Fig. II-11 GROUNDWATER RECHARGE AND DISCHARGE

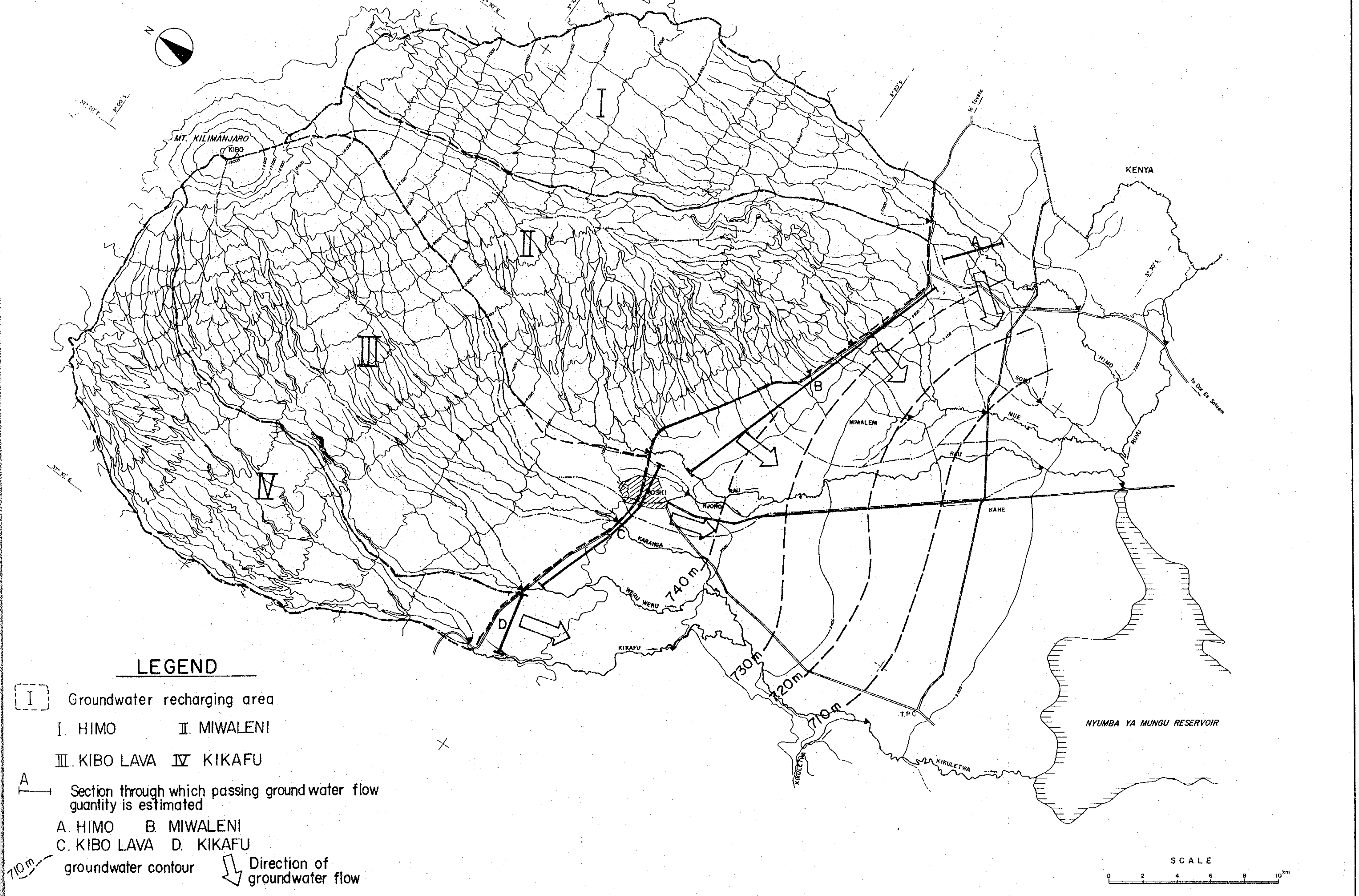


Fig. II-12 MAP OF WATER SAMPLES SITES

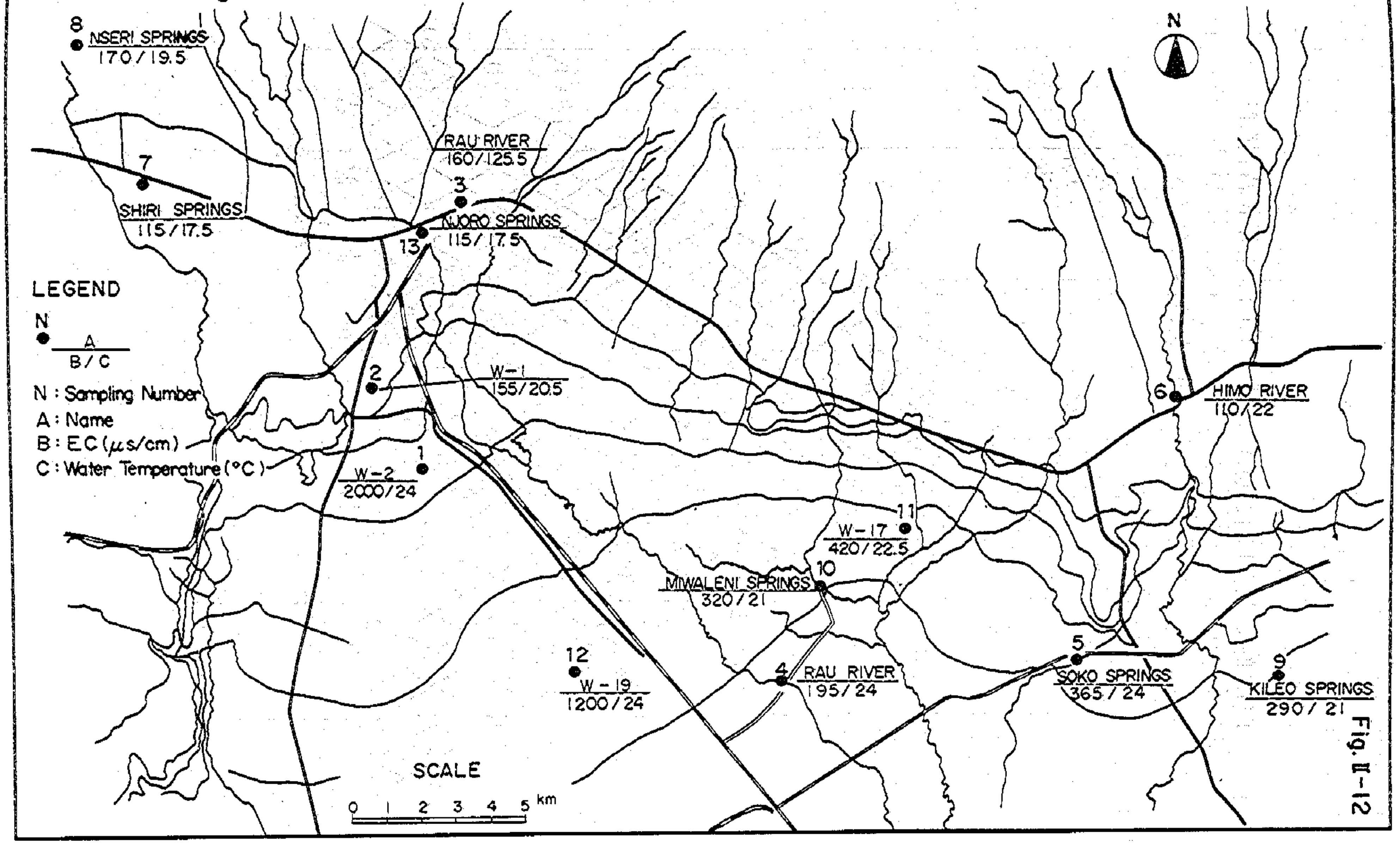


Fig. II-13 WATER QUALITY CLASSIFICATION

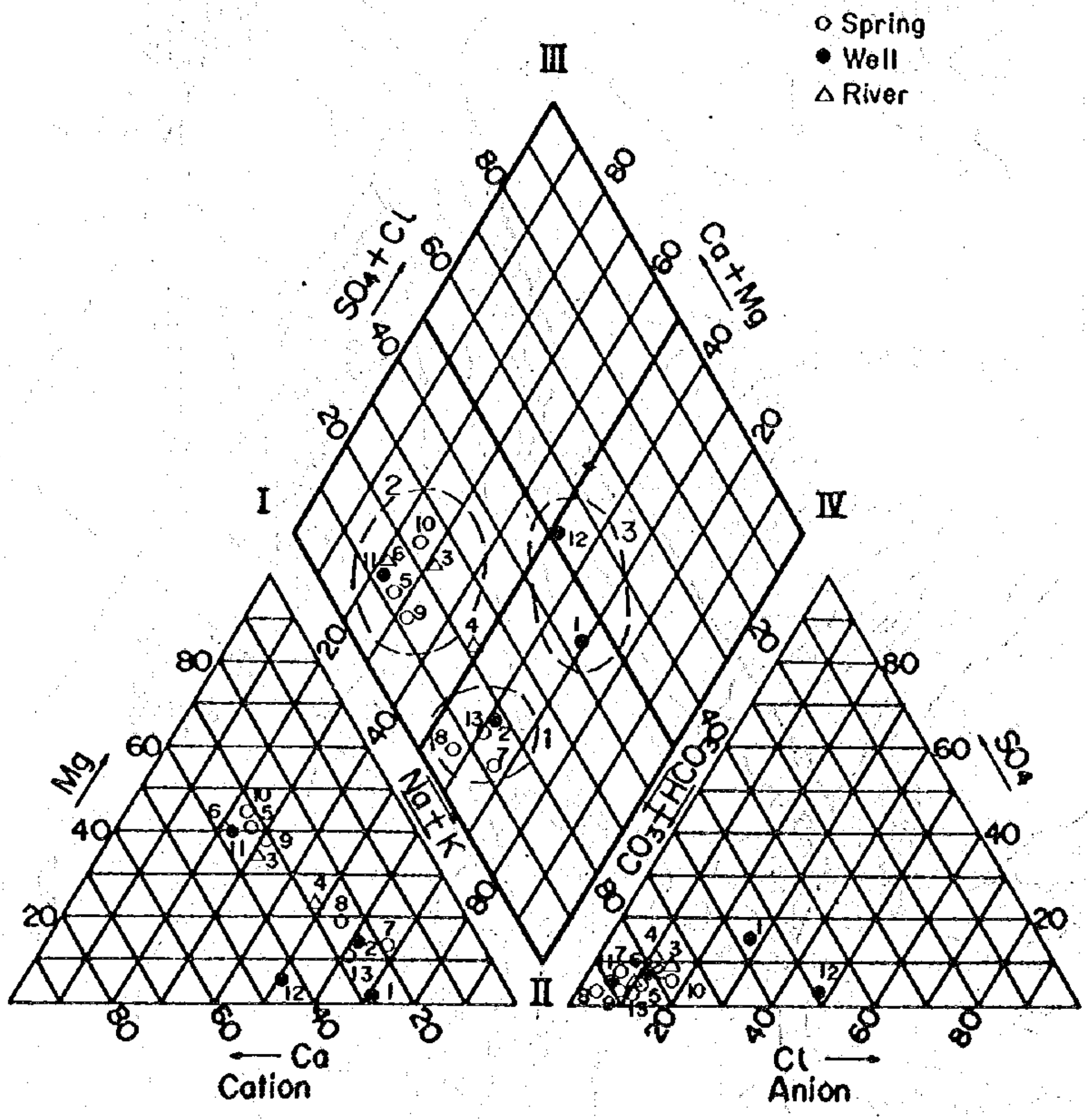


Fig. II-14 DIAGRAM FOR CLASSIFICATION OF IRRIGATION WATER

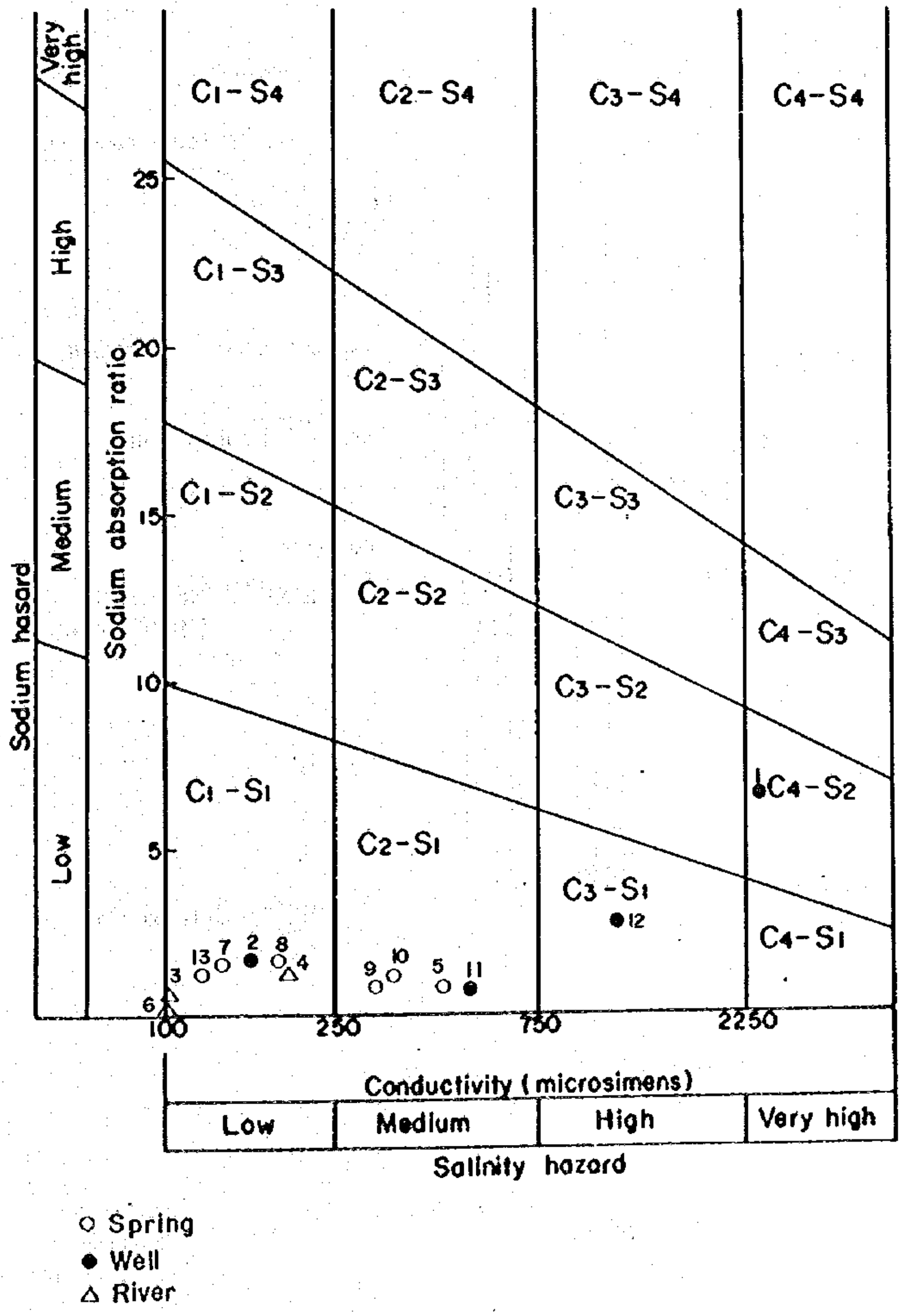
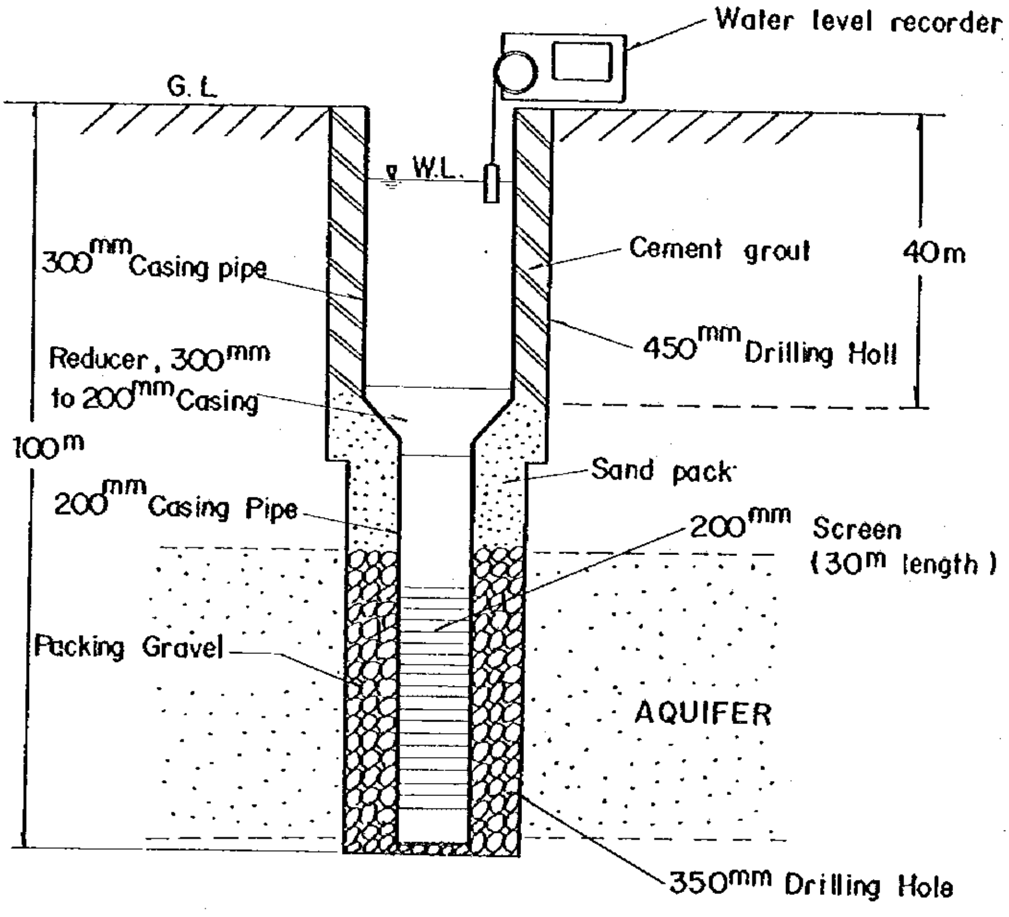


Fig. II-15 DESIGN OF TEST WELL



ANNEX III

SOIL AND LAND CLASSIFICATIONS

FEASIBILITY REPORT
ON
THE LOWER-MOSHI AGRICULTURAL DEVELOPMENT PROJECT

ANNEX III. SOIL AND LAND CLASSIFICATIONS

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ANNEX III

SOIL AND LAND SUITABILITY CLASSIFICATIONS

1. General

There are two references available for study on the soil and land suitability classification in the object area of the Lower-Moshi Agricultural Development Project. The primary soil investigation and study, covering approximately 27,000 ha of the Lower-Miwaleni and Kahe areas, were conducted in 1969 by the F.A.O. staff in conformity with "the Revised Seventh Approximation System" of the U.S. Department of Agriculture. In addition, the general reconnaissance soil survey, covering whole Kilimanjaro Region, was carried out in 1977 by the Study Team of Kilimanjaro Agricultural Development Project under the Japanese Technical Cooperation Programme, making reference to "the Soil Map of Africa" defined by D'Hoore, J., 1963. These previous soil investigations revealed that the land particularily in the lowlying area had scarcely any potential for agricultural development owing to the soil conditions strongly affected by salinity and alkalinity.

