جامعة الكويت

حوليات

كلية الآداب

# البيئة المائية في الأردن

د. عبد الرحيم مسعد

دائرة الدراسات - المركز الجغرافي الأردني

الحولية الثامنة

الرسالة الحادية والأربعون

١٤٠٧ / ١٤٠٨هـ

١٩٨٦ / ١٩٨٧م

### ثمن الرسالة

الكويت ٥٠٠ فلس ـ البحرين ٧٥٠ فلس ـ قطر ٨ ريالات ـ الامارات ٨ دراهم ـ السعودية ٨ ريالات ـ عمان ريال واحد ـ اليمن الجنوبي ٥٠٠ فلس ـ اليمن الشمالي ٥ ريالات ـ العراق ٥٠٠ فلس (نصف دينار) ـ مصر ٥٠ قرشا ـ لبنان ١٠ ليرات ـ الأردن ـ ٥٠٠ فلس ـ سوريا ١٠ ليرات ـ السودان ٥٠٠ مليم ـ ليبيا ٨٠ قرشا ـ الجزائر ١٠ دنانير ـ تونس ٥٠٠ مليم ـ المغرب ٨ دراهم.

### الاشتراك السنوي لعدد (٨) رسائل

| | | الاشتراك | المجلد |
|---|---|---|---|
| الكويت | افراد | ٤ر ـ د.ك | ٦ر ـ د.ك |
| | مؤسسات | ١٦ر ـ | ١٨ر ـ |
| الدول العربية | افراد | ٥ر ـ د.ك | ٧ر ـ د.ك |
| | مؤسسات | ١٨ر ـ | ٢٠ر ـ |
| الدول الاجنبية | افراد | ٣٢ر ـ د.ك | ٤٠ر ـ د.ك |
| | مؤسسات | ٦٤ر ـ دولار | ٧٠ر ـ دولار |

**لأعضاء هيئة التدريس والطلاب خصم ٥٠ ٪**

جميع المراسلات الخاصة بشروط النشر أو أية إستفسارات أخرى بشأن الحوليات توجه الي رئيس هيئة تحرير الحوليات ـ ص . ب : ١٧٣٧٠ الخالدية ـ الكويت : 72454

# حوليات كلية الآداب

تصدر عن كلية الآداب - جامعة الكويت

دورية علمية محكمة تتضمن مجموعة من الرسائل وتعنى بنشر الموضوعات التي تدخل في مجالات اهتمام الأقسام العلمية لكلية الآداب

الحولية الثامنة

الرسالة الحادية والأربعون

١٤٠٧هـ / ١٩٨٧م

# صدر من هذه الحوليات

## الحولية الأولى لعام ١٩٨٠ :

| | | |
|---|---|---|
| الرسالة الأولى | : الجذور الفلسفية للبنائية | د. فؤاد زكريا |
| الرسالة الثانية | : صفحات مجهولة من تاريخ ليبيا | د. محمد عيسى صالحية |
| الرسالة الثالثة | : ابن قلاقس، حياته وشعره | د. سهام الفريح |
| الرسالة الرابعة | : الأمير تنكز الحسامي | د. حياة ناصر الحجي |
| الرسالة الخامسة | : التدرج الطبقي الاجتماعي في بعض الأقطار العربية (باللغة الانجليزية) | د. خلدون حسن النقيب |

## الحولية الثانية لعام ١٩٨١ :

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| الرسالة السادسة | : علي أحمد باكثير | د. محمد عبده |
| الرسالة السابعة | : تحليل اخطاء الطلبة العرب في استعمال أدوات التعريف والتنكير الانجليزية (باللغة الانجليزية) | د. نايف خرما |
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| الرسالة التاسعة | : المرأة والفلسفة | د. محمود رجب |

## الحولية الثالثة لعام ١٩٨٢ :

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| الرسالة العاشرة | : الروابط العائلية القرابية في مجتمع الكويت المعاصر | د. فهد ثاقب الثاقب |
| الرسالة الحادية عشرة | : البيئة والسلوك | د. طلعت منصور |
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| الرسالة الثالثة عشرة | : لورنس ومحفوظ، دراسة أدبية سيكلوجية، مقارنة | د. محمد رجاء الدريني |
| الرسالة الرابعة عشرة | : آل قدامة والصالحية | د. شاكر مصطفى |

## الحولية الرابعة لعام ١٩٨٣ :

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| الرسالة الخامسة عشرة | : أسلوب إذ في ضوء الدراسات القرآنية والنحوية | د. عبدالعال سالم مكرم |
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| الرسالة الثامنة عشرة | : وحدة ميتافيزيقيا أرسطو ومنزلة الرياضيات فيها | د. أبو يعرب المرزوقي |
| الرسالة التاسعة عشرة | : مفهوم التهكم عند كير كجور | د. امام عبدالفتاح |

## الحولية الخامسة لعام ١٩٨٤ :

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| الرسالة العشرون | : «نظرة في قرينة الاعراب» في الدراسات النحوية القديمة والحديثة | د. محمد صلاح الدين بكر |
| الرسالة الحادية والعشرون | : الاخرويات الاسلامية في الكوميديا الالهية (باللغة الانجليزية) | د. رشا حمود الصباح |
| الرسالة الثانية والعشرون | : تسع وثائق في شئون الحسبة على المساجد في الأندلس | د. محمد عبدالوهاب خلاف |
| الرسالة الثالثة والعشرون | : مشروع سوريا الكبرى وعلاقته بضم الضفة الغربية | د. أحمد عبدالرحيم مصطفى |
| الرسالة الرابعة والعشرون | : مفاهيم العلاج النفسي وانماط التفاعل داخل الأسر المريضة (النشأة والتطور) | د. حامد عبدالعزيز الفقي |

## الحولية السادسة لعام ١٩٨٥ :

الرسالة الخامسة والعشرون : نحاة القيروان — د. يوسف أحمد المطوع
الرسالة السادسة والعشرون : من وثائق الحرم القدسي الشريف المملوكية — د. محمد عيسى صالحية
الرسالة السابعة والعشرون : الفصاحة : مفهومها وبم تتحقق. قيمها الجمالية — د. توفيق علي الفيل
الرسالة الثامنة والعشرون : مشكلة التأويل العقلي عند مفكري الاسلام في المشرق العربي وخاصة عند ابن سينا — الاستاذ / سعيد زايد

