours des dernières décennies ont contribué à fournir une base scientifique au problème de l’influence de la forêt sur le régime des eaux. A l’aide de nombreux exemples puisés dans les principaux continents l’auteur montre les fruits de ces recherches, à savoir l’assainissement de sols saturés d’eau à l’aide de plantations d’eucalyptus, la stabilisation de dunes à l’aide de reboisement, l’amélioration locale du climat par l’établissement de rideaux-abri, etc. D’autres exemples prouvent combien le problème de la régularisation du régime des eaux et de l’approvisionnement en eau peut exiger de solutions différentes en fonction des conditions locales. Suivant la nature du sol ou du climat, on procédera soit à des reboisements, soit à des éclaircies ou des transformations de peuplements existants, voire même à leur enlèvement complet. L’auteur met l’accent sur la nécessité, dans les recherches futures à ce sujet, de poser le problème d’une façon toujours plus spécifique.

L’influenza del bosco sul regime idrico, nella sua
applicazione mondiale

(Riassunto)

Questo lavoro dimostra come, attraverso le ricerche degli ultimi decenni, le nostre conoscenze relative all’influenza del bosco sul regime idrico poggino su base scientifica. Frutti di queste indagini sono gli esempi elencati e rilevati in diversi continenti, come il prosciugamento di regioni paludose mediante colture di ecalipti, il consolidamento di dune mediante imboschimenti, il miglioramento del clima locale mediante strisce frangivento, etc. Altri esempi dimostrano come il problema della regolazione del deflusso e l’approvvigionamento in acqua richiedano soluzioni fondamentalmente diverse, secondo le condizioni locali; in base al clima e al terreno si deve ora imboschire, o rimboschire, ora trasformare, oppure financo abbattere il bosco esistente. Si accenna corrispondentemente al fatto che le ricerche future circa questo problema, che si fa sempre più complesso, implicano interrogativi specifici in misura maggiore.