For the present feasibility study on the object Project, the previous soil studies are useful as the basic data and information, though a unification of soil classifications and confirmation of soil boundaries by detailed field survey is necessary. Thus, the present soil investigation primarily concentrates on confirmation of the soils particularily classified into saline and alkaline soils which were defined as the biggest limiting factor for the future development of the Lower-Moshi area. In the Kilimanjaro Region Integrated Development Plan (1977), the Project area was demarcated as approximately 4,000 ha. For comprehensive planning of a total agricultural development project, the present soil survey has been carried out on an area of about 42,000 ha, covering the whole Lower-Moshi area.

The soil profile survey and sampling were made by making exploratory pits and by the use of hand-auger. The profiles were examined to a depth of about 1.5 m or more and on an average density of one profile per 300 ha. In the profile examination, some 252 soil samples were collected from major horizons or layers. Additionally, about 7 groundwater samples were also taken at a representative shallow profile for chemical analysis. These soil and water samples were tested on their degree of salinity and alkalinity by the use of pH-meter and EC-meter at the field laboratory. Out of 252 soil samples, 45 representative samples selected based on results of field soil examination and they were sent to Tokyo for detailed chemical analyses.

Unification of the previous soil classifications and completion of the present soil mapping are herein presented, making reference to "The Soil Map of the World" defined by F.A.O/UNESCO, 1974. The land classification for the specific purpose of establishing the extent and degree of suitability of land for sustainable irrigation farming is made in conformity with the land classification system defined by the Bureau of Reclamation, U.S. Department of Interior in 1953 and modified in 1967.

2. General Conditions of Land and Soils

The Lower-Moshi area lies on the southeastern skirt of Mt. Kilimanjaro at altitudes between 700 m and 800 m above mean sea level. According to the zonal climate classification system by J. Papadakis, the area is characterized as "Semi-arid Monsoon Tierra Templada (Tt/Tp.c; mo)" as presented in detail in Table III-1.

From the geomorphological viewpoint, the land of the Lower-Moshi area is broadly divided into the following four categories of topography:

(1) Steep and stony Hills, which are tertiary volcanic land formations (volcanic cones), are patchily scattered over the north-easternmost part of the Lower-Moshi area and occupy about 3 % of the total acreages. The land generally consists of loamy to sandy skeletal (gravel and stony condition) soils, roughly covered with the Psammophytic vegetation. The land practically has no agricultural potential due to steep topography and unfavourable soils such as very shallow and gravel and/or stony.

(2) Colluvial Plain, having very gentle topography, lies on the foot of Mt. Kilimanjaro and occupies approximately 47 % of the total acreages. The land of this plain is dissected and/or eroded by the numerous gullies (seasonal rivers) and the lower most part of this plain is still classified as fan-formation. The land generally consists of fine textured colluvium transported directly from the Mt. Kilimanjaro.

Recently, almost all of the land has been developed as the agricultural land and cultivated with maize and to some small extent with cotton, beans, finger-millet, etc. mainly under rainfed conditions.

(3) Old Alluvial Plain, mainly extends over the south-eastern part of the Lower-Moshi area and it occupies about 33 % of the total acreages. The land generally consists of fine to medium textured old alluvium rather deeply deposited by the rivers Rau, Karanga, Mue, and Himo, and has nearly flat topography.

Almost half of this land category particularly the lowlying area in the southernmost part, is being seriously affected by salt accumulation in the surface soil due mainly to brackish shallow ground-water raised to the ground surface. Thus, the land of this area is, at present, barren of previous crop cultivation and mostly covered with the Hallophytic vegetation.

The other half of the land in this plain has been recently developed as the farm land with irrigation facilities (so-called traditional furrow) to its potential maximum, and farmers grow various kinds of crops, such as maize, cotton, beans, vegetables, paddy rice, sunflower, sesame, etc.

This land is mostly free from seasonal flooding and unfavourable saline and alkaline soil conditions.

(4) Recent Alluvial Plain, which is a narrow land mainly extending along the river Rau, Himo and Kileo, has very gengle topography including natural levees and slightly depressed land (seasonal marshes). The land generally consists of fine textured alluvium and partially of recent colluvium.

A seasonal flooding stands rather deeply for more than 120 consecutive days during the months from April to June in most areas, and for 160 consecutive days from early April to August in the alluvial depression.

Recently, the land of this plain has been gradually exploited as the agricultural land and farmers grow paddy rice, maize, and some small extent of cotton, beans, vegetables, etc. with the receeding of the seasonal flooding in the rainy season.

As broadly presented above, the soils in the Lower-Moshi area area are primarily derived from the clay to loamy alluvium and colluvium. These soil materials originate from volcanic production, such as ash and weathered tuff, and they are rather deeply deposited in most areas. These soil materials generally consist of about 35 to 50 % clay, 30 to 40 % silt fractions and in a few areas of about 30 % sandy particles.

The seasonal water stagnation has put the recent alluvium under the soil forming processes of hydromorphic weathering (i.e. gleization and mottlings) caused by the waterlogging and the seasonal fluctuation of shallow groundwater to a certain extent. Salinization of soils is also proceeded on this soil formation particularly in the lowlying area where the land lies an altitude at less than 705 m.

Most of the old allumium has been put under the soil forming processes with the oxidation weathering under the semi-arid monsoon tierra, templada climate, and cambic formation is being weakly developed in the rather shallow surface profile. With the exceptional soil formation other than the cambic formation, the old alluvium particularly deposited in the lowlying area at altitudes less than 705 m has been put under saline and alkaline soil forming processes which causes a raising of brackish shallow groundwater to the soil surface. The extent of these saline/alkaline soils is relatively wide and the degree of soil salinity and alkalinity is also increasing when compared with the previous conditions determined by FAO staff in 1969.

Colluvial deposits, which might be derived from the volcanic ash and weathered tuff, deeply overlie the volcanic sequences on the foot of Mt. Kilimanjaro. These soil materials have been put under the soil forming processes with the oxidation weathering under the semi-arid monsoon tierra templada climate, and some cambic soil formation is weakly developed in most of this colluvial plain. With the exception of the land in this colluvial plain at the eastern-most part of the Lower-Moshi area, the colluvium is rather shallowly underlain by the caliche layer (so-called petro-calcic layer) and calcic, saline as well as sodic soil formations have proceeded perfectly.

Other than the above soil formations, gravel and stony soils and/or outcrop are also found in small patches on the steep hills.

3. Soil Classification

3.1 Basic Considerations on Soil Classification

The present soil classification is made in conformity with "The Soil Map of the World" system compiled by F.A.O/UNESCO, 1974.

In reference to the F.A.O/UNESCO system, the following terms of soil features are particularly taken into consideration for this soil classification and mapping in the Lower-Mishi area.

(1) Parent materials and/or lithological materials:

- Recent alluvial deposits, generally having 35 to 40 % clay, 25 to 35 % silty fractions and 20 to 25 sandy particles (textural classes)

- Old alluvium, having 35 to 50 % clay, 15 to 30 % silty fractions and 30 to 40 % sandy particles (textural classes)

- Colluvium, which is generally consist of 25 to 45 % clay, 25 to 30% silty fractions and 20 to 30 % sandy particles (textural classes).

- Diluvium mainly from meta-morplice rocks in pre-combrian formation and/or from volcanic materials in tertiary formation (textural classes and stony phases)

(2) Lithological sequence in the specific soil depth (150 cm) of the profile:

- Out-crops or volcanic basement, i.e lava, taff, scoria layers underlies in shallow profile (lithic and stony phases)

- Groundwater formation in shallow profile (phreatic phase)

- Petro-calcic and/or Petro-ferric formation in shallow profile (petero-calcic or petro-ferric phases)

(3) Basic soil formation:

- Hydromorphic weathering such as leaching process of inherent basis, salinization/alkalinization process, and gleization and mottling caused by seasonal groundwater fluctuation and/or water logging in certain period. (Dystric, Entric, and/or Gleyic in unit factor, saline/sodic phase, etc.)

- Oxidation weathering such as laterization, formation of oxidic concretions, etc. (petric phase)

(4) Diagnostic profile features and soil chemical and physical properties:

- Surface horizon in which soil have different soil colour (mainly defined as ochric, umbic and mollic horizon), and humus contents (somewhat defined as humic horizon), and gravelly or stony regimes.
- Sub-surface horizon or layer lying within 150 cm below the ground surface in which the soils have shallow groundwater table, or gleyic horizon, calcic horizon, petro or petric horizon, eto.

In order to make the unification of the previous soil classifications made by F.A.O.(1969) and Japanese Teams (1977), the terms of the above soil features are carefully studied by cross-checking survey on both field and laboratory tests, also making reference to the previous field data and the results of soil tests.

3.2 Soil Classification

Upon the bases of the diagnostic soil characteristics and the profile features, the soils in the Lower-Moshi area are primarily classified into Lithsols, Regosols, Fluvisols, Gleysols, Nitosols and Cambisols in the highest category in the soil classification of the FAO/UNESCO system. Among them, Lithosols developed on the small volcanic cones scattered in the north-eastern most of the Lower-Moshi area. Regosols are the recent colluvial soils developed only in the narrow area on the foot of volcanic cones presented in the above. Fluvisols, which are generally referred to as the recent alluvial soils, extend narrowly along the rivers. Gleysols developed mainly on the narrow alluvial depression (old river trails) in the recent alluvial plain. Nitosols are the alkaline soils which developed mainly on the lowlying area extending over the lower-reaches of the Rau, Mue, Himo and Rufu rivers. Cambisols are primarily derived from the colluvium and old alluvium deeply deposited under the fan formation and are the most predominant soils in the Lower-Moshi area.

The soils of both Lithosols and Regosols are respectively correlated with the Typic sub-unit and the Typic phase.

The soils of Fluvisols are correlated with Entric Fluvisols and further classified into Typic and Sodic/saline phase categories.

The soils defined as Gleysols are classified into three subunits, i.e. Eutric Gleysols, Mollic Gleysols and Humic Gleysols. Of them, Eutric Gleysols are further classified into Typic, Petro-ferric and Saline soil phase in the lower category of this classification. The soils of other Gleysols are respectively correlated with Saline soil phase.

The soils defined as Cambisols are classified into five soil units such as Dystric Cambisols, Eutric Cambisols, Calcic Cambisols, Gleyic Cambisols and Vertic Cambisols. Among five soils, Calcic Cambisols have three phase, i.e. Petro-calcic, Stony/saline, and Petric/saline Calcic Cambisols. Vertic Cambisols are classified into Typic and Stony Vertic Cambisols soil phase. The soils of other Cambisols consist of one soil phase, namely, respectively correlating with Phreatic Dystric Cambisols, Phreatic/saline Eutric Cambisols and Petric/saline Gleyic Cambisols.

The correlation with the soil classes defined in the above are summarized in Table III-2, and the development of the soils classified herein above is illustrated on the semi-detailed soil map attached to this report.

4. Principal Natures and Properties of Soils

As stated in the Preceding Section 4.3, it is clarified that the soils in the survey area can be primarily classified into 6 major soil units, 14 soil sub-units and 21 soil phases. In due consideration of the soil use for agricultural production and also of the soil suitability for irrigation development, the principal natures and properties of each soil unit are explained in detail as follows:

4,1 Lithosols

Mapping unit (1): Lithosols major soil unit, Types Lithosols sub-unit.

The soils of Lithosols develop only on the narrow area of volcanic cones in the tertiary formation and steep hills in the pre-cambrian formation. The land of this soil unit extends over about 950 ha, corresponding to about 2.3 % of the total survey area.

The soils are derived from loamy to sandy diluvium originating from volcanic rocks and metamorphic rocks.

The soils herein classified into Lithosols are also identified with Lithosols in the previous soil studies. The main factor to identify the soils to Lithosols is that the soils have no diagnostic profile features except stony or gravel conditions and shallow soil depth limited by base-rocks.

Generally, the soils of Lithosols have Au/R horizon sequence. Au horizon having reddish brown (2.4 YR 5/4) soil colour is thin at less than 25 cm and sometimes absent in the profile because of heavy out-washing by rain water due to very scanty vegetation. R horizon is the basement i.e. lava, unweathered tuff, scoria and/or metamorphic rocks as biotitegneiss.

Regarding the soil chemical properties, the soils are slightly acid to almost neutral ranging between 6.75 to 7.20 in pH (1:2.5) value and ECe values are mostly less than 0.2 m.mho/cm/25°C, indicating that they have no salinity and alkalinity problems.

In the light of their profile features and topographic conditions, the soils of Lithosols are unsuitable for the agricultural utilization.

4.2 Regosols

Mapping unit (2): Regosols major soil unit, Dystric Regosols sub-unit, and Stony and/or lithic soil phase.

The soils of Dystric Regosols are primarily the sandy and loamy colluvium being deposited under the small fan formation. This soil unit is identified with Regosols intergraded to Reddish brown Orthird in the F.A.O. study and Lithosols in the KIDP study.

The soils of this soil unit develop only on the foot of volcanic corns or steep hills in the precambrian formation patches scattered in the Lower-Moshi area. The land of this soil extends only 250 ha, corresponding to about 0.6 % of the total survey area. At present, almost all of the land lies in waste without agricultural production but covered with sparse acacia shrub and short wild grasses.

The general horizon sequence of these soils is A1/A2/R, with practically no diagnostic features in the soil profile except fine stratification in the shallow profile. A1 horizon, is a surface soil having reddish brown (2.5 YR 5/4) soil colour, loamy to sandy texture qualities, and stony or petric (many course fragments) phase factor. A thickness of this horizon is 30 cm on average and the boundary with the next A2 horizon is diffuse and smooth in formation. A2 horizon is composed of course textured soil and have more stony conditions than the A1 horizon. A thickness of this horizon is rather wide ranging between 30 cm and 50 cm and then limitted by the basement volcanic rocks. The soils in both A1 and A2 horizons are generally compact, and massive in structure.

As for their chemical features, the soils have neutral to slightly alkaline conditions (pH 7.0 - 8.0), while at less than 0.3 m.mho/cm/25°C in ECe. Physical features of the soils are unfavorable for the profitable farming.

4.3 Fluvisols

Fluvisols are correlated with Eutric Fluvisols soil sub-unit and these soils are further classified into Typic (mapping unit (3) and saline/sodic mapping unit (4) soil phase.

The soils classified into Fluvisols are primarily the recent alluvium and/or recent colluvium deposited on a narrow riverine depression. In the previous soil study, these soils were identified with Haplorthent in soil classification (U.S.D.A. system).

Generally, the soils have no diagnostic profile features, except very few and week mottling formation in the shallow profile. The typical horizon sequence is A1/A2/C and total profile depth is deeper than 200 cm. A1 horizon is the surface soils having 25 cm thickness; brownish black (5 YR 2/2) colour; and clay to silty clay texture; medium size and weak sub-angular blocky structures; friable when wet and slightly hard consistence when dry; gradual and smooth boundary with underlying A2 horizon. A2 horizon is a soil having a depth of 50 - 60 cm; brownish black (7.5 YR 3/2) color; clay to silty clay texture; about 10 to 25% fine gravels; coarse and rather strong blocky structures; friable when wet, while hard consistency when dry; diffuse and smooth boundary with the next C horizon. C horizon is a dark brown soil having the features such as dull to dark brown (7.5 YR 3/4) matrix colour, silty clay to clay texture; massive structure; moist condition even in the most dry season.

No clear differences on the profile features are found between Typic phase (3) and Saline/Sodic phase (4) of these Eutric Fluvisols. The soils of both phases are distinguished by different percentages of their chemical properties, particularly of salinity and alkalinity. Namely, the Typic phase is a slightly alkaline soil having 7.5 to 8.0 in pH values and less than 0.3 m.mho/cm/25°C ECe throughout the profile, while strong to extremely strong saline and alkaline soils have pH 9.0 - 10.0 and ECe values more than 8 m.mhos/cm/25°C in Saline/Sodic phase. General properties of both soils are shown in Table III-3.

In the light of the soil nature and properties, and environmenta conditions of this soil area, the soils of Typic phase in Eutric Fluvisols are suitable for agricultural use. However, flood control and/or drainage improvement are indispensable for future land utilization. In contrast, the soils of Saline/Sodic phase are scarcely very suitable for profitable agricultural development.

4.4 Gleysols

The soils of this soil unit also develop rather narrowly over the depression in the recent alluvial plain where seasonal flooding stands rather deeply for more than 160 consecutive days during the months from April to August and the groundwater table stands relatively shallow throughout the year. The area of this soil unit extends approximately 3,970 ha, corresponding to about 9.4 % of the whole Lower-Moshi area. The soils have diagnostic profile features resulting from hydromorphic weatherings, i.e. gleization and mottlings. This soil unit is further correlated with humic Gleysols, Mollic Gleysols and Eutric Gleysols soil sub-units. Among them, the soils of Mollic and Eutric Gleysols are now cultivated with paddy rice and maize. The soils of Humic Gleysols still lie in waste due to deep flooding and high soil salinity.

4.4.1 Humic Gleysols

Mapping unit (5): Saline, Humic Gleysols soil phase.

The soils of Humic Gleysols are distinguished from other Gleysols by profile features having humic horizon and a strong saline factor. In the previous soil study, the soils are correlated with Hydromorphic Gley soils in papyrus swamps.

The soils classified into this Humic Gleysols develop only on the lowlying marshes along the Kileo river and Rufu river (easternmost of the Lower-Moshi area). Generally, these soils are mostly wet throughout the year. Typical soil horizon sequence is A/Cr and the profile depth is shallowly limited by the groundwater to only 30 cm from the ground-surface even in the dry season. A horizon (20 cm) is a humic soil having glayish black colour; very fine clay texture; massive structure; firm consistence; more than 7 % of organic carbon; 8.0 - 8.5 pH values; 10 - 15 m.mhos/cm/25°C ECe; and clear and smooth boundary with the next Cr horizon. Cr horizon is a gleyic soil having clay to silty clay texture, low organic carbon (less than 0.5 %); 8.0 - 8.5 pH values; 8 - 10 m.mhos/cm/25°C ECe.