الرسالة التاسعة والعشرون : واقع التاريخ في رواية وجوب العنف (باللغة الانجليزية) — د. رشا حمود الصباح
الرسالة الثلاثون : مكانة رواية روبنسون كروزو في القصص اللايوطوبي (باللغة الانجليزية) — د. محمد رجا الدريني
الرسالة الحادية والثلاثون : مفهوم المعنى «دراسة تحليلية» — **د. عزمي موسى اسلام**
الرسالة الثانية والثلاثون : الوصايا ومدى تطورها في العصر العباسي الأول — د. سهام الفريح

## الحولية السابعة لعام ١٩٨٦ :

الرسالة الثالثة والثلاثون : بردة البوصيري قراءة أدبية وفلكورية — د. محمد رجب النجار
الرسالة الرابعة والثلاثون : الارشاد النفسي تطور مفهومه وتميزه — د. عبدالله محمود سليمان
الرسالة الخامسة والثلاثون : اتجاهات الآباء والامهات الكويتيين في تنشئة الأبناء وعلاقتها ببعض المتغيرات — عبدالفتاح القرشي
الرسالة السادسة والثلاثون : علم العمران الخلدوني وعلم الاجتماع الحديث (باللغة الانجليزية) — د. فؤاد البغلي
الرسالة السابعة والثلاثون : قبلية تميم العربية بين الجاهلية والاسلام — د. عبدالجبار العبيدي
الرسالة الثامنة والثلاثون : عيوب الكلام، دراسة لما يعاب في الكلام عند اللغويين العرب — د. وسمية المنصور
الرسالة التاسعة والثلاثون : المواقع الاسلامية المندثرة في وادي حلي — د. احمد بن عمر الزيلعي
الرسالة الاربعون : البحر في شعر الاندلس والمغرب — د. منجد مصطفى بهجت

الرسالة الحادية والأربعون

# البيئة المائية في الأردن


د. عبد الرحيم مسعد

دائرة الدراسات - المركز الجغرافي الأردني



حوليات كلية الآداب - الحولية الثامنة - ١٤٠٧هـ / ١٩٨٧م

**المؤلـــف**

- د. عبدالرحيم محمد مسعد
- ماجستير جغرافية - جامعة دلهي - الهند ١٩٧٩
- دكتوراه جغرافية - جامعة بونا - الهند ١٩٨٣
- رئيس فرع البحوث والدراسات - المركز الجغرافي الاردني - عمان - الاردن
- محاضر غير متفرغ - دائرة علوم الارض والبيئة - جامعة اليرموك - الاردن

# ملخص

يعتبر توفر الأمطار والاستخدام الأمثل لها من العوامل الهامة في الزراعة خاصة في المناطق التي تعاني من عجز في مواردها المائية. من بين دول الشرق الأوسط تعتبر الأردن واحدة من الدول التي تشتمل على مساحات كبيرة من الأراضي الجافة وشبه الجافة لما يترتب عليه أن يكيف المزارعون الاسلوب والنمط الزراعي ليلائم الظروف المائية السائدة.

تهدف الدراسة إلى تقدير كمية المياه المتاحة وإمكانية تكييف المحاصيل الزراعية مع كل ما يستجد من متغيرات. لتقصي هذه الظاهرة تم تطبيق نظرية الموازنة المائية لـ«ثورنثويت» حيث وجد أنها ملائمة ومناسبة كليا ضمن الاطار المتعلق بايجاد نمط للرصد المائي البيئي، المخزون المائي في التربة والجريان السطحي. غالبا ما تتأثر وظائف النباتات ودرجة نموها بعناصر الموازنة المائية والتي بدورها ترسم الاطار العام لأهم مورد من موارد البيئة.

لقد تم التركيز في هذه الدراسة على جانبين هامين من جوانب البيئة، أولهما: تحديد كميات المياه المتاحة في الأردن بتطبيق أساليب علمية وطرق تقنية نظرية مطبقة عالميا، تقودنا لتقييم العرض والطلب على مصادر المياه. وثانيهما: البحث في النمط المحصولي السائد من خلال تأثير البيئة المائية على هذه المحاصيل.

# المجلة التربوية

تصدر عن كلية التربية - جامعة الكويت

فصلية ، تخصصية ، محكّمة




تنشر البحوث التربوية ، ومراجعات الكتب التربوية الحديثة

ومحاضر الحوار التربوي ، والتقارير عن المؤتمرات التربوية

- ★ تقبل البحوث باللغتين العربية والانجليزية .
- ★ تنشر لأساتذة التربية والمختصين فيها من مختلف الاقطار .
- ★ تطلب قواعد النشر من رئيس التحرير .
- ★ تقدم مكافأة رمزية للناشرين بها .

**الاشتراكات :**

| | | | | |
|---|---|---|---|---|
| للأفراد في الكويت | : | ٢ د.ك | وللطلاب | ١ د.ك |
| للأفراد في الوطن العربي | : | ٢٫٥ د.ك | وللطلاب | ١٫٥ د.ك |
| للأفراد في الدول الأخرى | : | ١٥ دولارا أمريكيا بالبريد الجوي | | |
| للهيئات والمؤسسات | : | ١٢ د.ك وفي الخارج ٤٥ دولارا أمريكيا | | |


**توجه جميع المراسلات إلى :**

رئيس التحرير ـ المجلة التربوية ـ ص.ب ١٣٢٨١ كيفان ـ الكويت

# مجلة دراسات الخليج والجزيرة العربية

تصدر عن جامعة الكويت

**صدر العدد الاول في يناير ١٩٧٥**
**تصل اعدادها الى ايدي نحو ٢٠٠ر٠٠٠ قارىء**

يحتوي كل عدد على حوالي ٢٥٠ صفحة من القطع الكبير تشتمل على:ـ
- مجموعة من البحوث تعالج الشئون المختلفة للمنطقة بأقلام عدد من كبار الكتاب المتخصصين في هذه الشئون.
- عدد من المراجعات لطائفة من اهم الكتب التي تبحث في المناحي المختلفة للمنطقة.
- ابواب ثابتة: تقارير وثائق ـ يوميات ـ بيبلوجرافيا.
- ملخصات للبحوث باللغة الانجليزية.