In regard to the physical properties, the soils have relatively high moisture holding capacity, with very slow permeability coefficients ranging from $3.5 \times 10^{-5} \times 8.5 \times 10^{-6}$ cm/sec.

In the light of the soil features and environmental conditions of this soil area, it is considered that the soils of this soil unit are economically unsuitable for agricultural development.

4.4.2 Mollic Gleysols

Mapping unit (6): Saline, Mollic Gleysols soil phase.

The soils of this unit develop mainly on narrow depressions (old river trials) mainly along the Rau and Kileo rivers. These soils have a thick mollic horizon at the soil surface and a mottled horizon at relatively shallow profile in sub-soil. The soils are slightly affected by salinity. In the previous soil study, the soils are classified into Gleic Orthid and/or Low-humic-Hydromorphic Gley soils.

Thesoils have a horizon sequence of A(p)/Bg/Cr in general, and the groundwater table fluctuates seasonally,but relatively deeply, at 150 - 200 cm in the dry season. A(p) horizon (25 cm) is a mollic soil having brownish black (7.5 YR 2/1) color; clay to silty clay texture; weak sub-angular blocky structures; friable when wet while hard consistency when dry; gradual and smooth boundary. Bg horizon is mostly the mottled soils having dark brown (10 YR 3/3) matric colour and many, fine, distinct reddish brown (10 YR 5/4) ferriginous mottling; silty clay to fine loam texture; coarse and strong blocky structures; friable when wet while very hard consistency when dry; diffuse and smooth boundary. Cr horizon is grey soil (7.5 YR 4/2) color which are put under strong reductive conditions with the seasonal groundwater fluctuation.

These gleyic soils generally have clay to silty clay texture; massive structures and a profile depth deeper than 200 cm. In a few cases, about 30 - 50 cm thickness of fine gravel layer intercalates in this Cr horizon at depths below 140 cm.

The soils show a strong alkaline reaction ranging between pH 8.5 and 9.0 throughout the profile, while their sodium adsorption ratio (SAR) and exchangeable sodium percent (ESP) are quite low at 0.3 - 0.5 and 4.0 - 10.0, respectively. Organic carbon is about 0.5 - 2.0 % in the surface soil but abruptly decrease to less than 0.5 % in the sub-soils. Cation exchangeable capacity is rather variable from 10 to 30 m.eq. in both surface and sub-soils. The degree of base saturation is estimated at 150 - 160 % in the surface soil, while more than 200 % in the sub-soils.

Among the bases, calcium carbonate is dominant (more than 50 % of the total bases). Groundwater qualities are relatively strongly saline ranging from 2.0 to 5.0 m.mhos/cm/25°C.

As regard their physical nature, the moisture holding capacity of these soils is as high as 45 - 50 % of the bulk dry solid while the low permeability coefficient of the sub-soil layer ranges between 5.0 x 10^{-4} and 5.0 x 10^{-5} cm/sec.

Taking into account the soil features above, these soils are suitable for paddy rice cultivation, though a rather high capital investment will be required for flood protection or drainage improvement. To realize the optimum production of upland crops, both surface and internal drainage improvement are in dispensable in this soil area. Besides, proper soil amendment, particularly for moderation of soil salinity, is required throughout the period of sustainable farming.

4.4.3 Eutric Gleysols

Mapping unit (7): Typic Eutric Gleysols,

" (8): Petro-ferric Eutric Gleysols,

" (9): Saline Eutric Gleysols.

The soils of this soil unit develop mainly on the lowlying area extending over along the upper-reaches Rau river. The soils have three soil phases as presented above. They are distinguished from each other by their specific profile features and salinity degrees. Petro-ferric soils (8) are the shallow Eutric Gleysols having a thick ferriginous hard pan within 50 cm of the surface profile. Saline soils (9) have the same profile features with the Typic soil (7), but are strongly affected by salinity similar to the Mollic Gleysols (6) presented in the preceding paragraph.

Generally, the horizon sequence of Typic soils is almost same as the soils of Mollic Gleysols. The major differences from Mollic Gleysols are that the soils have an ochric horizon in the surface profile and finer texture qualities.

Al horizon with about 25 cm thickness consists of very low humic soils having dark reddish brown (5 YR 2/3) color; clay texture; weak subangular blocky structures; very friable when wet and slightly hard consistency when dry; gradual and smooth boundary formation. Bg horizon (25 - 110 cm) is the mottled soil having grayish brown (5 YR 5/6) matrix colour and many, fine to coarse ferriginous mottlings (10 YR 3/5); clay texture;mmassive to very coarse and strong blocky structures; friable when wet but hard consistence when dry; diffuse and smooth boundary. Cr horizon (below 110 cm) is gleyic soil having grayish brown (7.5 YR 4/2) color clay texture; massive structures; and some yellowish brown mottlings

In case of the Petro-ferric soils (8), the profile sequence is commonly A/Bms/Cr. The characteristics of A horizon is same as Typic soils. Bms horizon is a ferriginous hard pan which is formed by sesquioxide accumulation (m) and cementation(s) under shallow fluctuation of groundwater. The thickness of this Bms horizon varies from 25 cm to 50 cm and penetration of roots is completely restricted by this horizon. Formation and characteristics of Cr horizon are almost same as that of the Typic soils.

Regarding the chemical properties of these soils, the surface soil has less than 0.5 % organic carbon; 8.0 to 8.5 pH values; 15 to 20 m.eq. cation exchange capacity. In case of the Typic soils and Petro-ferric soils, EC values are very low, less than 1.0 m.mho/cm/25°C, indicating it is quite free from the salinity, although base saturation is more than 100 % of the cation exchange capacity. In contrast, the salinity in Saline, Eutric Gleysols is indicated by high ECe value of more than 8 m.mhos/cm/25°C and base saturation more than 150 %.

The sub-soils have quite small amounts of organic matter, 8.5 pH value on average; 20 to 25 m.eq. cation exchange capacity (C.E.C.); more than 100 % base saturation; less than 2.0 m. mohs/cm/25°C EC, except Saline soils. The sub-soils of Saline Eutric Gleysols have base saturation of more than 150 % of C.E.C; 8.0 to 10 m.mhos/cm/25°C EC values, indicating a high degree of salinity constraint.

As for the hydrodynamic characteristics, these soils have high moisture holding capacity ranging from 50 to 55 % of the bulk dry solid, and a low permeability coefficient of $2.5 \times 10^{-4} - 5.0 \times 10^{-5}$cm/sec.

In the light of the soil conditions above, the soils of Typic and Saline, Eutric Gleysols are quite suitable for paddy cultivation, while marginally suitable for profitable farming with upland crops due to their unfavorable physical nature. The soils of Petro-ferric, Eutric Gleysols are unsuitable for profitable farming due to shallow soil and high groundwater in the main crop season (rainy season).

4.5 Nitosols

Mapping unit (10): Sodic/Saline, Eutric Nitosols.

Nitosols herein classified are strong alkaline cum saline soils developed on the lowlying alluvial plain which widely extends over the lower-reaches of Rau, Mue, Himo and Rufu rivers. Total area of these soils are estimated at about 5,010 ha, corresponding to about 12% of the whole Lower-Moshi area.

In the previous study, these soils are considered Solonetzic, Reddish brown Orthids or Ustoll in U.S.D.A classification (the 7th Approximation system).

Generally, the soils have Anz/Bmn/Crz horizon sequence, and the brackish groundwater (more than 9 m.mohms/cm/25°C EC) stands at relatively shallow depth at 150 cm in the profile (dry season). Anz horizon with a thickness of 15 cm is a surface soil having brownish black (10 YR 2/2) to black (10 YR 1.7/1) color; silty clay to clay texture; rather coarse and strong sub-angular blocky structures; friable when wet but hard consistency when dry; gradual and irregular boundary with the next Bmh horizon. On the soil surface, small salt spots (mainly sodium carbamate) are found in Places. Bmn horizon with a thickness of 50 cm is an argillic B horizon weakly developed. The soils have dark raddish brown (2.5 YR 3/6) to Grayish brown (10 YR 4/2) colour; clay texture; massive structures; duffuse and smooth boundary. In some part of this profile, many small blackish alkali spots are formated under the proceeding alkalirization. Crz horizon to a depth of 200 cm is primarily grey soil. The soils are Dull yellowish brown (10 YR 5/3) to gray (7.5 YR 5/6) color; silty clay to sandy clay texture; massive structures; and moist.

Regarding their chemical properties, the surface soil shows extremely strong alkali reaction with pH values of 10 to 11.5. Cation exchange capacity (C.E.C.) of this soil ranges between 45 to 50 m.eq. and base saturation degree is more than 200% in which sodium ions occupy more than 90% (about 180 - 190% in exchangeable sodium percent: ESP). Sodium adsorption ratio (SAR) is estimated at about 30 to 35. Organic carbon in the soils is commonly less than 0.5%. The soil of Bmn horizon also has extremely high alkali ranging from 9.5 to 11.0; 50 to 55 m.eq. C.E.C; 150 to 180% base saturation; 100 to 150% ESP and 20 to 25 SAR. Generally, the soils of Crz horizon show a lower degree of alkalinity and salinity than that in the upper soils, but still in a strong class with 150 to 180% base saturation degree; 100 to 130% ESP and 19 to 23 SAR.

Permeability coefficient of the sub-soils is less than 5.0 x 10^{-5} cm/sec, indicating a salt leaching difficulty.

The land of this soil unit is covered with wild palms, thorn bushes and short grasses. Recently, some 70 ha of paddy field and 700 ha of upland field have been reclaimed by the local inhabitants.

However, the crop production is still insubstantial, and some of the land lies waste from the cropping, at present. According to the field monitoring of the soil modification experiment conducted by the Japanese soil expert in the Kirya Pilot Farm, 1977, it is forecast that economical utilization of Nitosols could not be realized for agricultural production, although some small effects were obtained by such technical practices as gypsum treatment for moderation of soil alkalinity and/or leaching of salts in soils. Thus, the soils of Nitosols are graded as unsuitable in this soil and land classification study.

4.6 Cambisols

The soils of Cambisols develop widely over the Lower-Moshi area. These soils are primarily the raddish brown colluvial and/or old alluvial soils developed under the soil forming processes of oxidation weathering. The area of these soils is approximately 28,500 ha, corresponding to about 68% of the whole Lower-Moshi area.

4.6.1 Dystric Cambisols

Mapping unit (13): Phreatic, Dystric Cambisols.

The soils are reddish brown and neutral or slightly acid Cambisols. The soils are derived from the old alluvium deposited mainly by Rau and Himo rivers. Base saturation degree ranges between 45 5o 50%, and calcium is the dominant base. The soils have a cambic B horizon weakly developed under the ochric surface horizon. To a certain extent, the soils have a paralithic contact or underlying thin gravel layer in the profile shallower than 200 cm below the surface. These soils were considered as Regosols intergraded to Reddish brown Orthid in the U.S.D.A. classification in the previous soil study in this area.

The land of this soil group has a very gentle slope of less than 1/250 and has mostly been cultivated with maize, cotton, pulses, etc. under rainfed conditions. Those agricultural productions are, however, small due to shortage of soil moisture and infertility of soils.

Generally, the soils have an ochric A(P) horizon in the surface profile. Thickness of this horizon is about 15 cm on average. The soils are dark reddish brown (2.5 YR 2/4) color; silty clay to clay texture; sub-angular blocky structures; friable when wet and rather hard consistency when dry. The second horizon to a depth of about 65 cm in a cambic B1 horizon. The soil in this horizon are dark reddish brown (2.5 YR 3/3 - 7.5 YR 3/4) colour; clay texture, in which a few fine gravels are included; sub-angular blocky to blocky structures; rather friable when wet and hard consistency when dry; firmly consolidated under the natural conditions. The soils gradually change to underlying B2 horizon with a smooth boundary. B2 horizon is commonly dull reddish brown (5 YR 3/4) to reddish brown (5 YR 4/5) color; clay to silty clay texture; massive to very coarse blocky structures; compact and rather firmly consolidated. Generally, C horizon or layer underlies the surface below 200 cm.

The C1 horizon directly underlying the B2 horizon is a gravel soil having clay loam to sandy clay matrix color and 50 to 60% small gravels. Groundwater stands deeper than 200 cm in the dry season, while it will rise to 150 cm in the rainy season.

As for chemical features, the soils are neutral to slightly acid ranging from 6.5 to 7.5 pH throughout the profile; less than 0.5% organic carbon; 5 to 7 m.eq water soluble salts; less than 1 m.mho/cm/25°C ECe; 15 to 25 m.eq cation exchange capacity; 45 to 50% base saturation degree; less than 0.5 sodium adsorption ratio and less than 2.0% exchangeable sodium percent.

In regard to physical nature, the soils consist of 35 to 50% clay and 15 to 30% silt and 30 to 40% sandy particles. Generally the soils have a high moisture holding capacity ranging from 35 to 50%, but a slow permeability coefficient ranging from 3.5×10^{-4} to 5.6×10^{-5} cm/sec in the sub-soil layer and a moderately high basic intake rate ranging between 45 and 50 mm/hr in the surface soils.

In the light of the soil features presented above, it is considered that the soils of this unit are very suitable for irrigation development and high production could be anticipated for both paddy and upland crops.

4.6.2 Eutric Cambisols

Mapping unit (14): Phreatic, saline/sodic, Eutric Cambisols.

The soils of this unit have quite similar profile and features to the former Dystric Cambisols. These soils are, however, distinguished only due to the chemical properties expressed in a base saturation degree higher than 50% of cation exchange capacity. In the Lower-Moshi area, these soils are mainly found on the old levee narrowly extended along the river trails of the Rau river. At present, the land of this soil area is used for village accommodation and is also used for upland cropping with maize and banana plantation to some extent.

In continuous hydromorphic cum oxidation weathering, the soil formation is proceeding with base accumulation, and at present, the soils are under alkaline conditions.

Generally, the surface soil is strong alkali ranging between 9.0 to 9.5 pH values which gradually decrease to 8.5 with depth. Cation exchange capacity ranges from 15 to 20 m.eq. and these are mostly saturated by bases. The base saturation degree (BSD) is estimated at about 80% to 130% in which amount of sodium is expressed as 50 to 60% of exchangeable sodium percent (ESP) and 3 to 5 sodium adsorption ratio (SAR). In the sub-soils, those degrees of BSD, ESP and SAR are rather lower than that of the surface soil. The quality of the groundwater is rather strongly saline ranging from 8 to 10 m.mhos/cm/25°C EC.

In consideration of the above soil features, the soils of this unit are usable for crop cultivation, though some constraints such as strong alkaline conditions, poor drainability will limit the productivity to some extent.

4.6.3 Calcic Cambisols

Mapping unit (16): Petro-calcic, Calcic Cambisols
(17): Stony and saline, Calcic Cambisols
(18): Petric and saline, Calcic Cambisols

Calcic Cambisols are soils having calcic hrizon within 100 cm of the surface profile. The calcic horizon herein defined has characteristics such as Petro-calcic contact (lime crust formation), calcareous contact (lime accumulation) and petric contact (lime concretionary formation).

At present, all the land of this soil unit still lie in waste from agricultural production, except use for village yards to small extent. Under the natural conditions, the soils generally have a horizon sequence of A/Bkw or Bcw/C with gradual boundary formation. A horizon to a depth of about 25 cm on average is a mineral soil which can be specified as ochric epipedon. The soils are brownish black or dark reddish brown (7.5 YR 3/2) colour; silty clay to clay texture. They have soft and friable consistency when wet while hard and firm consistency when dry. Bkw horizon to a depth of about 70 cm has cambic characteristics and is under lime accumulation soil forming process. Generally, the soil of this horizon is dark brown (10 YR 3/3) to dull reddish brown (7.5 YR 5/5) colour; clay to clay loam texture; sub-angular to weak blocky structures; soft and friable consistency when wet, while firm when dry. Many and fine powder-like lime spots are found in this horizon. C horizon is a soil that has cull brown (5 YR 5/4) to reddish brown (7.5 YR 6/3) colour; silty clay to fine loam texture; massive structures; friable when wet but hard and firm consistency when dry.

If the soils correlate with stony phase (17), the profile is characterized by many and large size gravel and lava fragements in the shallow profile. The soils of petric phase (18) are specified by Bck horizon having many fine lime concretions. Petrocalai phase (16) exist only to a small extent. The soils of this phase have a shallow profile bottomed by a lime crust with a thickness of about 30 cm. Under the lime crust, C horizon lies deeply.

With regard to their chemical properties, the soils show strong alkaline reactions ranging from 8.5 to 9.5 pH throughout the profile. Organic carbon is less than 0.5%. Cation exchange capacity (C.E.C) is 20 to 25 m.eq. and is saturated by bases of more than 200% in which calcium is the predominant base. ECe ranges between 8.5 and 15 m.mhos/cm/25°C, indicating that the soils are strongly affected by salinity.

In the light of the profile features and chemical properties, the soils are classified as marginally suitable for the profitable farming.

4.6.4 Gleyic Cambisols

Mapping unit (19): Petric and saline, Gleyic Cambisols

The soils of this unit are primarily the wet cambisols. They have gleyic horizon in shallow profile. Under soil gleization farming processes, concretions of sesquioxides develop in the gleyic horizon. A part of these soils might be intergraded to the Petroferric, Eutric Gleysols.

Generally, the soils have a diagnostic profile sequence of A/Bcs/Cr. A horizon to a depth of about 20 cm is mineral soil having very dark brown (5 YR 3/2) colour; clay texture; weak blocky structures; friable when wet, but hard consistency when dry; clear and smooth boundary with the next B horizon. Bcs horizon is a gleyic soil having grayish brown (2.5 YR 5/4) matrix colour; many coarse and distinct ferriginous matting; many and fine concretions of susquioxides; clay to silty clay texture; friable when wet but hard consistency when dry. Cr horizon is also the gleyic soil having gray (2.5 YR 5/6) colour; clay texture; massive structures.

Regarding their chemical features, the soils are strongly alkali ranged from 8.5 to 9.0 pH; 5 to 8.5 m.mhos/cm/25°C EC, indicating that the soils are slightly affected by salinity. Cation exchange capacity of these soils ranges between 15 and 20 m.eq. and the saturation degree of bases is estimated about 150% on average. Groundwater, which stands at the rather shallow depth of 150 cm in the dry season, is rather strong in salinity ranging from 5 to 9 m.mhos/cm/25°C.

In due consideration of the soil characteristics above, it is considered that the soils in this unit are usuable for paddy rice cultivation, but are not suitable for profitable farming with upland crops. To realize upland cropping, it is required to improve the drainage conditions particularly to expel the brackish groundwater.

4.6.5 Vertic Cambisols

Mapping unit (20): Typic, Vertic Cambisols
(21): Stony, Vertic Cambisols

The soils of this unit are the most predominant soils for agricultural utilization in the Lower-Moshi area. Recently, all of the land of this soil area has been reclaimed to its potential maximum and cultivated with maize, mostly under the rainfed conditions.

In the previous soil study made by the F.A.O team, these soils were considered Vertic Haplorthents or Grumsols intergraded to Reddish brown Andiptic Usterts.

The soils are derived from the clayey colluvium deeply deposited with the fan formation. Generally, these soils have diagnostic horizon sequence of A/Bw/C. Deep and wide cracking when dry as well as girgai formation are the main profile features of these soils.

A horizon to a depth of about 25 cm is a mineral soil which is specified as ochric epipedon. The soils in this horizon are dark reddish brown (10 YR 2/2 - 3/2) colour; clay texture; weak subangular blocky structures; friable when wet and rather hard consistency when dry; gradual and smooth boundary with the next B horizon. Bw horizon or layer is generally deeper than 150 cm. The soils of this horizon are dark reddish brown (10 YR 3/2) to dull reddish brown (7.5 YR 3/3) colour; clay texture; blocky structures; friable when wet, while very hard consistency when dry; diffuse and smooth boundary formation. C horizon consists of reddish brown (5 YR 3/3 or 7.5 YR 4/3) clayey soils having massive structures.

The soils classified into Stony phase of this soil unit have a shallow profile and many coarse gravel and lava fragments throughout the profile.

As regard to their chemical properties, the soils are slightly alkaline ranging from 7.5 to 8.5 pH and less than 0.3 m.mho/cm/25°C ECe throughout the profile. Organic carbon in the surface is 0.3 to 0.5% and less than 0.2% in sub-soils. Cation exchange capacity ranges from 15 to 20 m.eq. Base saturation degree is estimated at 80 - 120%. Exchangeable sodium percent and sodium adsorption ratio are estimated less than 0.05 and 0.3, respectively.

In regard to their physical nature, the soils consist of 30 to 45% clay, 25 to 30% silt and 25 to 30% sandy particles. Generally, the soils have high moisture holding capacities ranging between 30 and 50%, and relatively large basic intake rates at 50 - 80 mm/hr. Permeability coefficient in the sub-soils ranges from 5.0×10^{-3} to 5.0×10^{-4} cm/sec indicating good internal drainability. The main characteristics of these soils are a strong shrinkage when dry and formation of wide and deep cracking in both surface and sub-soils.

Taking into consideration the soil features above, the soils in Typic phase are very suitable for profitable upland cropping, with low suitability for paddy cultivation mainly because of a high percolation coefficient due to cracking caused by shrinkage characteristics.

The soils of Stony phase are unsuitable for profitable farming due to shallow and stony conditions.

5. Land Classification

5.1 Basic Considerations on Land Classification

The land classification for delineation of the potential arable area is made in accordance with the land classification system defined by the Bureau of Reclamation, the U.S. Department of Interior, 1953 as modified in 1967.

For the specification of the land defined in the above reference the following soil and physical environments are taken into consideration as the essential ones for evaluation.

(1) Soil textural qualities (s): limitation due to coarse texture with gravel for economic development of paddy field with irrigation facilities, and or limitation due to very fine texture for upland crops with irrigation.

(2) Effective soil depth (k): limitation due to sand, gravel, cobble, petro and/or petric formation and/or impermeable layer within shallow depth below ground surface.

(3) Soil salinity and alkalinity (a): limitation due to strong saline and alkaline reaction high exchangeable sodium percent and/or sodium adsorption ratio of the soils.

(4) Topography (t): limitation mainly due to unsuitable land elevation for economical gravity irrigation, and relief conditions unsuitable for economical field arrangement..

(5) Drainage (d): limitation mainly due to the seasonal flooding or very poor internal drainability caused by high groundwater table and heavy clayey texture.

Among the limiting factors above, seasonal flooding is the biggest constraint to the proper agricultural development, although present crop cultivation is more or less sustained by the use of flood water. Very poor internal drainability caused by heavy clayey texture and high groundwater table is also a limitation, particularly for the economic farming of upland crops. In order to develop the Project area successfully, rather high capital investment is required for the flood control and drainage improvement.

The main topographic constraint are the relief conditions in the hilly area. Mainly due to steep slopes, it is difficult to make economical field arrangement for proper irrigation farming.

The fine textural features which consist of 35 to 50% clay, 30 to 45% silt and 15 to 25% sandy particles are generally accepted for paddy rice cultivation. However, the cultivation of upland crops is restricted to a certain degree due to unfavourable characteristics such as very low intake rate, very high moisture holding capacity, and very low permeability coefficient of soils.

The fine textured soils having very hard consistency when dry, while very soft and friable consistency when wet, will also restrict the soil preparation work to some extent.

Coarse textured soils having rapid percolation rate and low moisture holding capacity, are also not suitable for economical irrigation development due to the large water requirements for maintaining a favourable range of soil moisture in a certain depth of the soil. Gravelly and stony soils in the hilly area will largely limit farm operations and limit the rooting of crops.

Shallow soil depth especially due to petro-calcic and petroferric horizon will restrict not only the crop production but also economical field arrangement. In order to reclaim these soils successfully, it is necessary to study the specific land use and irrigation cum drainage engineering, from the viewpoint of soil improvement and land conservation.

Some other constraints are also found in the survey area, such as the prevalence of various pests and diseases, low familiarity of the farmers with the modernized farming practices and improved varieties of crops, low intensity of agricultural supporting services and so on. So far as the purpose of this land classification is concerned; however, these conditions can be excluded from this land classification study, which is conceptual.

5.2 Specification of Land Classification

Taking into account the soil and land conditions presented in the preceding Sections and also the plant-physiological characteristics of paddy rice and upland crops, the terms of land classification and their specific degree of correspondence to the land suitability classes are established in accordance with the land classification standard defined by the U.S. Bureau of Reclamation.

The criteria for rating of soil and land factors is tabulated in Table III-4. The terms of land classification and their specific degree of correspondence are summarized in Table III-5.

5.3 Land Classification

In rating the irrigation suitability of land, limiting factors of soil and land are assessed whether they are corrigible or difficult to involve in land development. Hence, the potential land suitability herein defined are graded by applying the lowest amount of limiting factors. In this context, physical features such as soil depth, soil texture, drainability, and chemical properties such as strong salinity and alkalinity, and topographic conditions are the essential limitations in the Lower-Moshi area.

In light of the profile features, as well as soil chemical properties and physical features, the soils correlated with Typic Eutric Fluvisols (3), Typic Eutric Gleysols (7) and Phreatic Dystric Cambisols (13) are found in the highly suitable land class (I) for irrigated paddy rice cultivation. The soils of Saline Mollic Gleysols (6), Saline Eutric Gleysols (9), Phreatic and Saline Eutric Cambisols (14) and Petric and Saline Gleyic Cambisols (19) are graded as suitable land class (II) for paddy cultivation, though rather high capital investment is required for flood protection and rather expensive management cost is required for surface drainage during the crop season particularly in the rainy season. Salinity constraints in these soils can be neglected so far as paddy rice cultivation is concerned. The soils correlated with Petric and Saline Calcic Cambisols (18) and Typic Vertic Cambisols (20) are arable (graded as land class III) for paddy cultivation. From the irrigation engineering point of view, however, it is not recommended for developing paddy fields because of the rather high investment required for correction of the high percolation coefficient. The other soils are graded into scarcely suitable or unsuitable land grades from both the engineering and economical points of view.

As far as the irrigation development for upland cropping is concerned, the land suitability grades in each soil unit could be made separately from the above classification, taking into account the specific irrigation practices and adaptability of the upland crops. The soils correlated with Phreatic Dystric Cambisols and Typic Vertic Cambisols are graded into the highly suitable class (I) and the soils of Typic Eutric Flurisols are put into the second grade (II), although flood control and drainage improvement are required to a certain extent. The other soils, except those correlated with Lithosols (1), Regosols (2), Nitosols (10) and a part of Gleysols (5 and 8), could also grade as arable (III and IV), but profitable development cannot be expected because of the high capital investment and recurrent cost required for connection of flood or drainage constraints and amelioration of salinity and alkalinity of soil. The soils defined as phase (1), (2), (5), (8) and (10) are graded as unsuitable land. They have very scarce potential for crop productivity and/or no-possibility of soil improvement.

From the above land evaluation, the land in the survey area is classified into four suitable land classes for paddy and upland crops with irrigation as shown in Table III-6, and the extent of each class is illustrated in the land classification map attached to this report.

The first class is the highly suitable class. The land in this class has no limitation for future development in general, and high return on crop production can be anticipated with the Project.

The second class includes suitable land (II) in which sufficiently high productivity and profitability can be expected from the soil and land. However, there are moderate limitations caused by relatively strong alkaline soil reaction, slight salinity, poor essential plant nutrients, and seasonal flooding, etc. These factors are likely to reduce crop yield and/or to increase recurrent costs for crop production and improvement of soil and land conditions.

The third class is moderately suitable land (III). The land of this class is also expected to be fairy productivity for paddy and upland crops, although there are some limitations which may reduce crop yield and call for higher recurrent costs for production and soil amelioration. Rather deep flooding will be the biggest constrain in this land class.

The fourth class is scarcely suitable land (IV). The land of this class has a serious constraints such as poor drainage, strong soil salinity and alkalinity, seasonal flooding, etc., and hence, it is not recommended for future development with the Project.

The last class is economically unsuitable land (VI) for the irrigation development programme. Because of the land having very serious limitations such as deep water stagnation and extremely strong saline and alkaline soils in the low-lying area and coarse textured soil with gravel, shallow soil depth, rolling or undulating topography in the hilly or colluvial plain, etc. economic development by this Project cannot be expected for the land in this class, although some possibilities for agricultural development with other specific crops and trees is recognized.

6. Demarcation of Potential Arable Land

According to the systematic appraisal of soils and land made in the preceding section 5, the land in the survey area is classified into four land classes in which the first two classes are the suitable land for irrigated farming and the third to fifth classes are economically marginally suitable to unsuitable land for the irrigation development.

In this land classification, about 24,700 ha or about 58.7 % of total survey area is selected as the potential arable land (classes I and II). Generally, these lands have sufficiently deep soil, moderate tillability, high irrigability and sustainable surface drainability. The physical constraints prevailing in the area could be improved and/or modified satisfactorily with a reasonable amount of capital investment.

About 9,750 ha or 23.2 % of the land is graded into marginally arable land (classes III and IV). These lands are also considered as potential arable land. However, special measures will be required for agricultural utilization, particularly for amelioration of aggravated soil features. It is rather difficult, at present, to expect economical use of these soils for profitable irrigation farming of paddy rice and other common upland crops by implementation of a comprehensive irrigation and drainage system. Accordingly, the land in this class is not recommended for the project.

The remaining area, 7,500 ha or 18.1 % is classified into class VI (economically unsuitable for irrigation farming), and the lands are excluded from the project study.

Based on the above land classification, demarcation of irrigable land to be taken for project study is made as shown in Table III-7.

Table III-1 CLIMATE TYPE BY J. PAPADAKIS CLASSIFICATION SYSTEM

Name of Meteorological Station	Type of Climate	Winter type			Summer type			Temperature Regime		Humidity Regime		Annual Rainfall	Annual Evapotranspiration (Ln)	Leaching Rainfall in Humid Season	Drought Stress in Dry Season	Humid Season	Dry Season
		1	2	3	1	2	3	1	2	1	2						
Moshi	Dry Monsoon Tierra Templada	14.^{4}	(Tp) 16.^{0}	25.^{2}	12	(C) 31.^{6}	31.7 18.0	(Tt)		(Mo) Ln:17.5%	0.51	926.3	1,806	317	1,455.9	5 (4 - 8)	7 (9 - 3)
T.P.C.	Semiarid Monsoon Tierra Templada	12.^{0}	(Tp) 14.^{0}	26.^{8}	12	(C) 32.^{1}	32.9 18.0	(Tt)		(Mo) Ln:3.4%	0.29	573	1,928	66	1,449	4 (5 - 8)	8 (9 - 4)
Miwalemi	Semiarid Monsson Tierra Templada	14.^{5}	(Tp) 16.^{1}	26.^{6}	12	(C) 32.^{5}	32.9 19.2	(Tt)		(Mo) Ln:1.4%	0.33	706	2,127	31	1,789	5 (4 - 8)	7 (9 - 3)
Lyamungu	Moist Monsoon Tierra Templada	10.^{6}	(Tp) 11.^{8}	21.^{3}	12	(C) 26.^{7}	27.4 13.4	(Tt)		(Mo) Ln:78.8%	1.20	1,663	1,376	1,084	845	6 (4 - 9)	6 (10 - 3)

Table III-2

SUMMARY OF SOIL CLASSIFICATION

	SOIL UNITS		SOIL PHASE	MAPPING UNITS	EXTENT AREA (ha)	PROPORTIONAL EXTENT (%)
Lithosols	- Typic Lithosols	(I-2c)	Typic phase	(1)	950	2.3
Regosols	- Dystric Regosols	(Rd-2b)	Typic phase	(2)	250	0.6
Fluvisols	- Eutric Fluvisols	(Je-2/3a)	Typic phase	(3)	2,590	6.2
			Saline/sodic phase	(4)	650	1.6
Gleysols	- Humic Gleysols	(Gh-3a)	Saline phase	(5)	1,220	2.9
	- Mollic Gleysols	(Gm-3a)	Saline phase	(6)	2,220	5.3
	- Eutric Gleysols	(Ge-3a)	Typic phase	(7)	380	0.9
			Petro-ferric phase	(8)	50	0.1
			Saline phase	(9)	100	0.2
Nitosols	- Eutric Nitosols	(Ne-3a)	Phreatic/sodic phase	(10)	5,010	11.9
Cambisols	- Dystric Cambisols	(Bd-3a)	Phreatic phase	(13)	7,700	18.4
	- Entric Cambisols	(Be-3a)	Phreatic/saline and sodic phase	(14)	1,050	2.5
	- Calcic Cambisols	(Bc-2/3a)	Petro-calcic phase	(16)	140	0.3
			Stony/sodic phase	(17)	280	0.7
			Petric/saline phase	(18)	2,900	6.9
	- Gleyic Cambisols	(Bg-3a)	Petric/saline phase	(19)	1,230	2.9
	- Vertic Cambisols	(Bv-3a)	Typic phase	(20)	14,370	34.3
			Stony phase	(21)	830	2.0
			Total		41,920	100.0

Table III-3 (1)

CHEMICAL PROPERTIES OF MAJOR SOILS

Name of Soil Unit & Sample No.	Horizon Depth (cm)	pH (H_2O) (1:1)	ECe (m.mhos)	Total Organic Carbon (mg/100g)	Total Nitrogen (mg/100g)	Water Soluble Salts (m.eq/100g) Na	K	Ca	Mg	CO_3	Ch	SO_4	Total Soluble Salts (m.eq/100g)
Vertic Cambisols													
LM 4-1	0 - 15	6.90	0.22	13.8	93.6	0.06	0.28	0.12	0.21	0.	1.18	0.48	2.34
LM 4-2	15 - 60	6.50	0.09	9.6	78.6	0.13	0.20	0.12	0.34	0.	1.75	0.03	2.58
LM 4-3	60 - 150$^+$	7.20	0.13	12.1	59.5	0.13	0.03	0.	0.04	0.	2.15	0.	2.35
Mollic Gleysols													
LM 12-1	0 - 35	8.40	0.57	24.1	160.2	1.30	0.30	0.24	0.70	1.10	1.85	0.40	5.89
LM 12-2	35 - 85	8.60	0.78	8.4	63.7	2.50	0.	0.04	0.28	1.06	1.78	0.22	5.88
LM 12-3	85 - 140$^+$	8.20	0.45	23.8	45.9	0.50	0.04	0.26	0.51	0.53	2.03	0.16	4.03
Calcic Cambisols													
LM 13-1	0 - 40	10.10	15.50	5.6	71.5	8.76	1.37	78.57	0.50	19.27	45.94	7.09	161.50
LM 13-2	40 - 100	10.30	12.00	3.8	44.5	7.50	0.82	67.43	0.20	38.67	19.64	4.20	138.46
LM 13-3	100 - 200$^+$	10.50	8.00	4.5	41.2	4.45	0.57	40.27	0.30	28.36	12.54	2.05	88.54
Humic Gleysols													
LM 22-1	0 - 20	7.25	0.27	14.1	147.5	0.20	0.28	0.32	0.27	9.	1.74	0.18	2.98
LM 22-2	20 - 45	7.35	0.16	10.1	105.7	0.20	2.39	0.68	2.87	0.	0.64	0.24	7.05
LM 22-3	45 - 105$^+$	8.00	0.20	8.2	74.0	0.30	0.15	0.36	0.28	0.	2.86	0.06	4.02
Vertic Cambisols													
LM 25-1	0 - 15	7.40	0.23	14.2	101.4	0.13	0.82	0.24	0.32	0.	24.57	0.06	26.15
LM 25-2	15 - 35	7.70	4.00	25.2	106.3	11.22	0.10	4.63	2.92	1.15	18.51	0.59	39.12
LM 25-3	35 - 65$^+$	7.50	10.00	10.4	64.2	46.85	0.08	6.95	4.64	0.	26.51	0.50	85.54
Eutric Nitosols													
LM 29-1	0 - 10	10.36	19.50	10.6	81.6	122.78	0.26	0.33	0.02	95.84	28.41	5.69	253.34
LM 29-2	15 - 50	9.80	10.75	2.7	45.6	57.07	0.	0.52	0.05	46.50	5.80	2.80	112.73
LM 29-3	50 -	9.80	6.00	2.6	20.0	20.89	0.	0.	0.03	18.45	3.43	0.36	43.15
Vertic Cambisols													
LM 38-1	0 - 15	7.70	0.45	21.4	117.2	0.01	0.10	0.45	0.32	0.	1.98	0.24	3.19
LM 38-2	15 - 100	9.00	0.25	12.8	74.8	0.20	0.10	0.29	0.30	0.	0.79	0.27	1.96
LM 38-3	100 -	8.20	0.10	10.7	60.1	0.43	0.05	0.12	0.09	0.	7.89	0.13	8.71
Eutric Cambisols													
LM 44-1	0 - 30	7.82	1.65	26.4	157.4	3.87	1.13	1.81	0.91	0.56	5.02	0.26	13.57
LM 44-2	30 - 100	8.11	1.07	8.7	64.9	2.95	0.46	0.44	0.24	0.	2.31	0.69	7.10
LM 44-3	100 - 150$^+$	8.89	1.30	1.3	46.1	4.87	0.95	0.22	0.10	3.41	2.05	0.25	10.95
Eutric Nitosols													
LM 45-1	0 - 15	10.20	8.95	6.8	59.4	44.54	0.30	0.47	0.10	31.39	4.49	3.66	85.95
LM 45-2	15 - 45	9.75	4.25	7.2	55.6	16.48	0.13	0.39	0.06	11.58	1.46	1.02	31.11
LM 45-3	45 - 100	9.52	3.25	1.0	32.5	12.22	0.95	0.24	2.99	8.85	1.19	0.58	27.02
LM 45-4	100 - 150$^+$	9.10	3.00	3.6	26.5	11.06	1.01	0.68	4.59	8.37	1.07	0.94	27.72
Dystric Cambisols													
LM 64-1	0 - 30	7.30	0.18	7.0	63.0	0.16	0.39	0.08	0.05	0.	1.56	0.29	2.44
LM 64-2	30 - 65	7.20	0.14	3.5	34.9	0.26	0.32	0.13	0.18	0.	0.91	0.29	2.09
LM 64-3	65 - 120$^+$	7.30	0.11	3.2	40.4	0.45	1.09	0.27	2.27	0.	1.18	0.24	5.49
Mollic Gleysols													
LM 77-1	0 - 15	6.70	3.25	12.8	37.9	7.38	0.70	3.47	2.62	0.	14.49	1.10	29.76
LM 77-2	15 - 120	6.95	2.30	8.6	53.1	7.15	0.15	1.77	1.80	0.	9.57	1.56	22.00
LM 77-3	120 - 150$^+$	7.95	0.65	7.3	50.8	2.05	0.05	0.16	0.13	0.	1.06	1.17	4.61