**منشورات المجلة**

اضطلعت المجلة باصدار عدد من سلاسل الكتب هي:ـ

**اولا: سلسلة المنشورات**، وقد صدر منها حتى الان سبعة عشر منشورا احدثها:
- الاتجاهات الحديثة في محاسبة النفط والغاز، د. صادق البسام
- الصحافة اليمنية قبل ثورة ١٩٦٢، علوي عبدالله طاهر

**ثانياً: سلسلة الاصدارات الخاصة**، وصدر منها حتى الآن خمسة عشر إصداراً، من أحدثها:
- المرأة في النصوص والآثار، د. عبد العزيز صالح
- رأي المتدربين والمدربين في برامج تدريب المعلمين التي عقدتها وزارة التربية عام ٨٣/ ٨٤ بدولة الكويت، د. عبدالرحمن الأحمد

**ثالثا: سلسلة كتب الوثائق**، وقد صدر منها كتب الوثائق للاعوام: ٧٥ ـ ٧٦ ـ ٧٧ ـ ٧٨ ـ ٧٩ ـ ٨٠.

**الاشتراكات**

ثمن العدد: ٤٠٠ كويتي أو ما يعادلها في الخارج.
الاشتراك للافراد: سنويا ديناران كويتيان أو ١٥ دولارا امريكيا في الخارج (بالبريد الجوي)
الاشتراك للمؤسسات والدوائر الرسمية: سنويا ١٢ دينارا كويتيا أو ٤٠ دولارا امريكيا في الخارج (بالبريد الجوي).

**العنوان**: جامعة الكويت ـ كلية الآداب ـ الشويخ ـ دولة الكويت
**ص.ب**: ١٧٠٧٣ ـ الخالدية ـ الكويت 72451
**الهاتف**: ٨١٦٨٠٧ ـ ٨١٦٧٩٩ ـ ٨١٦٨٢٤
جميع المراسلات توجه باسم رئيس التحرير