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Name of Soil Unit & Sample No.	Horizon Depth (cm)	pH (H_2O) (1:1)	ECe (m.mhos)	Total Organic Carbon (mg/100g)	Total Nitrogen (mg/100g)	Water Soluble Salts (m.eq/100g)							Total Soluble Salts (m.eq/100g)
						Na	K	Ca	Mg	CO_3	Ch	SO_4	
Eutric Gleysols													
LM 86-1	0 - 15	7.45	0.20	20.1	102.2	0.40	0.43	0.49	0.33	0.	2.02	0.26	3.92
Dystric Cambisols													
LM 90-1	0 - 20	8.70	1.00	21.3	114.5	0.64	0.43	0.27	0.17	9.	0.29	1.22	3.02
LM 90-2	20 - 50	9.10	2.25	3.1	36.5	0.71	0.48	0.08	0.14	0.30	0.36	0.75	2.82
LM 90-3	50 - 100	8.90	1.85	2.2	35.3	0.63	0.37	0.09	0.12	0.	0.65	0.56	2.41
LM 90-4	100 - 150+	8.60	0.73	2.1	24.3	0.29	0.27	0.14	0.11	0.	0.50	0.32	1.63
Vertic Cambisols													
LM 84-1	0 - 20	7.50	0.05	14.5	59.2	0.13	0.05	0.16	0.17	0.	1.84	0.05	2.40
LM 84-2	20 - 130	6.95	0.05	13.2	43.6	0.19	0.04	0.12	0.18	0.	1.31	0.07	1.92
LM 84-3	130 -	7.60	0.32	7.4	33.0	0.20	0.05	0.24	0.28	0.	2.29	0.07	3.14
Eutric Fluvisols													
LM 95-1	0 - 25	7.85	2.15	21.6	126.7	3.89	0.16	4.44	3.31	0.	9.80	0.67	22.27
LM 95-2	25 - 50	8.00	7.75	18.9	100.5	35.93	0.08	4.45	4.91	0.	35.30	0.77	81.43
LM 95-3	50 - 100+	8.40	9.50	16.7	89.9	15.56	0.03	0.33	0.62	0.	15.07	0.89	32.50

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Table III-3 (2)

CHEMICAL PROPERTIES OF MAJOR SOILS

Name of Soil Unit & Sample No.	Horizon Depth (cm)	Cation Exchange Capacity (m.eq/100g)	Exchangeable Bases				Total Exchangeable Bases (m.eq/100g)	Sodium Adsorption Ratio	Exchangeable Sodium Percent (%)	Base Saturation Degree (%)
			Na	K (m.eq/100g)	Ca	Mg				
Vertic Cambisols										
LM 4-1	0 - 15	18.39	0.03	2.38	8.66	7.24	18.31	0.01	0.26	99.56
LM 4-2	15 - 60	18.14	0.07	0.90	8.88	7.93	17.76	0.02	0.39	97.91
LM 4-3	60 - 150$^+$	11.81	0.08	0.78	9.32	8.30	18.48	0.03	0.68	156.48
Mollic Gleysols										
LM 12-1	0 - 35	33.93	1.40	4.27	26.07	25.63	57.37	0.27	4.13	169.08
LM 12-2	35 - 85	21.03	2.99	1.09	21.78	22.16	48.02	0.64	14.22	228.34
LM 12-3	85 - 140$^+$	17.47	0.74	1.45	32.97	16.27	51.43	0.15	4.24	249.39
Calcic Cambisols										
LM 13-1	0 - 40	18.99	18.20	4.76	33.09	3.34	59.40	4.26	30.64	312.80
LM 13-2	40 - 100	27.11	18.51	5.58	41.14	4.30	69.53	3.88	26.62	256.47
LM 13-3	100 - 200$^+$	32.77	12.24	7.44	34.49	12.21	66.37	2.53	18.44	202.53
Humic Gleysols										
LM 22-1	0 - 20	30.95	0.07	4.33	14.83	9.63	28.85	0.02	0.23	93.21
LM 22-2	20 - 45	31.17	0.56	3.58	15.82	10.91	30.86	0.02	1.80	99.01
LM 22-3	45 - 105$^+$	35.42	0.08	3.64	25.52	13.36	42.60	0.02	0.23	120.27
Vertic Cambisols										
LM 25-1	0 - 15	39.73	0.03	4.91	22.10	13.78	40.83	0.01	0.08	102.77
LM 25-2	15 - 35	41.92	6.50	2.62	38.27	17.46	64.86	1.23	15.51	154.72
LM 25-3	35 - 65$^+$	39.95	18.25	1.48	37.63	18.33	75.69	3.45	45.68	189.46
Eutric Nitosols										
LM 29-1	0 - 10	56.52	107.63	3.95	17.77	3.21	132.56	33.23	190.43	234.54
LM 29-2	15 - 50	59.88	79.31	2.75	18.08	3.36	103.50	24.22	132.45	172.85
LM 29-3	50 -	58.31	77.76	1.76	18.81	10.18	108.51	20.42	133.36	186.09
Vertic Cambisols										
LM 38-1	0 - 15	37.00	0.06	5.53	20.61	12.29	38.48	0.01	0.16	104.00
LM 38-2	15 - 100	31.95	0.08	1.26	15.11	13.89	30.33	0.02	0.25	94.93
LM 38-3	100 -	28.49	0.67	0.28	11.13	10.26	22.33	0.20	2.35	98.38
Eutric Cambisols										
LM 44-1	0 - 30	51.72	3.12	8.52	34.31	14.50	60.44	0.63	6.03	116.86
LM 44-2	30 - 100	38.37	3.76	5.44	20.73	11.62	41.55	0.93	9.80	108.29
LM 44-3	100 - 150$^+$	41.09	12.03	2.34	27.88	22.74	64.99	2.39	29.28	158.17
Eutric Nitosols										
LM 45-1	0 - 15	38.22	48.22	5.41	22.21	6.35	82.19	12.76	126.16	215.04
LM 45-2	15 - 45	37.76	38.93	4.53	22.47	6.36	72.29	10.25	103.10	191.45
LM 45-3	45 - 100	39.66	43.74	5.31	23.23	6.63	78.90	11.32	110.29	198.94
LM 45-4	100 - 150$^+$	45.95	45.71	5.86	20.88	9.53	81.99	11.72	99.48	178.43
Dystric Cambisols										
LM 64-1	0 - 30	19.66	0.04	1.50	4.89	2.42	8.85	0.02	0.05	45.00
LM 64-2	30 - 65	20.28	0.04	0.85	7.63	1.62	10.14	0.02	0.39	50.01
LM 64-3	65 - 120$^+$	22.70	0.44	0.62	7.99	2.15	11.20	0.19	3.92	49.50
Mollic Gleysols										
LM 77-1	0 - 15	32.23	3.43	2.78	17.96	11.84	36.01	0.89	10.64	111.73
LM 77-2	15 - 120	30.86	4.04	1.13	16.56	11.99	33.72	1.07	13.09	109.27
LM 77-3	120 - 150$^+$	32.61	3.60	0.88	19.90	14.35	38.72	0.87	11.04	118.74

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Name of Soil Unit & Sample No.	Horizon Depth (cm)	Cation Exchange Capacity (m.eq/100g)	Exchangeable Bases				Total Exchangeable Bases (m.eq/100g)	Sodium Adsorption Ratio	Exchangeable Sodium Percent (%)	Base Saturation Degree (%)
			Na	K (m.eq/100g)	Ca	Mg				
Eutric Gleysols										
LM 86-1	0 - 15	17.46	0.02	1.80	11.80	4.26	17.88	0.01	0.11	102.41
Dystric Cambisols										
LM 90-1	0 - 20	22.41	0.51	0.30	7.55	2.56	10.92	0.23	4.67	48.75
LM 99-2	20 - 50	19.52	0.12	0.46	2.48	6.01	9.07	0.06	1.32	46.50
LM 90-3	50 - 100	24.53	0.10	0.49	7.67	2.35	10.61	0.04	0.94	43.25
LM 90-4	100 - 150⁺	23.67	0.40	0.29	6.97	4.20	11.86	0.17	3.37	50.12
Vertic Cambisols										
LM 94-1	0 - 20	25.42	0.04	0.50	10.72	10.56	21.83	0.01	0.16	85.88
LM 94-2	20 - 130	25.01	0.04	0.50	10.01	11.46	22.01	0.01	0.16	88.00
LM 94-3	130 -	32.46	0.45	0.64	13.79	13.21	22.09	0.12	1.39	68.05
Cutric Pluvisols										
LM 90-1	0 - 25	62.56	2.41	0.15	47.40	23.85	73.82	0.40	3.85	118.00
LM 90-2	25 - 50	60.47	16.61	1.88	42.56	29.41	90.47	2.76	27.47	149.61
LM 90-3	50 - 100⁺	58/88	34.65	1.73	32.30	29.21	97.89	6.25	59.98	169.45

Table III-4 Criteria for Rating of Land Factors

1. Soil Conditions

1.1 Soil Texture Qualities

	Surface Soils	Sub-surface Soils
s0:	Coarse loamy to fine loam	Fine loamy to fine clay
s1:	Fine loamy to fine clay	Coarse loamy to fine clay
s2:	Coarse loamy and/or very fine clayey	Coarse loamy and/or very fine clayey
s3:	Sandy and/or histic soils	Sandy and/or histic soils

1.2 Effective Soil Depth

Depth to sand, gravel, cobble, plinthite, mud-clay or histics

k0: Very deep - more than 90 cm
k1: Deep - 50 to 90 cm
k2: Moderate - 20 to 50 cm
k3: Shallow - les than 20 cm

Depth to impermeable layer for Diversified Crops		for Paddy Rice	
i0:	Very deep - more than 150 cm	k0:	Very deep - more than 90 cm
i1:	Deep - 120 to 150 cm	k1:	Deep - 50 to 90 cm
i2:	Moderate - 100 to 120 cm	k2:	Moderate - 20 to 50 cm
i3:	Shallow - less than 100 cm	k3:	Shallow - less than 20 cm

1.3 Soil Acidity (pH: H_2O 1:1 soil-water suspension)

a0: Slightly alkaline to neutral - 6.1 to 7.5
a1: Moderately strong alkaline - 2.6 to 8.5
a2: Strong alkaline - 8.6 to 9.0
a3: Very strong alkaline - 9.1 to 9.5
a4: Extremely strong alkaline - more than 9.5

2. Topography

2.1 Relief Conditions

r0: Flat to nearly flat
r1: Gently sloped land
r2: Undulating
r3: Rolling

2.2 Sloping Conditions

t0: 0 to 2%
t1: 2 to 5% in single slope
t2: 5 to 8% in single slope
t3: 8 to 15%
t4: more than 15%

3. Drainage Conditions

3.1 Soil Drainability

d0: Well drainable
d1: Moderately drainable
d2: Somewhat poorly drainable
d3: Poorly drainable
d4: Very poorly drainable

3.2 Seasonal Flooding

f0: Non seasonal flooding (non inundation)
f1: Seasonal flooding shallowly (sometime inundated)
f2: Seasonal flooding deeply (frequently inundated)
f3: Flooding throughout the year (inundated all the times)

Source: Irrigation suitability classification, US Bureau of Reclamation, 1967

Table III-5 LAND SUITABILITY CLASSIFICATION BY DEGREE OF SOIL CHARACTERISTICS

Suitability Class	Suitable				Unsuitable
Specific Degree	Very High (1)	High (2)	Moderately High (3)	Low (4)	Very Low (5)
Soil and land Qualities					
1. Soil fertilities					
- organic carbon (%)	more than 0.75	more than 0.75	0.15 to 0.75	less than 0.15	less than 0.15
- total nitrogen (%)	more than 0.05	more than 0.05	0.01 to 0.05	less than 0.01	less than 0.01
- available P_2O_5 (ppm)	high	moderate	low	very low	very low
- C.E.C (m.eq.)	more than 10	more than 10	3 to 10	less than 3	less than 3
- potassium (m.eq.)	more than 0.2	more than 0.2	0.1 to 0.2	less than 0.1	less than 0.1
- base saturation (%)	more than 40	more than 40	10 to 40	less than 10	less than 10
2. Alkalinity of soils (pH: 1:25 soil-water suspension)					
	less than 8.5	less than 8.5	8.5 to 9.0	more than 9.1	more than 9.5
3. Soil Depth (cm)					
- depth to sand, etc.	more than 90	more than 90	50 to 90	20 to 50	less than 20
- depth to impermeable layer	more than 150	120 to 150	120 to 150	100 to 120	less than 100
4. Topography					
- relief	flat to nearly flat	flat to nearly flat	gently sloped	undulating	rolling
- slope (%)	0 to 2	2 to 5	5 to 8	8 to 15	more than 15
5. Drainage Conditions					
- drainability	well	moderate	somewhat poor	poor	very poor
- seasonal flooding	non flooding	non flooding	short and shallowly flooded	long and deeply flooded	permanently and deeply flooded
Land Capability					
6. Conditions for seeding establishment and tillability					
- soil structure	structureless & granular	sub-angular block	sub-angular blocky	blocky to massive	massive
- consistence	friable	friable	firm	very firm	extremely firm
- susceptibility to surface sealing	slight	slight	moderate	strong	strong
7. Workability					
- consistence when wet	non to slightly sticky & plastic	slightly sticky & plastic	sticky & plastic	very sticky & very plastic	very sticky & very plastic
- consistence when dry	loose to moderate	moderately hard	moderately hard to hard	very hard	very hard to extremely hard
8. Possibility for farm mechanization					
- land form & slope	flat to gently sloped	gently undurating	undulating	rolling	rolling and steeply sloped
9. Capability for maintaining surface water					
- permeability	less than 1.4×10^{-4} cm/sec.	1.3 to 5.5 x 10^{-4} cm/sec.	1.6×10^{-3} to 5.5×10^{-4} cm/sec.	less than 1.6×10^{-3} cm/sec.	less than 1.6×10^{-3} cm/sec.

Note: Sources: Land suitability classification for irrigated paddy and diversified crops defined by U.S. Bureau of Reclamation, 1967.

Criteria for land capability appraisal is preliminarily estimated based on the specific degree generally accepted.

Table III-6

SUMMARY OF LAND CLASSIFICATION BY SOIL PHASE

SOIL PHASE	LAND SUITABILITY CLASES For Upland Crops	LAND SUITABILITY CLASES For Paddy Rice	EXTENT AREA (ha)	PROPORTIONAL EXTENT (%)
Typic, Lithosols	6st	6st	950	2.3
Typic, Regosols	4t	6st	250	0.6
Typic, Eutric Fluvisols	2d	1	2,590	6.2
Salenelsodic, Eutric Fluvisols	4sd	4s	650	1.6
Saline, Humic Gleysols	6sd	4sd	1,220	2.9
Saline, Mollic Gleysols	3sd	2s	2,220	5.3
Typic, Eutric Gleysols	3d	1	380	0.9
Petro-ferric, Eutric Gleysols	6sd	4s	50	0.1
Saline, Eutric Gleysols	4sd	2s	100	0.2
Phreatic/sodic, Eutric Nitosols	6sd	6sd	5,010	11.9
Phreatic, Dystric Cambisols	1	1	7,700	18.4
Phreatic/saline and sodic, Eutric Cambisols	4sd	2s	1,050	2.5
Petro-calcic, Calcic Cambisols	4st	4st	140	0.3
Stony/saline, Calcic Cambisols	4s	4s	280	0.7
Petric/saline, Calcic Cambisols	4s	3s	2,900	6.9
Petric/saline, Gleyic Cambisols	4sd	2s	1,230	2.9
Typic, Vertic Cambisols	1	3s	14,370	34.3
Stony, Vertic Cambisols	4st	4st	830	2.0
	Total		41,920	100.0

Table III-7 DEMARCATION OF POTENTIAL ARABLE LAND

LAND SUITABILITY CLASSES		EXTENT AREA For Upland Crops (ha)	EXTENT AREA For Paddy Rice (ha)
Class I:	Highly suitable		
	- 1	22,070	10,670
Class II:	Suitable		
	- 2s	-	4,600
	- 2d	2,590	-
	(sub-total)	(2,590)	(4,600)
Class III:	Moderately suitable		
	- 3s	420	17,270
	- 3d	380	-
	- 3sd	2,220	-
	(sub-total)	(3,020)	(17,270)
Class IV:	Marginally suitable		
	- 4s	2,900	700
	- 4sd	2,610	1,220
	- 4t	250	-
	- 4st	970	140
	(sub-total)	(6,730)	(2,060)
Class VI:	Unsuitable		
	- 6s	-	700
	- 6sd	6,560	4,590
	- 6st	950	2,030
	(sub-total)	(7,500)	(7,320)
	Total	41,920	41,920

Note: The symbol of land suitability sub-class shows the limiting factors for development of the irrigated agriculture.

Example; " 3sdt"

where 3: land suitability grade

s: soil limitations, such as saline, alkaline, stony, etc.

d: drainage problems inclusive of seasonal flooding

t: topographic conditions which unsuitable for setting the irrigation facilities, land reclamation, etc.

Table III-8 QUANTITY OF GROUNDWATER

Water Samples	pH	EC value (m.mho/cm/27^{0}C)	Total Salts (ppm)
Pit No. LM-12	8.60	0.55	340
Pit No. LM-15	9.20	0.12	75
Pit No. LM-31	9.95	2.80	1,750
Pit No. LM-39	9.00	2.20	1,370
Pit No. LM-45	9.45	9.00	5,630
Pit No. LM-87	7.95	0.18	110
Pit No. LM-86	8.10	0.29	180

Note Total salts are estimated based on the EC value.

Water samples are taken from the bottom of auger-hole where the groundwater springs.

Above water qualities are measured at the field laboratory temporarily set in Moshi.

Table III-9 (1) **FIELD TEST RESULTS OF SOIL SALINITY AND ALKALINITY**

(Lower-Moshi Area)

PIT No. & HORIZON		DEPTH (cm)	SOIL COLOUR (when wet)	SOIL TEXTURE	p^H	ECe (m.mhos/cm)
LM 1	- 1	0 - 55	5YR 2/3	CL	7.60	0.15
	- 2	55 - 65	5YR 3/4	SiC	8.00	0.15
LM 2	- 1	0 - 15	5YR 2/4	CL	7.50	0.33
	- 2	15 -	5YR 2/5	CL	7.40	0.19
LM 3	- 1	0 - 10	5YR 3/6	SiC	7.40	1.03
	- 2	10 - 100+	5YR 3/4	SiC	7.50	0.11
LM 4	- 1	0 - 15	5YR 3/4	C	6.80	0.22
	- 2	15 - 60	5YR 2/3	C	7.20	0.09
	- 3	60 -	5YR 2/3	SiC	7.20	0.13
LM 6	- 1	0 - 45	5YR 2/4	L	7.20	0.30
	- 2	45 -	5YR 3/3	L	8.20	0.13
LM 7	- 1	0 - 30	5YR 2/3	CL	7.20	0.23
	- 2	30 - 95	5U 3/4	L	7.20	0.15
	- 3	95 -	5YR 3/3	Sol	7.70	0.12
LM 8	- 1	0 - 45	5YR 2/3	CL	7.30	0.40
	- 2	45 - 85	5YR 3/4	C	7.90	0.15
	- 3	95 -	5YR 4/2	C	8.20	0.16
LM 9	- 1	0 - 40	5YR 3/4	C	7.40	0.16
	- 2	40 - 85	5YR 3/4	CL	7.40	0.10
	- 3	85 -	5YR 4/3	CL	7.30	0.10
LM 10	- 1	- 20	10YR 3/4	C	9.10	2.75
	- 2	20 - 45	10YR 3/3	CL	9.20	4.50
	- 3	45 -	2.5YR 3/3	C	8.90	6.25
LM 11	- 1	0 - 15	7.5YR 3/3	C	9.50	0.55
	- 2	15 - 60	7.5YR 3/2	C	10.60	2.75
	- 3	60 -	7.5YR 3/2	C	10.50	3.25
LM 12	- 1	0 - 35	7.5YR 1.7/1	C	9.10	0.57
	- 2	35 - 85	10YR 3/3	CL	9.70	0.78
	- 3	85 - 140+	7.5YR 4/2	SL	9.10	0.45
LM 13	- 1	0 - 40	7.5YR 3/2	L	11.00	15.50
	- 2	40 - 100	10YR 3/3	L	11.10	12,00
	- 3	100 -	10YR 4/3	L	11.00	8.00
LM 14	- 1	0 - 40	7.5YR 3/3	CL	7.50	18.00
	- 2	40 - 55	7.5YR 3/3	CL	7.70	20.25
	- 4	55 - 120	7.5YR 3/2	L	10.90	9.25
	- 4	120 -	7.5YR 3/2	LS	11.00	2.75

- continued -

Table III-9 (2) **FIELD TEST RESULTS OF SOIL SALINITY AND ALAKLINITY**

(Lower-Moshi Area)

PIT No. & HORIZON	DEPTH (cm)	SOIL COLOUR (when wet)	SOIL TEXTURE	pH	ECe (m.mhos/cm)
LM 15 - 1	0 - 20	7.5YR 2/2	CL	10.30	3.00
- 2	20 - 55	10YR 4/2	SL	9.80	1.45
- 3	55 -	10YR 5/3	Scl	9.70	1.35
LM 15' - 1	top few cm			11.10	12.00
- 2	under the above layer			10.10	2.07
LM 17 - 1	0.- 25	2.5YR 2/3	CL	7.40	0.16
LM 19 - 1	0 - 15	10YR 2/2	L	7.10	0.23
- 2	15 - 70	10YR 2/3	L	7.80	0.11
LM 21 - 1	0 - 15	5YR 2/2	Sc	7.60	0.23
- 2	15 - 40	5YR 2/2	L	7.70	0.14
LM 22 - 1	0 - 20	5YR 3/3	CL	7.60	0.27
- 2	20 - 45	5YR 2/3	CL	7.80	0.16
- 3	45 - 105+	5YR 2/4	C	8.60	0.20
LM 23 - 1	0 - 15	2.5YR 3/3	L	8.50	0.35
- 2	15 - 35	2.5YR 3/3	CL	8.00	0.27
- 3	35 - 100+	5YR 2/4	CL	8.30	0.65
LM 24 - 1	0 - 15	2.5YR 3/3	L	7.50	0.72
- 2	15 - 35	2.5YR 3/2	CL	7.40	0.35
- 3	35 - 105	5YR 2/4	CL	8.50	0.40
LM 25 - 1	0 - 15	5YR 3/3	L	8.10	0.23
- 2	15 - 35	5YR 3/3	CL	8.20	4.00
- 3	35 - 65	5YR 2/3		8.40	10.00
LM 26 - 1	0 - 30	5YR 2/2	CL	8.20	0.30
- 2	30 - 50	5YR 2/3	C	8.40	0.32
- 3	50 - 90	5YR 3/3	CL	8.80	0.37
- 4	90 - 120	5YR 2/4	Gc	8.80	0.80
LM 27 - 1	0 - 20	5YR 1/1	C	9.80	1.03
- 2	20 - 40	7.5YR 3/2	C	10.90	10.00
- 3	40 - 100	10YR 3/4	CL	10.70	4.50
- 4	100 -	10YR 8/1	C	10.20	2.00
LM 28 - 1	0 - 15	10YR 2/2	C	10.00	3.25
- 2	15 - 40	7.5YR 3/3	C	11.00	12.00
- 3	40 -	7.5YR 5/4	C	11.10	12.30
LM 29 - 1	0 - 10	5YR 3/3	C	11.10	19.50
- 2	15 - 50	2.5YR 3/6	C	10.80	10.75
- 3	50 -	10YR 3/3	C	10.70	6.00
LM 30 - 1	0 - 5	5YR 2/4	CL	10.80	69.00
- 2	5 - 20	2.5YR 2/4	C	11.00	15.00
- 3.1	20 - 150	5YR 3/6	C	10.90	6.50
- 3.2	"	"	C	10.10	1.85

- continued -

Table III-9(3) FIELD TEST RESULTS OF SOIL SALINITY AND ALKALINITY

(Lower-Moshi Area)

PIT No. & HORIZON	DEPTH (cm)	SOIL COLOUR (when wet)	SOIL TEXTURE	pH	ECe (m.mhos/cm)
LM 31 - 1	0 - 10	7.5YR 4/4	L	11.20	23.00
- 2	10 - 25	7.5YR 4/4	CL	10.60	3.75
- 3.1	25 - 70	7.5YR 4/4	CL	10.20	3.50
- 3.2	70 - 70	7.5YR 4/4	CL	10.40	3.50
- 4	70 - 130	5YR 3/4	CL	10.20	2.50
LM 32 - 1	0 - 30	5YR 2/4	C	8.80	0.85
- 2	30 - 100	2.5YR 2/4	C	8.10	9.00
- 3	100 - 140+	2.5YR 3/4	CL	10.40	4.75
LM 33 - 1	0 - 25	5YR 2/2	C	8.50	3.00
- 2	25 - 80	7.5YR 3/2	C	8.50	21.00
- 3	80 - 200+	7.5YR 3/4	C	9.40	16.50
LM 34 - 1	0 - 25	5YR 2/4	C	8.90	0.85
- 2	25 -	7.5YR 2/4	C	9.00	6.00
LM 35 - 1	0 - 20	7.5YR 3/4	CL	8.80	1.00
- 2	20 - 70	7.5YR 4/6	C	10.80	7.00
- 3	70 - 150+	7.5YR 4/3	C	10.70	13.25
LM 36 - 1	0 - 20	2.5YR 3/4	C	7.70	0.35
- 2	20 -	2.5YR 3/3	C	8.20	0.65
LM 38 - 1	0 - 15	2.5YR 3/4	C	7.70	0.45
- 2	15 - 100	2.5YR 3/4	C	7.50	0.25
- 3	100 -	2.5YR 3/2	CL	7.40	0.10
LM 39 - 1	0 - 25	10YR 1.7/1	C	10.40	5.00
- 2	25 - 70	10YR 2/3	C	10.30	3.00
- 3	70 - 120+	10YR 3/4	C	10.20	2.50
LM 40 - 1	0 - 20	5YR 2/1	C	10.40	4.00
- 2	20 - 55	7.5YR 4/4	C	10.00	1.57
- 3	55 - 100*	7.5YR 4/4	C	9.40	1.20
LM 41 - 1	0 - 20	5YR 2/1	C	8.60	1.65
- 2	20 - 145	10YR 5/4	C	9.90	3.25
- 3	145 - 200+	10YR 7/2	C	9.80	3.50
LM 42 - 1	0 - 35	7.5YR 2/2	C	10 90	7.25
- 2	35 - 75	5YR 4/4	C	10.40	2.43
- 3	75 - 180	7.5YR 4/4	CL	9.90	1.70
- 4	180 -	7.5YR 7/4	C	9.60	1.03
LM 43 - 1	0 - 20	10YR 2/2	CL	10.40	3.50
- 2	20 - 40	10YR 3/1	CL	10.00	1.80
- 3	40 - 120+	10YR 6/3	SL	9.00	0.50
LM 44 - 1	0 - 30	10YR 2/1	C	8.50	1.65
- 2	30 - 100	7.5YR 3/4	C	8.80	1.07
- 3	100 - 150+	7.5YR 4/4	C	9.60	1.30

- continued -

Table III-9(4) FIELD TEST RESULTS OF SOIL SALINITY AND ALKALINITY

(Lower-Moshi Area)

PIT No. & HORIZON	DEPTH (cm)	SOIL COLOUR (when wet)	SOIL TEXTURE	pH	ECe (m.mhos/cm)
LM 45 - 1	0 - 15	7.5YR 4/4	CL	10.90	8.59
- 2	15 - 45	7.5YR 4/6	CL	10.60	4.25
- 3	45 - 100	7.5YR 4/6	CL	10.30	3.25
- 4	100 - 150+	5YR 4/6	CL - L	10.40	3.00
LM 47 - 1	0 - 25	5YR 2/2	C	9.00	0.57
- 2	25 - 90	5YR 3/1	C	9.60	2.10
- 3	90 -	7.5YR 4/2	C	10.70	3.37
LM 48 - 1	0 - 40	2.5YR 2/3	C	8.40	0.25
- 2	40 - 55+	5YR 2/3	C	7.95	0.77
LM 49 - 1	0 - 35	7.5YR 2/2	CL	10.45	2.87
- 2	35 - 100+	7.5YR 3/3	Scl	10.50	2.62
LM 50 - 1	0 - 35	7.5YR 3/2	C	10.40	3.75
- 2	35 - 110	5YR 4/3	C	10.20	2.12
- 3	110 - 140	7.5YR 3/4	C	9.60	1.50
- 4	140 - 200+	7.5YR 5/3	C	9.65	1.20
LM 51 - 1	0 - 30	7.5YR 4/2	C	8.80	0.82
- 2	30 - 100	5YR 4/2	C	9.50	0.90
- 3	100 -	5YT 3/2	C	9.60	0.85
LM 52 - 1	0 - 25	5YR 2/3	C	7.70	2.25
- 2	25 - 65	5YR 3/3	C	7.75	2.00
- 3	65 - 145+	5YR 3/3	C	9.40	1.37
LM 53 - 1	0 - 15	2.5YR 2/4	C	8.40	0.32
- 2	15 - 75	2.5YR 3/3	C	8.50	0.07
- 3	75 - 100+	5YR 3/4	CL	8.90	0.25
LM 56 - 1	0 - 25	5YR 2/3	C	7.95	0.30
- 2	25 - 95	2.5YR 2/4	C	7.75	0.05
- 3	95 - 150+	2.5YR 3/3	C	7.95	0.10
LM 58 - 1	0 - 20	5YR 2/2	C	8.20	0.90
- 2	20 - 80	5YR 2/3	CL	7.10	1.05
- 3	80 - 140	5YR 3/3	L	7.70	3.00
- 4	140 - 200+	5YR 4/3	CL	9.20	1.67
LM 59 - 1	0 - 20	5YR 2/3	CL	8.55	0.37
- 2	20 - 60	5YR 2/4	C	8.05	0.20
- 3	60 - 110	5YR 3/3	CL	8.50	0.35
LM 60 - 1	- - 30	5YR 2/3	C	6.60	0.45
- 2	30 - 110	5YR 2/4	C	7.00	0.08
- 3	110 - 200+	5YR 3/3	C	7.80	0.35
LM 62 - 1	0 - 20	5YR 4/3	C	7.40	0.60
- 2	20 - 100	2.5YR 4/4	C	7.20	0.15
- 3	100 -	2.5YR 2/3	CL	7.00	6.25
LM 63 - 1	0 - 20	5YR 3/4	CL	7.80	0.55
- 2	20 - 50	5YR 3/3	CL	7.10	7.00
- 3	50 - 120+	5YR 3/4	L	7.90	11.50
LM 64 - 1	0 - 30	2.5YR 2/4	C	6.80	0.18
- 2	30 - 65	2.5YR 2/3	C	6.00	0.14
- 3	60 - 120+	5YR 3/4	C	6.20	0.13

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Table III-9(5) FIELD TEST RESULTS OF SOIL SALINITY AND ALKALINITY

(Lower-Moshi Area)

PIT No. & HORIZON	DEPTH (cm)	SOIL COLOUR (when wet)	SOIL TEXTURE	pH	ECe (m.mhos/cm)
LM 65 - 1	0 - 25	5YR 3/3	CL	7.65	0.57
- 2	25 - 90	5YR 3/4	C	7.20	6.50
- 3	90 - 130+	5YR 3/4	CL	7.05	9.75
LM 66 - 1	0 - 35	5YR 3/2	C	7.20	0.37
- 2	35 - 90	2.5YR 3/3	C	6.60	0.35
- 3	90 - 150+	5YR 2/4	C	7.00	7.00
LM 68 - 1	0 - 25	2.5YR 3/2	CL	7.05	0.23
- 2	25 - 65	2.5YR 2/4	C	7.40	0.16
- 3	65 - 110	2.5YR 2/4	C	8.30	0.30
- 4	110 - 140+	2.5YR 2/4	CL-SL	8.40	0.55
LM 69 - 1	0 - 30	5YR 2/3	CL	7.30	0.60
- 2	30 - 100+	2.5YR 2/3	C	6.50	0.14
LM 70 - 1	0 - 40	5YR 3/4	C	7.30	0.53
LM 71 - 1	0 - 15	5YR 3/3	C	7.30	0.35
- 2	15 - 70	5YR 3/3	C	7.20	0.14
- 3	70 - 140+	5YR 3/4	C	7.65	0.18
LM 74 - 1	0 - 10	5YR 3/2	C	7.30	0.35
- 2	10 - 40	7.5YR 3/4	C	7.50	2.67
- 3	40 - 110+	5YR 3/3	C	7.50	0.17
LM 75 - 1	0 - 20	5YR 2/3	C	6.80	0.35
- 2	20 - 70	5YR 3/3	C	7.20	0.27
- 3	70 - 150+	2.5YR 3/3	C	7.30	0.12
LM 77 - 1	0 - 15	2.5YR 3/4	C	6.90	3.25
- 2	15 - 120	2.5YR 2/3	C	7.00	2.30
- 3	120 - 150+	2.5YR 3/3	C	8.90	0.65
LM 78 - 1	0 - 25	5YR 2/3	C	8.40	0.52
- 2	25 - 75	5YR 3/3	C	8.90	0.45
- 3	75 - 230+	5YR 3/3	CL	9.10	0.65
LM 79 - 1	0 - 15	5YR 3/2	C	7.60	0.23
- 2	15 - 55	2.5YR 3/3	C	7.80	0.14
- 3	55 - 100	2.5YR 3/3	C	7.80	0.13
- 4	100 - 125	2.5YR 3/4	CL	7.80	0.14
- 5	125 - 210+	5YR 2/2	C	8.00	0.14
LM 80 - 1	0 - 20	5YR 3/3	C	7.20	0.53
- 2	20 - 110	2.5YR 3/3	C	7.20	0.35
- 3	110 - 150+	2.5YR 3/4	C	8.40	0.24
LM 81 - 1	0 - 15	5YR 2/3	C	7.00	0.35
- 2	15 - 95	5YR 3/4	CL	6.10	0.78
- 3	95 - 150+	5YR 3/4	C	7.20	0.09

- continued -

Table III-9(6) FIELD TEST RESULTS OF SOIL SALINITY AND ALKALINITY

(Lower-Moshi Area)

PIT No. & HORIZON	DEPTH (cm)	SOIL COLOUR (when wet)	SOIL TEXTURE	pH	ECe (m.mhos/cm)
LM 82 - 1	0 - 25	YR 3/3	C	6.70	0.37
- 2	25 - 55	5YR 3/3	C	7.10	0.13
- 3	55 - 110	5YR 3/4	C	7.30	0.03
LM 83 - 1	0 - 20	5YR 2/4	C	7.20	0.45
- 2	20 - 60	2.5YR 3/3	C	6.60	0.03
- 3	60 -	2.5YR 3/4	C	6.50	
LM 84 - 1	0 - 20	5YR 2/3	C	7.00	0.20
- 2	20 - 70	5YR 3/4	C	7.20	0.03
- 3	70 - 110	5YR 3/4	C	7.60	0.03
LM 85 - 1	0 - 10	5YR 2/2	C	7.60	0.33
- 2	10 - 40	5YR 3/3	C	7.60	0.08
- 3	40 - 70	2.5YR 2/3	C	7.50	0.13
- 4	70 - 115	5YR 3/4	C	7.50	0.08
LM 86 - 1	0 - 15	5YR 3/1	CL	7.50	0.20
LM 87 - 1	0 - 10	5YR 2/3	C	7.80	0.08
- 2	10 - 40	5YR 2/2	C	7.90	0.08
- 3	40 - 100	5YR 3/3	CL	8.70	0.07
LM 88 - 1	0 - 20	5YR 2/3	C	7.60	0.10
- 2	20 - 60	5YR 3/3	C	7.80	0.08
- 3	60 - 100*	5YR 3/6	C	7.60	0.03
LM 89 - 1	0 - 15	5YR 3/3	C	7.90	0.47
- 2	15 - 65	2.5YR 2/3	C	9.90	
- 3	65 - 120+	5YR 2/4	C	9.60	1.15
LM 90 - 1	0 - 20	2.5YR 2/1	C	8.80	1.00
- 2	20 - 50	5YR 3/3	C	10.40	2.25
- 3	50 - 100	5YR 3/4	C	9.90	1.85
- 4	100 - 150+	7.5YR 3/4	C	9.20	0.73
LM 93 - 1	0 - 15	2.5YR 2/4	C	7.10	0.25
LM 94 - 1	0 - 20	5YR 2/4	C	6.70	0.05
- 2	20 - 130	2.5YR 3/3	C	6.80	0.05
- 3	130 -	2.5YR 3/4	CL	8.10	0.32
LM 95 - 1	0 - 25	7.5YR 3/1	C	8.40	2.15
- 2	25 - 50	5YR 4/1	C	8.50	7.75
- 3	50 - 100+	2.5YR 4/1	C	8.90	9.50
LM 96 - 1	0 - 20	5YR 2/2	C	6.90	0.48
- 2	20 - 45	2.5YR 3/4	C	8.10	0.27
LM 97 - 1	0 - 25	5YR 3/3	C	7.00	10.25
- 2	25 - 80	5YR 2/4	C	7.10	6.50
- 3	80 - 150+	5YR 2/4	C	7.10	5.75