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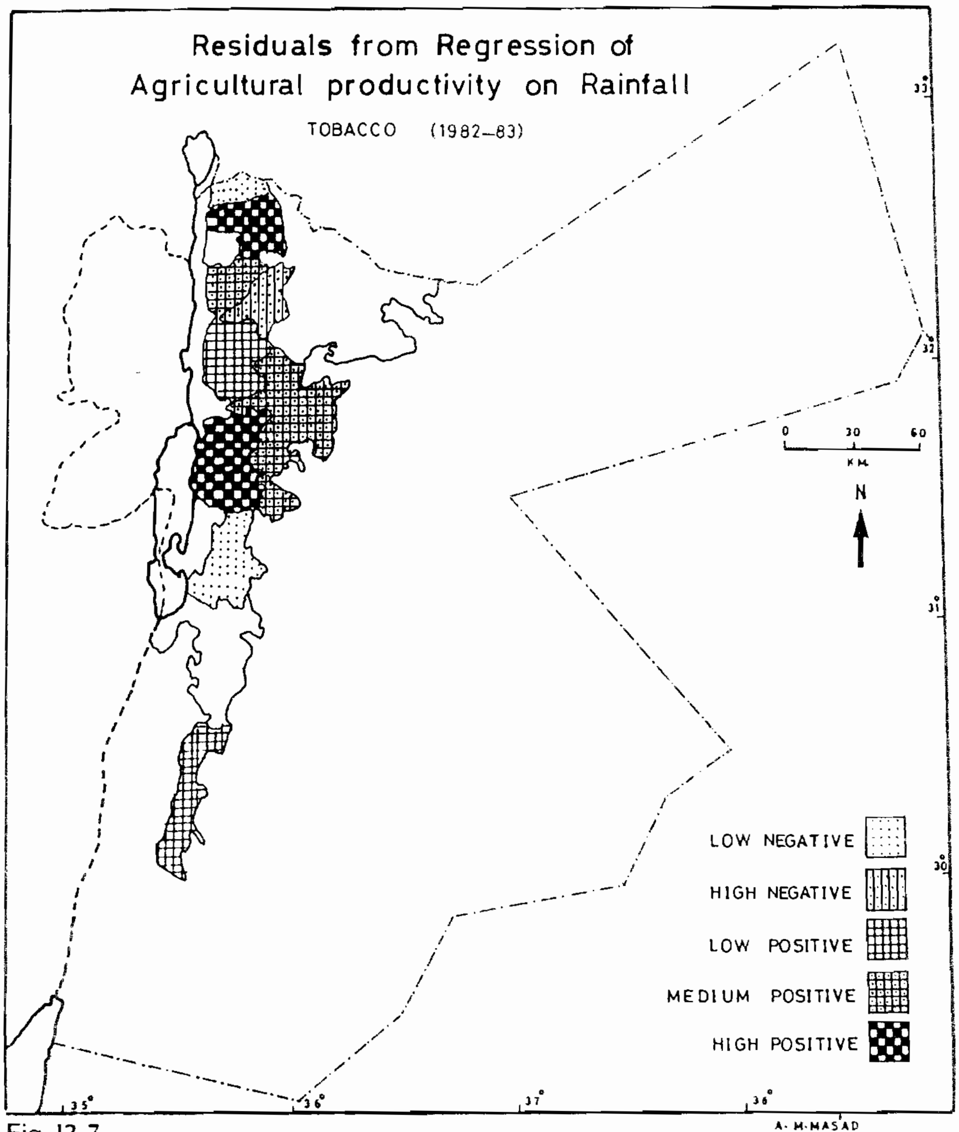
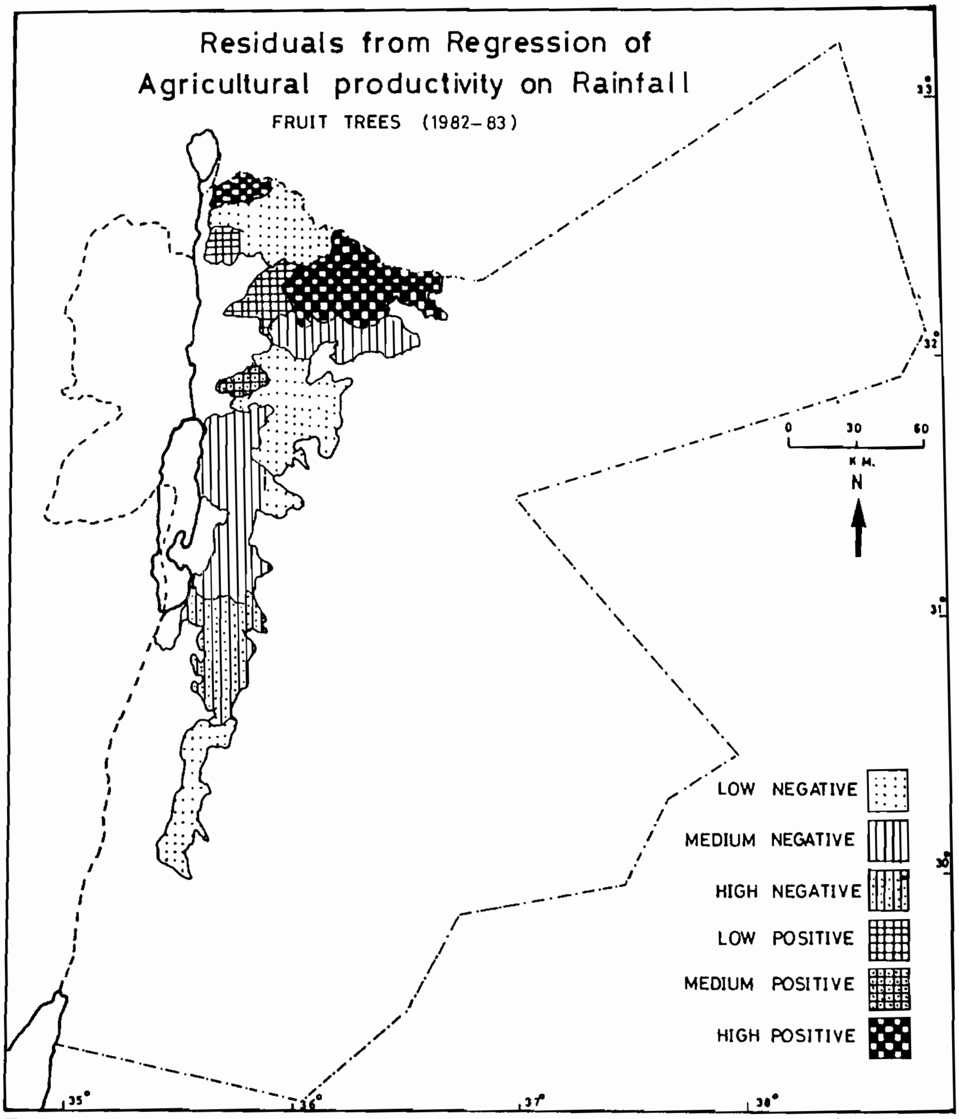
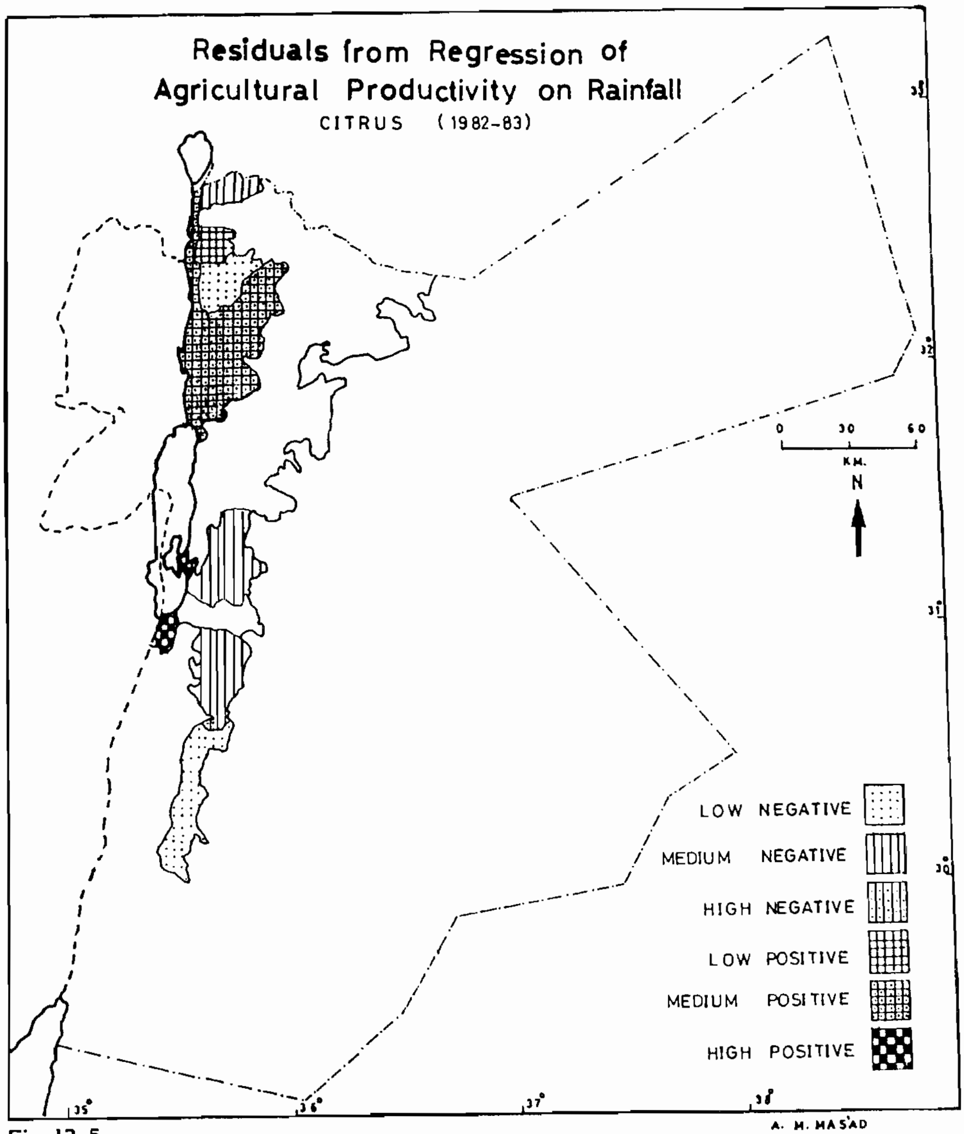

Residuals from Regression of
Agricultural productivity on Rainfall
TOBACCO (1982–83)
LOW NEGATIVE
HIGH NEGATIVE
LOW POSITIVE
MEDIUM POSITIVE
HIGH POSITIVE
N
KM
A. M. MASAD
Fig. 12.7


Residuals from Regression of
Agricultural productivity on Rainfall
FRUIT TREES (1982-83)
LOW NEGATIVE
MEDIUM NEGATIVE
HIGH NEGATIVE
LOW POSITIVE
MEDIUM POSITIVE
HIGH POSITIVE
0 30 60
KM.
N
35°
36°
37°
38°
33°
32°
31°
30°
A. M. HAS'AD
Fig.12.6


Residuals from Regression of
Agricultural Productivity on Rainfall
CITRUS (1982-83)
0 30 60
KM.
N
LOW NEGATIVE
MEDIUM NEGATIVE
HIGH NEGATIVE
LOW POSITIVE
MEDIUM POSITIVE
HIGH POSITIVE
A. M. MAS'AD
Fig. 12.5

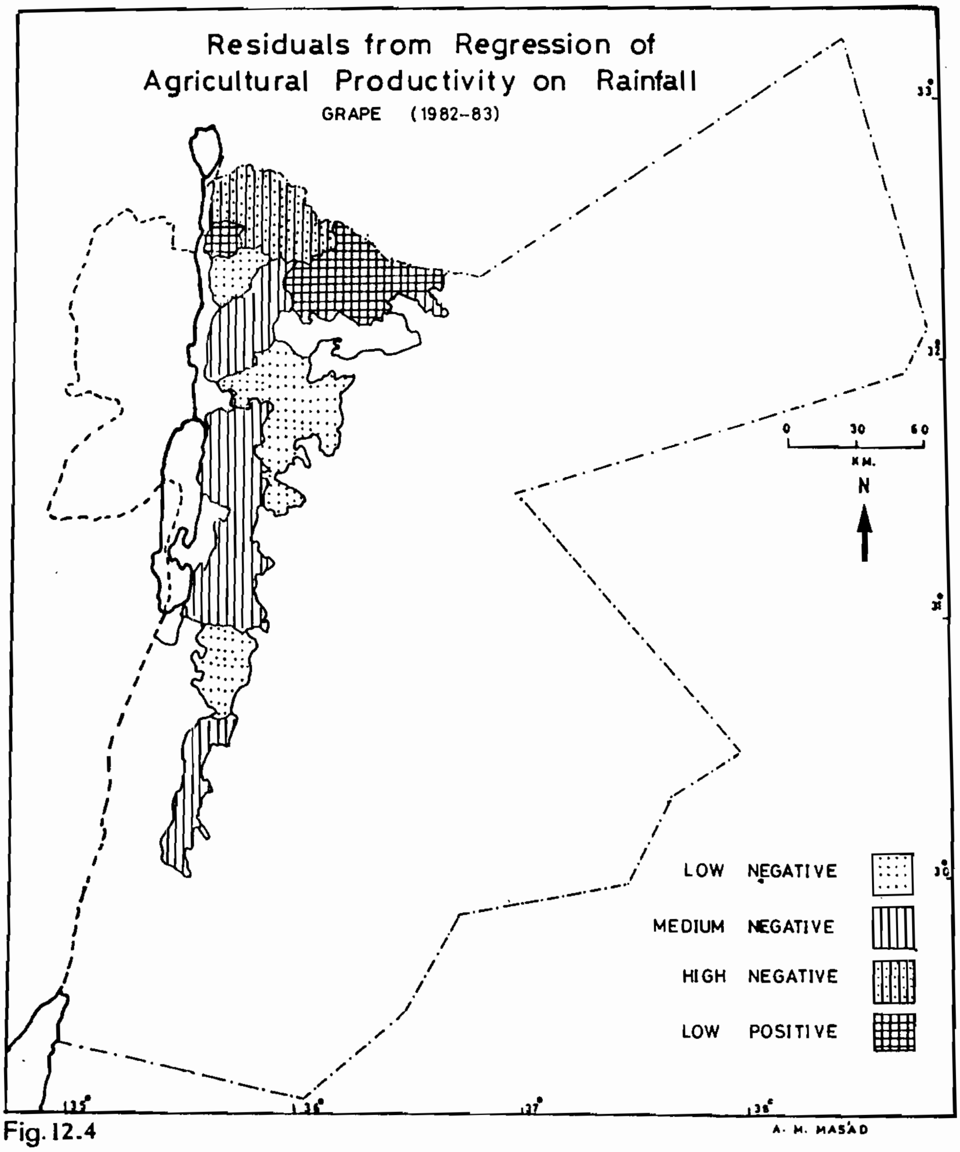

Residuals from Regression of
Agricultural Productivity on Rainfall
GRAPE (1982-83)
0 30 60
KM.
N
LOW NEGATIVE
MEDIUM NEGATIVE
HIGH NEGATIVE
LOW POSITIVE
A. M. MASAD