- continued -

Table III-9(7) FIELD TEST RESULTS OF SOIL SALINITY AND ALKALINITY

(Lower- Moshi Area)

FIT No. & HORIZO	DEPTH (cm)	SOIL COLOUR (when wet)	SOIL TEXTURE	pH	ECe (m.mhos/cm)
LM 98 - 1	0 - 25	2.5YR 2/4	C	6.90	0.15
- 2	25 - 100	2.5YR 3/2	C	7.40	0.05
- 3	100 - 200+	5YR 3/3	C	7.60	0.05
LM 100- 1	0 - 20	5YR 2/2	CL	7.90	0.20
- 2	20 - 65	5YR 2/4	C	9.40	0.53
- 3	65 - 110	5YR 3/3	CL	9.30	0.65
- 4	110 -	6 3/6	Ls	9.30	0.47
LM 101- 1	0 - 25	10R 3/2	C	7.90	0.20
- 2	25 - 80	10R 3/2	C	7.70	0.57
- 3	80 -	10R 3/3	C	7.50	0.20
LM 39 - 4				7.40	0.27

ANNEX IV

IRRIGATION AND DRAINAGE

FEASIBILITY REPORT

ON

THE LOWER-MOSHI AGRICULTURAL DEVELOPMENT PROJECT

ANNEX IV. IRRIGATION AND DRAINAGE

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ANNEX IV IRRIGATION AND DRAINAGE

1. Existing Irrigation System

1.1 Existing Irrigation System

On the slope of Mt. Kilimanjaro between El. 900 - 2,000 m, a great number of small-scale irrigation systems have prospered for centuries. Such irrigation systems are called "traditional furrows" because of then ancient origin and small canal size. The traditional furrows have no legal water rights.

There are presently 40 irrigation intakes in the Lower Moshi area, of which 28 are distributed along the Rau river, 12 along the Njoro river and 3 each along the Mue and Himo rivers. The Kahe irrigation project is the biggest project in the Lower Moshi area; it was constructed in 1970 as a national project and is now operated by the National Agricultural and Food Corporation (NAFCO) in Kahe. NAFCO is growing maize and other food crops drawing the irrigation water from the Miwalwni springs. There are three borehole irrigation schemes operating in Uchira village. They are called Miwaleni borehole Nos. 1, 2 and 3, of which borehole No.1 belongs to the Miwaleni Experimental Sub-station of the Ministry of Agriculture, and the others are for village use. The locations of the existing irrigation schemes are shown in Fig. IV-1 and the features are listed in Table IV-1.

There are more than 40 intakes from rivers in the Lower Moshi area, of which very few are provided with weirs, either made from banana leaves and logs or concrete. Most traditional furrows have no structure to secure the necessary water level at their intakes, which supposedly ariginates from the difficulty in maintaining banana leaf weirs against flooding.

The Njoro river, which is fed by a group of Njoro springs, has fairly constant perennial flows, and therefore is the most easily usable river in the Lower Moshi area. There are 12 intakes, most of which have no weir, but all were taking water for paddy cultivation in the investigation period.

The Mue river has 2 intakes in the stretch from the national road to the Miwaleni confluence, but they are almost totally destroyed. The Mue itself is dried up from September to February upstream of the Miwaleni confluence.

The Himo has two concrete weirs constructed by the Department of Irrigation downstream for the Taveta road. Although the river has a perennial flow, the valley is formed by 20 m high cliffs on both sides near Himo town, gradually getting shallower downstream; this topography counteracts farmers' efforts to set up intake structures. The downstream weirs do not seem to function well, because lots of cobble are placed by farmers on the crest of weir to raise the intake water level, but still the intake flow seems to be very small.

Under the present conditions of intake structures, regardless of with-weir or non-weir, a regulated and stable intake cannot be expected. Where there are too many traditional furrows in a short distance, like the Rau and Njoro rivers, integration of neighbouring intakes is needed. Newly constructed weirs should be permanent ones made of concrete.

Most canals in the Lower Moshi area are unlined earth canals; the only exception are the Miwaleni borehole irrigation schemes which have concrete lined canals. The biggest problem for earth canals is the seepage loss. According to the investigation of canal seepage, a canal from the Himo river runs on the steep valley wall about one kilometer from the intake up to the plateau, losing 62 % of the discharge in this stretch (eg. 0.315 m^3/sec at the intake and 0.119 m^3/sec at 1 km downstream).

The existing canals are entirely lacking of or very poorly provided with structures, such as division structures, bridges or culverts, crossing drains, measuring devices, etc. Without such structures, canals cannot function fully or be free from damage.

Measures should be taken to decrease the canal losses by means of concrete lining, etc. At the same time necessary structures should be installed in proper places in order to achieve proper functioning of the irrigation system.

1.2 Water Rights

The water utilization (Control and Regulation) Act was enacted in 1974 and then supplemented by subsidiary legislation published in October 1975. According to the regulation, an application for water rights is examined by the Ministry of Water Development and Power and the Ministry of Agriculture. The Water Advisory Board to be formulated on that occasion makes the final decision for the grant of water rights. The application should be attached with fees, but after the grant is published, the users are entitled not to pay any charge for the water use. No one is allowed to take water from any sources without a granted water right. However, there exist in fact plenty water users who have had traditional unwritten water rights.

The Government Notice No. 242 published in October 1975 declared that the major water resources in the country to be the national water supply sources, in which the Rau, Mue and Himo rivers and Miwaleni springs were included. As regards these rivers, control and regulation of water utilization are dealt with on the national level.

Granted water rights in the Lower Moshi area totals 136.9 cusecs (3.88 m^3/sec): 20.8 cusecs for four schemes in the Rau, 108 cusecs (3.06 m^3/sec) for one scheme from Miwaleni springs and 8.1 cusecs (0.23 m^3/sec) for four schemes in the Himo. Each water right is as shown in Table IV-2.

1.3 Irrigation Practice

There are various irrigation practices with different irrigation times in and around the Project Area. TPC is undertaking both the sprinkler irrigation (24 hours a day with two shift operation) and the furrow irrigation. NAFCO is carrying on the border irrigation, 16 hours a day with two shifts. And in Chekereni Village the furrow and border irrigation is undertaken 24 hours a day: on the communal plots from 6 A.M. to noon, and on the individual plots from noon to 6 A.M. throughout night.

In the case of the TPC sprinkler method and Chekereni Village, no regulating pond is necessary, but in case of NAFCO, a regulating pond is principally needed in ordinary irrigation practice. In any irrigation system, if the delivery hour of the canal differs from the irrigation hour in fields, a regulating pond has to be provided.

In the Lower Moshi area, the water resources are more scarce than any other resources, such as land, labour etc. Therefore, it would be logical to plan 24-hour intake from rivers or springs and to provide certain means to adjust the difference between the delivery and irrigation hours, if any.

As for on-farm irrigation practice, the prevailing method is both inefficient and non-disciplinary. The main reason of inefficiency may be attributed to the cultivation method adopted and the topographical condition of land. The upland field customarily is ploughed by tractor and planted with crops without any harrowing and ridging; therefore, the ground surface is so rough that no kind of irrigation method seems to be applicable except overhead irrigation. Besides, there are small undulations of the ground surface which further accelerate inefficiency. Due to the undulations, certain areas in a plot are always either non-irrigated or overirrigated, and fluctuation in unit yields by plot or within a plot are exagerated in the dry season. In order to avoid the effect of unfavourable micro-topography, farmers try to divide their field into very small irrigation units, 10 meters square or less, which then apparently lowers the irrigation efficiency.

In the Project area, modern scientific surface irrigation is seen in Miwaleni Experimental sub-station, where the land grading was primarily conducted with terrace formation. Fields are located to give milder irrigation slopes with some intersecting angles toward contour lines. The water is supplied into furrows with syphon pipes.

Plot rearrangement or land consolidation is more effective where plots are of small size and irregular shape. It necessitates the land grading or levelling.

2. Irrigation Water Requirement

2.1 General

The crops proposed in the Project are paddy rice and upland crops such as maize, cotton, pulses, soybeans, vegetables, etc. The irrigation water requirements for them are separately estimated based on the proposed cropping pattern. The irrigation water requirement consists of crop water consumption, irrigation losses, and ancillary water demands for respective crops.

The irrigation water requirements for the Project are estimated on a monthly basis, using daily climatic data for estimating crop water consumption and the effective rainfall.

The irrigation water requirements are estimated by the following procedure:

Paddy Rice

- Estimate of paddy rice water consumption from potential evapotranspiration calculated by climatic data and crop coefficients varying with growth stages, CU.
- Estimate of percolation rate, P.
- Estimate of effective rainfall, ER.
- Estimate of nursery water, NW, and puddling water requirement, PW.
- Estimate of net irrigation water requirement NR.

  $NR = CU + P - ER + NW + PW$
- Estimate of gross irrigation water requirement, GR, based on NR divided by irrigation efficiency.

Upland Crops

- Estimate of crop water consumption, CU.
- Estimate of pre-irrigation water, PI.
- Estimate of effective rainfall, ER.
- Estimate of net irrigation water requirement, NR.

  $NR = CU + PI - ER$
- Estimate of gross irrigation water requirement, GR, based on NR divided by irrigation efficiency.

2.2 Water Consumption

2.2.1 Potential evapotranspiration

Crop water consumption is estimated as a product of potential evapotranspiration (PET) calculated from climatic data and crop coefficients (Kc) relating crop growth stages. The modified Penman method[1], being generally accepted as the most accurate prediction method, is employed since the climatic data necessary for applying the method is adequate in and around the Project area. At three locations (Moshi, Miwaleni and Arusha Chini), the data were made available. They are situated transversely from north to south and at altitudes which decrease to the south. Their potential evapotranspiration is estimated by the modified Penman method as shown below. The detailed calculations are presented in Table IV-3.

Location	Meteorological station	Data used
Moshi	Moshi Meteorological Station	1970 to 1979
Miwaleni	Miwaleni Agricultural Experimental Sub-station	1972 to 1979
Arusha Chini	Tanganyika Planting Company	1970 to 1979

Unit: mm/day

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Moshi	5.8	5.9	5.6	4.7	3.9	3.4	3.8	4.1	5.1	5.8	5.7	5.7
Miwaleni	6.1	6.3	6.1	5.4	4.4	4.0	4.0	4.6	5.5	6.0	6.2	6.4
Arusha Chimi	5.7	5.9	6.0	4.9	4.4	3.8	3.9	4.4	5.2	5.7	5.7	5.7

It is noted that there is no distinct trend based on altitude difference between three locations, but the maximum values of potential evapotranspiration in all months occur at Miwaleni which is located in-between the others and in the central part of the Project area. Therefore, potential evapotranspiration at Miwaleni is used in estimation of the irrigation water requirement for all the schemes.

Note: [1]: Irrigation and Drainage Paper, Crop Water Requirements, revised 1977, FAO.

2.2.2 Crop coefficient

The proposed cropping pattern consists of paddy rice, maize, cotton, pulses, soybeans, vegetables and perennial plants such as banana, coffee. The crop coefficients differ according to kind of crop, time of planting or sowing, stage of crop development and climatic conditions. The determination of crop coefficients of the proposed crops in the Project area is primarily based on the before mentioned FAO publication since it provides the information for all the crops for the Project and is well agreed with the applied water consumption prediction method.

In determination of crop coefficients for the proposed crops, the crop growing seasons of each crops is divided into four stages according to the FAO publication, and crop coefficient curves are established, as shown in Fig.IV-2. The average crop coefficients are estimated on the half monthly bases for the proposed crop timing as shown in Table IV-4.

2.2.3 Water consumption

Water consumption by each proposed crop is calculated by multiplying potential evapotranspiration by crop coefficient as shown in Table IV-5.

2.3 Percolation

The field measurements of vertical percolation rate in the existing paddy field in Msaranga Mandaka Village were carried out during the field investigation by means of cylindrical instruments together with measurements of rice water consumption. The soil in the field test is a type of clay. The test results show the average consumption rate was 1 mm/day. The soil profile survey made in the Project area revealed that the soils in the proposed paddy field were clay to clay loam. The vertical percolation rate in those soils will be 1.0 mm/day to 2.0 mm/day. Thus, the percolation rates of 1.0 and 2.0 mm/day in respective rainy and dry seasons was adopted in estimating the water demand of the paddy field of the Project.

As regards horizontal percolation, it functions to supply water to adjacent fields. Thus, such percolation will not need to be considered in estimation of the overall irrigation requirements.

2.4 Other Water Demands

2.4.1 Puddling water requirements

The puddling water requirements to be supplied before puddling work consists of water equivalent to the difference in soil moisture before and after puddling, the standing water required above soil surface and evaporation and percolation losses from paddy field. The amount is largely subjected to such factors as soil characteristics, puddling method and period, groundwater table depth in the field, etc. In view of these factors, the puddling water is assessed as follows:

(i) Depth of soil and porocity

Surface soil : 20 cm 50 %
Subsoil : 10 cm 50 %

(ii) Soil vapour phase after puddling : 5 %

(iii) Soil moisture before water supply : 15 %

(iv) Water to be supplied

Water to be supplied to soil profile : 90 mm
Evaporation : 40 mm
Percolation : 10 mm
Standing water depth after puddling : 40 mm
Total 180 mm

The puddling water requirement schedule is as shown in Table IV-6.

2.4.2 Nursery water requirements

The nursery water requirements consist of water needed for preparation of nursery bed, and evapotranspiration and percolation during the nursing period. The water requirement is estimated under the following conditions, with details shown in Table IV-7.

(i) Area required for nursery bed : 1/20 of paddy field

(ii) Nursery period : 25 days

(iii) Required water for 25 days

Preparation of nursery bed : 180 mm
Evapotranspiration : 7 mm/day
Percolation, 2 mm/day : 50 mm

2.5 Effective Rainfall

The effective rainfall for crops is estimated by means of the daily water balance method, under the following conditions:

1) Rainfall less than 5 mm/day is considered ineffective.

2) Water holding capacity in the soil profile is 80 mm, then the excess rainfall above 80 mm is considered ineffective,

3) When the soil profile dries up to 80 mm, irrigation of 80 mm is supplied.

4) Potential evapotranspiration is employed for water consumption from the soil profile

As explained in ANNEX I, HYDROLOGY, the rainfall intensity and depth vary with locations over the Project area. To estimate the effective rainfall to suit such different rainfall characteristics in the envisaged irrigation scheme areas, effective rainfall at Miwaleni, Kahe, Himo and Moshi for 20 years are estimated as shown in Table IV-8. Probable effective rainfalls are estimated as shown in Table IV-9. Among them, effective rainfall with 80% dependability as shown below is applied to the Project.

Unit: mm/month

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Miwaleni												
	0	6	14	88	41	0	0	0	0	0	9	8
Himo												
	0	8	22	63	43	0	0	0	0	0	24	9
Kahe												
	6	0	8	70	25	0	0	0	0	0	4	5
Moshi												
	0	6	16	86	38	0	0	0	0	0	10	0

2.6 Irrigation Efficiency

The proposed land use plan of the Project consists of paddy field and upland field irrigation farming. Thus, the irrigation efficiency for each plan is assessed as follows:

As regards the irrigation method to be applied for upland fields in the Project area, a furrow irrigation method will be favorable in view of topography and soil texture as detailed in the succeeding section. Irrigation losses in the fields, generally, are dealt with as an application loss. It includes deep percolation and surface runoff. The extent of such losses will depend on a number of different factors. Among them, the most influential factor is the skillfulness and intensiveness of irrigators to practice good water management. In estimating the application efficiency, an approximate standard which is commonly used in the United States /1 is employed. According to the standard, an application efficiency of a furrow irrigation method between 60% to 70% averaging 65% is expected after the complete exploitation of the Project. Whereas, in the paddy field where the continuous water supply will be practiced, the application efficiency of 85% is employed in consideration of surface runoff to drains during water supply.

During conveyance of water from an intake to fields, seepage and canal operational losses occur. The magnitude of the losses depends on the type of canal, provision of lining and canal operation and maintenance. Taking into account these conditions for the Project, conveyance losses of 90% and operation losses of 80% to 85% are adopted.

Therefore the overall irrigation efficiencies for respective paddy and upland fields are estimated as summarized below.

	Paddy field	Upland field
Application efficiency	85 %	65 %
Operation efficiency	80	85
Conveyance efficiency	90	90
Overall efficiency	61	50

2.7 Diversion Water Requirements

The diversion water requirement for the Project is estimated based on the effective rainfall with a dependability of 80%. The diversion requirement is computed by dividing the net water requirement by the overall irrigation efficiency. To meet the varied climatic conditions over the Lower Moshi area, the effective rainfall at the following stations is applied for the respective irrigation schemes.

Miwaleni Sub-station:	Rau River System Upper Mabogini, Mabogini and Rau Ya Kati schemes Miwaleni Pump Lift schemes North Groundwater and East Groundwater schemes
Kahe NAFCO Station :	Rau River System Chekereni schemes
Himo Sisal Estate :	Himo River System Makuyuni and Ghona & Kileo schemes

Based on the principal figures as calculated above and the effective rainfall for each scheme, the irrigation water requirement for each crop is first calculated as shown in Table IV-10. Then, according to the cropping patterns of each scheme, the diversion water requirements are calculated as shown in Table IV-11, 12 and 13 and summarized below.