Fig. 12.4

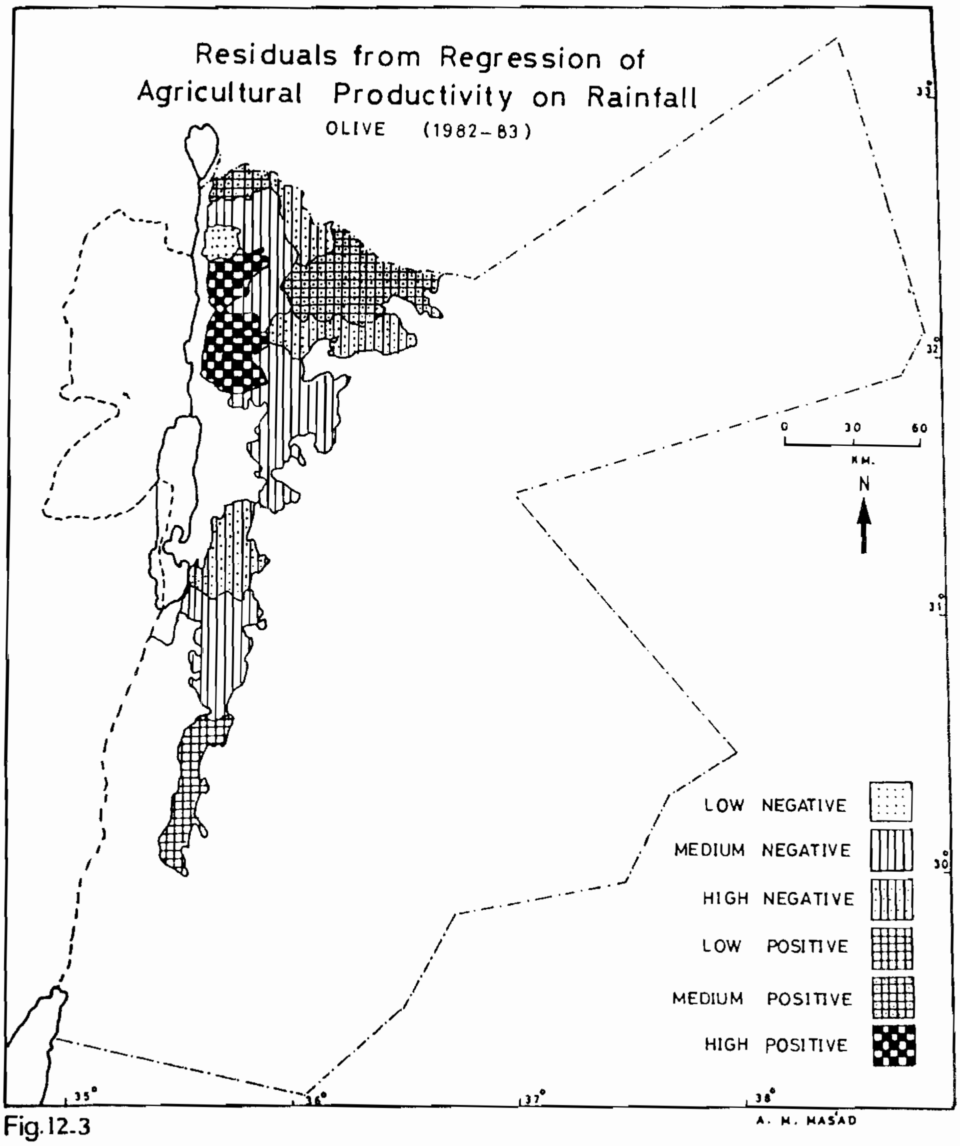

Residuals from Regression of
Agricultural Productivity on Rainfall
OLIVE (1982-83)
0 30 60
KM.
N
LOW NEGATIVE
MEDIUM NEGATIVE
HIGH NEGATIVE
LOW POSITIVE
MEDIUM POSITIVE
HIGH POSITIVE
35°
36°
37°
38°
A. H. MAS'AD

Fig. 12-3

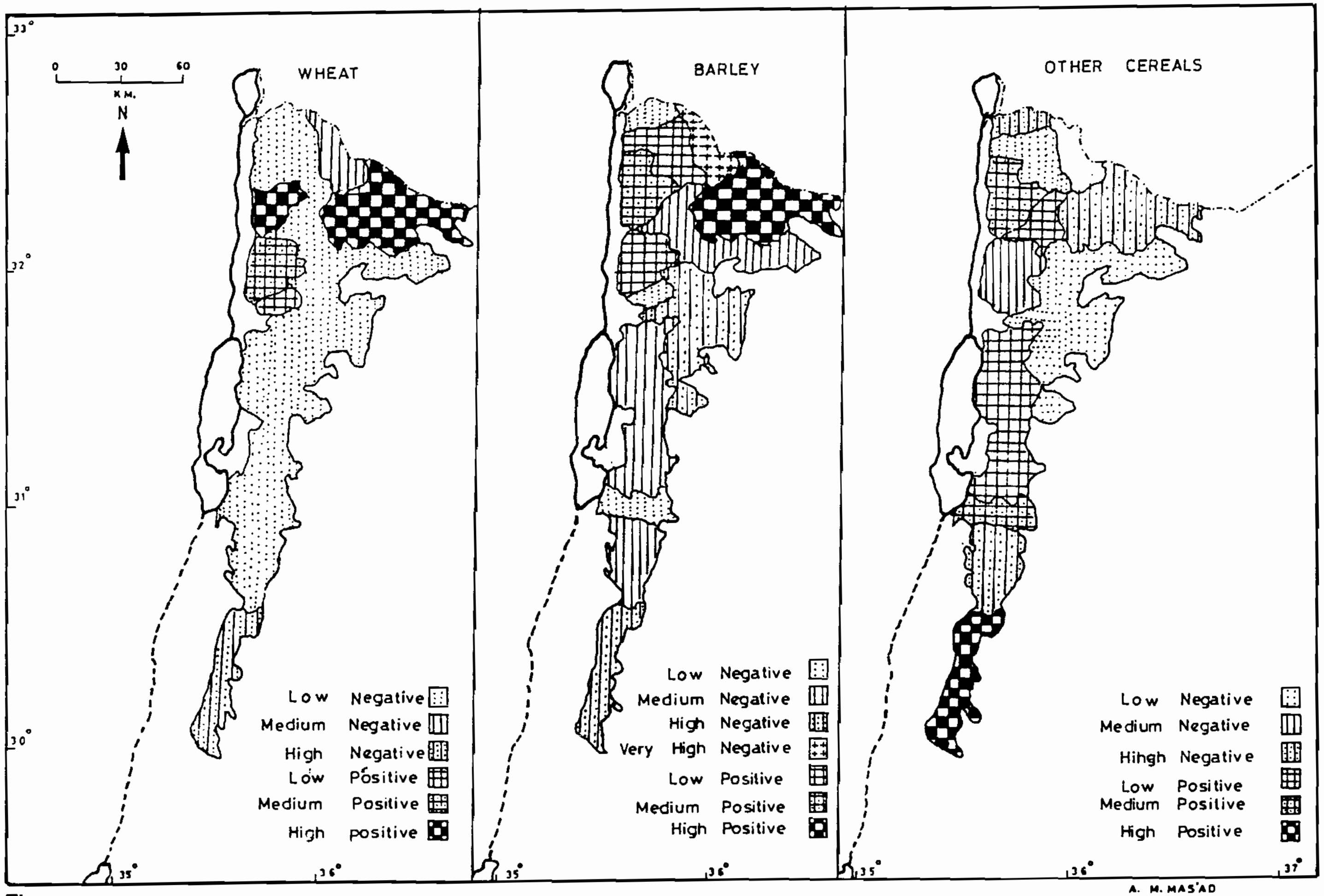



Fig. 12.2 Residuals from Regression of Agricultural Productivity on Rainfall — CEREALS (1982-83)

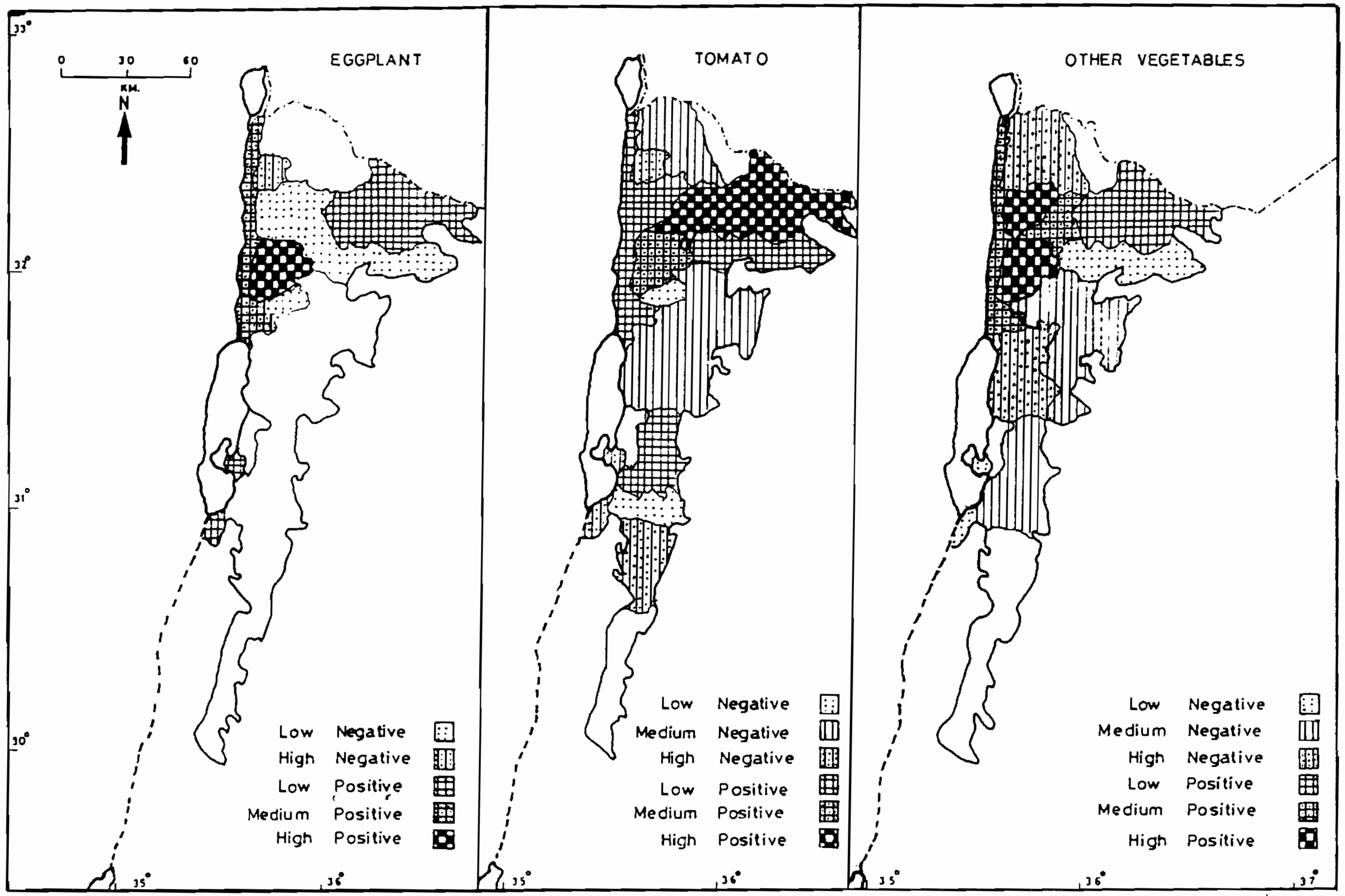



Fig.12.1 Residuals from Regression of Agricultural Productivity on Rainfall — VEGETABLES (1982-83)