	J	F	M	A	M	J	J	A	S	O	N	D
Rau River System												
Upper Mabogini (m^3/sec)	0.04	0	0.04	0.20	0.14	0.17	0.08	0	0.01	0.09	0.08	0.09
Mabogini (m^3/sec)	0.33	0.13	0.33	1.08	0.75	0.95	0.49	0.07	0.15	0.52	0.52	0.56
Rau Ya Kati (m^3/sec)	0.18	0.10	0.19	0.58	0.40	0.51	0.27	0.04	0.09	0.28	0.27	0.30
Chekereni (m^3/sec)	0.34	0.13	0.33	1.11	0.86	0.95	0.49	0.07	0.17	0.53	0.55	0.60
Miwaleni Pump Lift (m^3/sec)	0.44	0.24	0.94	1.44	1.56	2.00	0.92	0.31	0.34	0.90	0.88	0.91

J	F	M	A	M	J	J	A	S	O	N	D
Himo River System											
Makuyuni (m^3/sec)											
0.22	0.11	0.30	0.18	0.32	0.44	0.20	0.18	0.20	0.21	0.18	0.07
Ghona & Lotima (m^3/sec)											
0.02	0.09	0.26	0.34	0.37	0.48	0.23	0.16	0.18	0.20	0.18	0.07
North Groundwater for 60-ha scheme (ℓ/sec)											
0	13	38	12	41	53	24	39	42	54	52	15
East Groundwater for 30-ha scheme (ℓ/sec)											
0	7	19	6	20	26	12	20	22	29	27	8

3. Soil Characteristics and Irrigation Schedule

3.1 Available Soil Moisture

The available moisture holding capacity of the soil is expressed as the moisture amount held by the soil in the range between the field capacity and the wilting point. The terms "Field Capacity" and "Wilting Point" are defined by the Soil Science Society of America as follows:

Field Capacity :	the moisture content of a deep, permeable, well-drained soil several days after a deep melting
Wilting Point :	the moisture content at which the leaves of a test plant growing in the soil fail to regain turgidity in a saturated atmosphere

These approximate values are obtained for each soil in the laboratory test. For loam or finer textured soil, the moisture level at 1/3 atmosphere tension usually is considered to be the field capacity. The wilting point corresponds to the moisture held at an atmosphere tension of 15. Soil moisture content near the wilting point, however, is not readily available to the plant; this varies with the type of crop. Some crops, such as vegetables, potatoes and onions, require relatively wet soil to produce acceptable yields. Other crops such as cotton and maize will tolerate high soil water depletion levels. The Irrigation and Drainage Paper, Crop Water Requirements by FAO, 1977 gives the depletion levels for each crop as a fraction of the total available soil water (Field capacity minus initial wilting point).

The soil moisture relationships of the soils taken at 3 sites were analysed in the laboratory. The results are plotted logarithmically to indicate the relation between moisture stress and moisture content (Fig.IV-3). The total available soil water is determined for the range between atm. 0.2 and atm. 2.5. The results are summarized below.

Pit No.	Total Available Soil Moisture (mm/M)	Soil Characteristics
LM - 15	135	loam
LM - 45	250	clay
LM - 55	170	clay

For the subsequent discussion on irrigation schedule, it seems preferable to classify the soil into two groups according to the available water and the soil texture as follows:

Category	Total Available Soil Water
Fine soil	200 mm/M
Medium soil	140 mm/M

3.2 Intake Rate

3.2.1 Cylinder intake rate

The cylinder intake rate tests were carried out at ten sites with representative soils in the envisaged irrigation scheme areas. The locations of test sites are as shown in Fig.IV-4. The basic intake rate which is used for the design of irrigation is defined as the intake rate at which water absorption into soil becomes nearly constant after water supply.

The relationships between the accumulated intake depth of water and the elapsed time, and the intake rate and the elapsed time are graphically analysed. The accumulated intake are expressed by the following formula when the test data are plotted on log paper on the vertical axis and time on the horizontal axis.

$$D = CT^n$$

where; D = Accumulated intake of the soil (mm)

C = Accumulated intake intercept at unit time

T = Time that water is on the surface of the soil (min)

n = Slope of the line

By differentiating the above formula, the intake rate is expressed by: $I = C \cdot n \cdot T^{n-1}$.

The basic intake rate, I_B, is practically obtained as the intake rate at the elapsed time of 600(1-n) minutes after test commencement.

$$I_B = 60 \cdot C \cdot n \cdot \left[600(1-n)\right]^{n-1}$$

The basic intake rates for each test site are calculated as shown in Table IV-14. The test results show that the basic intake rates lies between 5 to 50 mm/hr, of which higher values are observed in the northern and eastern steep areas extending on fine textured colluvium. For irrigation planning, the Project area is broadly classified into three categories according to the magnitudes of the basic intake rate as shown below.

Category	Average Basic Intake Rate (mm/hr)	Area
1. High	50	Makuyuni, Upper Miwaleni
2. Moderate	20	Mabogini, Mandaka, Chekereni, Miwaleni, Rilereni
3. Low	10	Lower Miwaleni, Soko, Kileo

3.2.2 Furrow intake rate

The furrow tests were carried out by means of diverting different size streams into several furrows and checking the rate at which the stream fronts advance down them. The representative sites of furrow tests were selected in Chekereni and Miwaleni in view of soil characteristics and water availability for testing. The testing furrows are those with land slopes of 0.5 % and 0.3 % using typical furrows with length, interval and depth are 100 m, 60 cm and 30 cm. The results are as shown in Fig.IV-5, the rate of advance curve.

In general, furrows in the field should be long enough to permit economical handling of farm equipment but not too long for safe irrigation. Evaluation of the furrow irrigation system is extremely important. Erodibility of the soil, size of the stream, steepness of the slope, and shape of the furrow should be carefully determined. Experience gained indicates that the intake rate under irrigated condition was as small as one-third to a half of that of virgin conditions. Because of lack of enough information for evaluation of the future conditions to cover the whole Project area inclusive of the above principal items, irrigation planning is supplemented by the commonly used criteria[1] prepared by U.S.D.A.

The minimum allowable stream is given by the following empirical formula:

$$Q = \frac{10}{S} \text{ (gallon/min)}$$

$$\fallingdotseq \frac{37.9}{S} \text{ } (\ell\text{/min})$$

where; Q = Maximum allowable stream

S = Irrigation slope in percent

The results of the field tests showing the maximum unit streams of 2 ℓ/s and 3 ℓ/s for irrigation slopes of 0.3 % and 0.5 % indicated that this formula was applicable to the Project area.

3.3 Irrigation Schedule

Field irrigation schedules are based on the crop water balance and are expressed in depth and interval of irrigation. Depth of irrigation application is the depth of water that can be stored within root zone between the field capacity and the allowable soil depletion level of water which is easily made available for crops, as mentioned in the previous section.

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[1] Instruction and Criteria for Preparation of Irrigation Guides. United State Department of Agriculture, Soil Conservation Service

Total readily available soil water for crops is calculated from the total available soil water and the allowable soil depletion level, which is expressed as a fraction of the total available soil water. Net depth of irrigation application is determined for the expected rooting depths of crops. The following table shows the total readily available soil water and the net depth of irrigation application at the full development stages of crops.

		Readily Available Soil Water			Net Depth of Irrigation Application	
Crop	Fraction of[1] Total Available Soil Water	Fine Soil (mm/M)	Medium Soil (mm/M)	Rooting[1] Depth at Full Growth Stage (mm)	Fine Soil (mm)	Medium Soil (mm)
Maize	0.6	120	80	1.0	120	80
Cotton	0.65	130	90	1.0	130	90
Pulses	0.45	90	65	0.6	54	39
Soybeans	0.5	100	70	0.6	60	42
Vegetables						
Onions	0.25	50	35	0.25	25	18
Tomatoes	0.4	80	60	0.40	56	42
Cabbages	0.45	90	65	0.45	36	26

Irrigation intervals can be calculated with the information on the net depth of irrigation application and the rate of evapotranspiration as follows:

$$\text{Irrigation Interval (day)} = \frac{\text{Net Depth of Irrigation Application (mm)}}{\text{Evapotranspiration Rate (mm/day)}}$$

The irrigation intervals of the proposed crops at the highest rate of water consumption are calculated as follows:

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[1] Refers to the generalized data on root depth of full growth crops, fraction of available water and readily available soil water, Crop Water Requirements, prepared by FAO, 1977.

Crops	Maximum Water Consumption (mm/day)	Irrigation Intervals			
		Fine Soil		Medium Soil	
		Net Application Depth (mm)	Interval (day)	Net Application Depth (mm)	Interval (day)
Maize	6.9	120	17	80	11
Cotton	6.9	130	18	90	13
Pulses (Beans)	6.9	54	7	39	5
Soybeans	6.6	60	9	42	6
Vegetables					
Onion	6.3	25	3	18	2
Tomatoes	7.0	56	8	42	6
Cabbages	6.3	36	5	26	4

Timing of irrigation is principally needed to conform to soil water depletion requirements of the crops which varies with crop growth stages. Therefore, considerable flexibility in time and depth of irrigation should be considered to accommodate distinct difference in various crop water needs. In planning, for deep rooting crops, such as maize and cotton, and for shallow rooting crops such as pulses, soybeans and vegetables, the following schedules are taken.

	Net Depth of Irrigation Application (mm)	Irrigation Interval (day)
Deep rooting crops	80	10
Shallow rooting crops	40	5

4. Irrigation Method and Field Layout

4.1 Selection of Irrigation Method for Upland Field

Irrigation efficiency varies with the irrigation method effected by many factors among which the most influential factor is the basic intake rate of the soil. The basic intake rates in the Project area were found to be 10 mm to 50 mm as described in section 3.2.1. The allowable basic intake rate of all the irrigation methods is less than 75 mm/hr. Thus from the viewpoint of the basic intake rate, any irrigation method could be used in the Project area.

The land slope is another important factor for selection of the irrigation method. The upland field in the land use plan of the Project is contemplated to be implemented in the rather steep area. The surface irrigation method requires a mild and smooth field surface to attain the desired irrigation efficiency, whereas, the sprinkler method adapts to all land slopes without the land levelling.

In making the choice of the best suited irrigation method in the Project area, a comparison was made to select the representative area in the groundwater scheme area. In the area, the basic intake rate is high, and the land slope is relatively steep. Further, irrigation is made by the high head pumping up water lifted from tube wells, i.e., by expensive irrigation water.

The following shows the basic irrigation plans for the surface method and sprinkler method in the north groundwater area.

4.1.1 Basic plans of surface and sprinkler irrigation

(1) Irrigation efficiency

Topography in the area is rather steep and the soil has high intake rates. Thus, the irrigation efficiency of the surface method in the area is selected as 60 % which differs from the other areas of 65% as mentioned in Section 2. The canal is of open type and is lined with concrete up to the field outlet. The conveyance efficiency will be 90 % because of the short length of concrete lined canals.

The application efficiency of the sprinkler method is determined by such factors as the irrigation application depth, the peak consumption requirement and climatic conditions. The sprinkler irrigation losses consist of evaporation loss, deep percolation loss, and other operational losses such as surface runoff. In view of high wind velocity and low relative humidity in the area, the evaporation loss is inherently high. Therefore, an application efficiency for the sprinkler method of 70 % is selected in this study. Since all the distribution system is of buried pipe type, the conveyance efficiency is set at 95 %.

In consideration of the above, the irrigation efficiency for each method is as follows:

	Surface Method	Sprinkler Method
Application efficiency	0.55	0.70
Conveyance efficiency	0.90	0.95
Overall efficiency	0.50	0.67

(2) Irrigation water requirement and command area

The irrigation water requirements for the respective plans are calculated based on the proposed cropping pattern of the groundwater scheme and the expected irrigation efficiency as shown in Table IV-15. Therefore, the command area of a tube well will be 60 ha and for the surface and sprinkler methods, 70 ha.

(3) Irrigation system layout

The surface irrigation method will be a furrow method. The field layout is such that the field ditches from which the water is supplied to the field are placed following the contour, and the tertiary canals which supply water to the field ditches are constructed parallel to the field ditches. The furrow direction is selected to intersect the general ground slope at about 45°, to reduce the levelling requirement. As irrigation operation in the peak demand period is practiced 18 hours a day, a regulating pond is needed to store the difference in continuous water supply from the tube well and the intermittent diversion to the field. The layout is as shown in Fig. IV-6.

The distribution system of the sprinkler system is a buried pipeline system and a semi-portable lateral, on which the sprinkler sets are attached, is contemplated. The irrigation system comprises 5 tertiary pipelines, 2 secondary pipelines and a lead pipeline. The sprinkler set selected should be the medium pressure type in consideration of the following: (1) more uniform distribution pattern normally results from longer settings, (2) most users prefer systems requiring less moving per day and (3) there is a tendency toward soil structure improvement where application rates lower than necessary are selected.

Since the tube well pump operates continuously for 24 hours and the sprinkler operation contemplated is also to be 24 hours, no storage reservoir is provided in the system. The sprinkler system layout is as shown in Fig. IV-6.

The operation methods of each plan is presented in Table IV-16. The general features of the facilities are as shown in Table IV-17.

4.1.2 Comparison of surface and sprinkler irrigation

The comparison of the construction cost is made for the surface irrigation method commanding 60 ha, and the sprinkler irrigation method serving 70 ha in case the systems are contemplated in the groundwater area. The cost includes only the direct construction cost for irrigation, drainage and road systems, exclusive of well and power line construction. The results are as shown in Table IV-18. The results indicate that the construction cost of the surface method on the unit area basis is lower than that of the sprinkler system. Further, the sprinkler system needs higher pumping cost for supplying the additional water head to the sprinkler head. The surface method is economically more advantageous than the sprinkler system.

Consequently, the surface irrigation method is selected for the upland irrigation.

4.2 Water Supply Operation Method

Water supply operation greatly influences irrigation water supply efficiencies and irrigation system capacities.

It is clear that 24-hour supply operation makes the minimum canal system capacity and efficient water intake from the river flow. This method can be applied to paddy fields because during water supply no special water management in the field or at the field intake is required even during night irrigation, whereas, upland irrigation requires precise management of water supply in the field to attain the expected high irrigation efficiency. The soil texture and topography in the Project area show that as irrigation operation will be finished in a comparatively short period, frequent water management practice is required. Thus the continuous irrigation, which premises night irrigation, is unlikely to be practicable. This means that, for upland irrigation, provision of a night storage pond is required to store the water for difference in the supply from the continuous river flow and intermittent diversion to the field. Taking into account the occurrence of the high variation in the water requirements throughout a year in the peak demand period, prolonged supply operation has to be introduced.

It is proposed, therefore, that the water supply operation for paddy fields will be made on continuous 24-hour basis, and for upland fields on an 18-hour basis with provision of farm ponds.

4.3 Standard Field Layout

A proper layout of the farm plots, farm roads, and irrigation and drainage canals is necessary for well management of irrigation farming. The size, shape and location of fields are to be suited for the farming practices to be adopted. For the upland farm, farming is proposed to some extent, whereas for the paddy field mechanization will remain on a small scale.

The irrigation method to be adopted in the upland field will be the surface irrigation method within which the furrow method is satisfactorily applied over most of the Project area. The border irrigation method is considered not practical since it needs a comparatively flat field surface resulting in the heavy grading. In planning of a standard upland field layout, due consideration is given to save grading requirements as much as possible and yet secure efficient irrigation.

The length of the irrigation run, which is one of decisive factors for field size, is to be the longest distance in which the maximum allowable furrow stream can effect nearly uniform distribution of water in soil. Therefore, the length of furrow irrigation run is a function of the irrigation slope, the furrow stream adopted, the soil intake rate, and the application depth. Thus, to supplement the furrow test data, the criteria on a wide range of such information has to be employed in irrigation planning. According to the criteria for preparation of irrigation guide by U.S.D.A., the maximum irrigation runs are estimated for different irrigation slopes in the three areas as classified in Section 3.2. These are as shown in Table IV-19.

In order to unify the plot size as much as possible for securing efficient and easy water management at the field inlet and efficient farm operation, the furrow lengths of 100 m and 150 m are adopted depending on the irrigation slope and the intake rate. In the steep areas the direction of irrigation run is set to have somewhat milder slope with intersection angles to the natural gradient. The intersection angles will range between 30° to 45° depending on the natural slope.

The terminal irrigation canals, drainage canals and farm roads are provided at intervals of 400 m to connect the field plots. Three typical layouts are contemplated according to the allowable maximum extent of furrow irrigation run as shown in Fig.IV-7.

As for the typical layout of the paddy field, due consideration is given to expansion of field plots for future mechanization and the reduction of land preparation cost. The size and shape of a plot is 0.3 ha (100m x 30m) consisting of sub-fields of 0.1 ha. The field plots of 0.3 ha extend on both sides of a farm ditch and a field road. In view of efficient operation and maintenance, and good water management of a terminal system, irrigation and drainage ditches are separately provided. The on-farm irrigation block is about 40 ha that consists of 2 rotation irrigation blocks of 20 ha. The on-farm works comprises farm ditches, farm drains, field roads and border ridges, and their related structures. The typical layout is as shown in Fig.IV-8.

5. Scale of Irrigation Area

5.1 Water Distribution Plan

The surface water sources to be made available for irrigation in the Lower Moshi area can be divided into three in view of occurrence of dependable flow and irrigable area extending around them. These rivers discharges are analyzed in ANNEX I.

(1) The Rau river including the Njoro river

(2) The Miwaleni springs

(3) The Himo river

The water of the above rivers has been tapped through many intakes, both legal and traditional ; however, intakes have not been efficiently utilized. In making the irrigation plan based on the limited water sources in the Project area, a comprehensive water use plan is first needed, including the revision of all the existing schemes.

The Rau river presently serves areas extending on both its banks. In view of the geographical location of the left bank area and the present water use of the Miwaleni springs, which is mentioned later, the left bank area can be efficiently served from the Miwaleni springs. Whereas, the right bank area has no water source except the Rau river and the Njoro river. In consideration of the above, the principal plan of the Rau river system is such that the Rau river flow is preferentially allocated to the right bank area, and compensation of the existing water use in the left bank area is made from the Miwaleni springs.

The Miwaleni springs have been used by NAFCO Kahe, and legal water rights have been given for the major part of the flows. NAFCO, however, has not utilized the full amount of water granted by the water rights, since the NAFCO scheme is less developed than the original plan due to greater salinity problems surrounding the original scheme which reduced its original extent. In spite of the ample outflow of the springs, the Miwaleni discharges downstream without effective use in the Lower Moshi area. Such surplus flow should be brought into productive use by introducing it to the Miwaleni upland area.

The Himo river exists independently from the other water sources. Therefore, its water is to be supplied to the area lying along the river course as effectively as possible.

In the Lower Moshi area, abundant groundwater has been confirmed and the hydrogeological investigation revealed the development potential of groundwater scheme. In the northern part of the Project area, excellent groundwater acquifers are confirmed and in the eastern area, good acquifers are also disclosed. As those areas have no dependable surface water, the groundwater development schemes are contemplated for those areas.