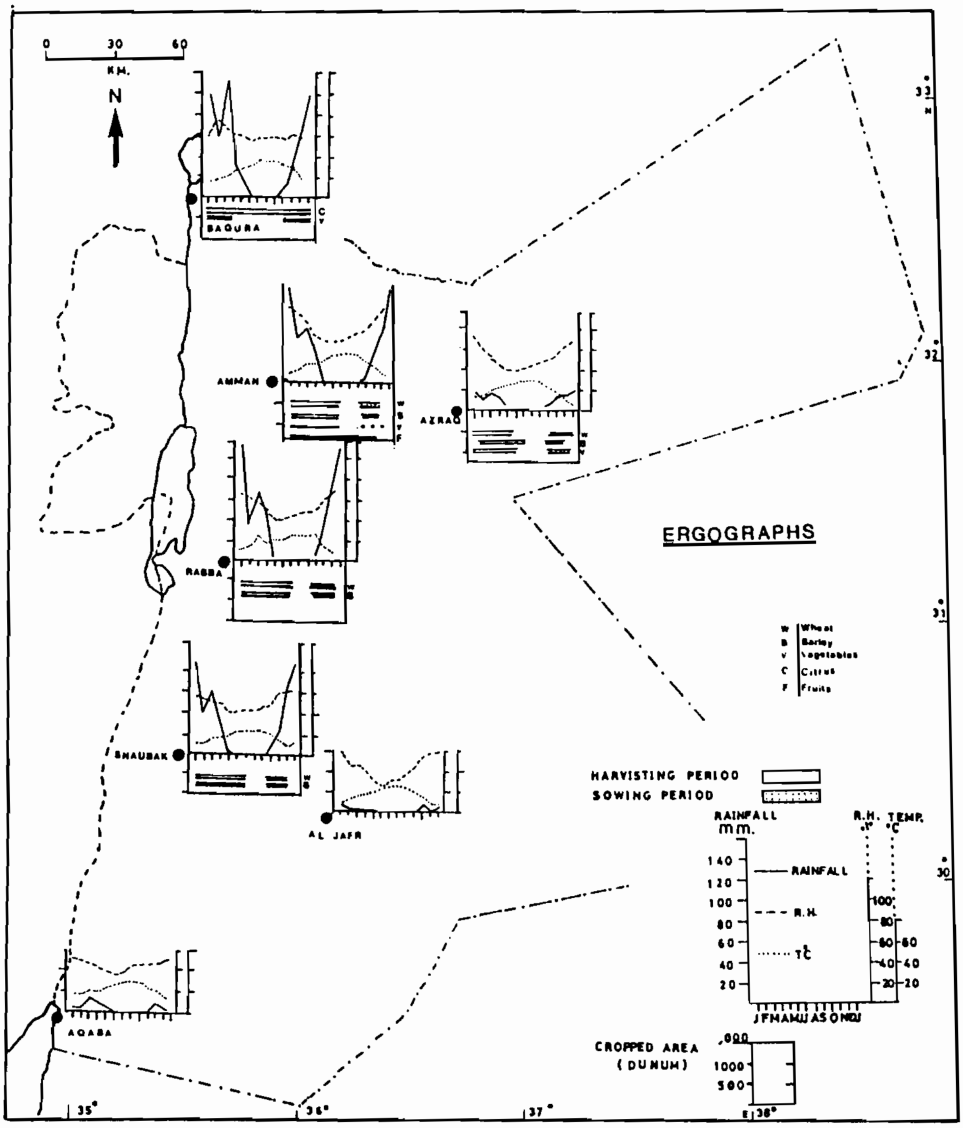


Fig.II-3

A.M. MASAD

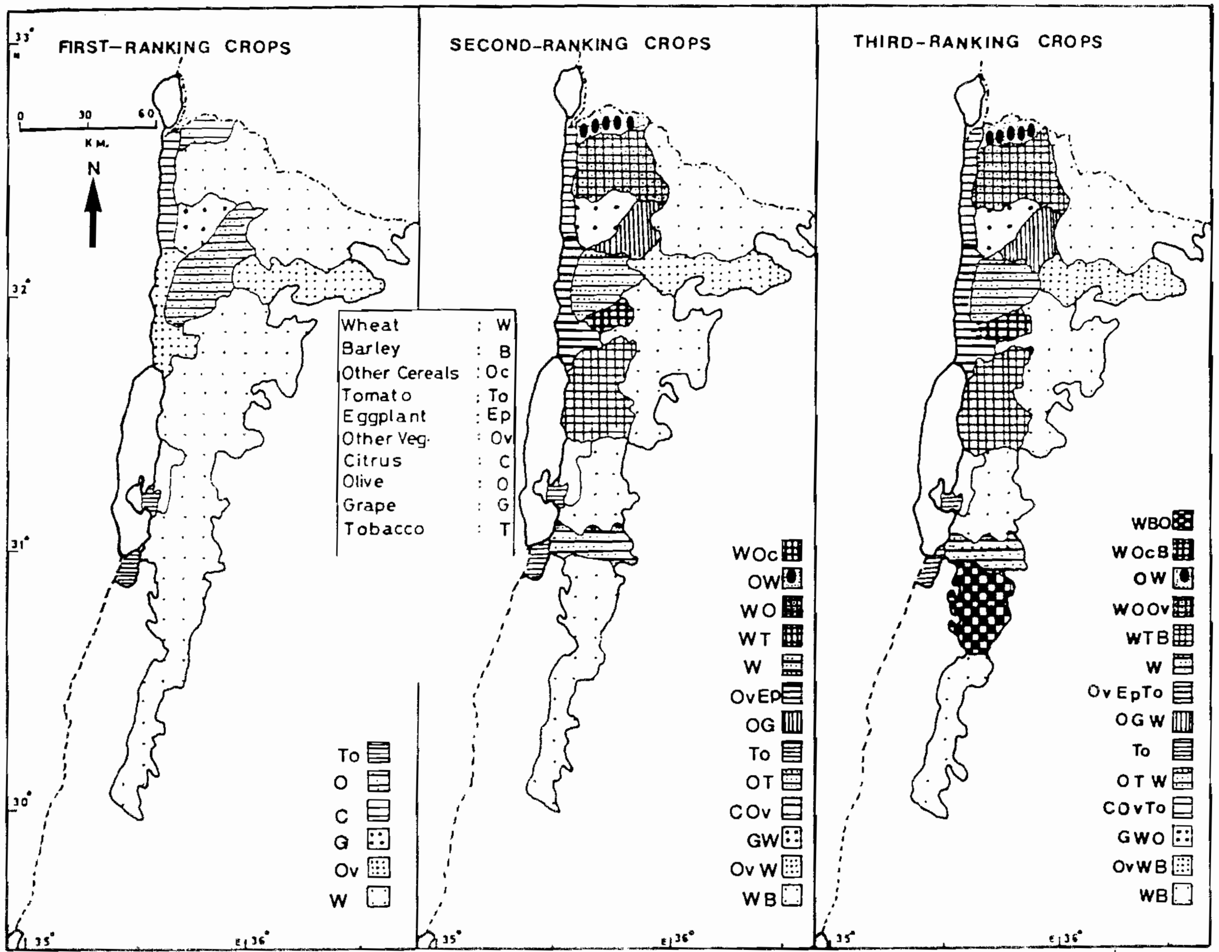



Fig. II-2 CROP — COMBINATION REGIONS. RANKING DISTRIBUTION (MINIMUM DEVIATION METHOD)

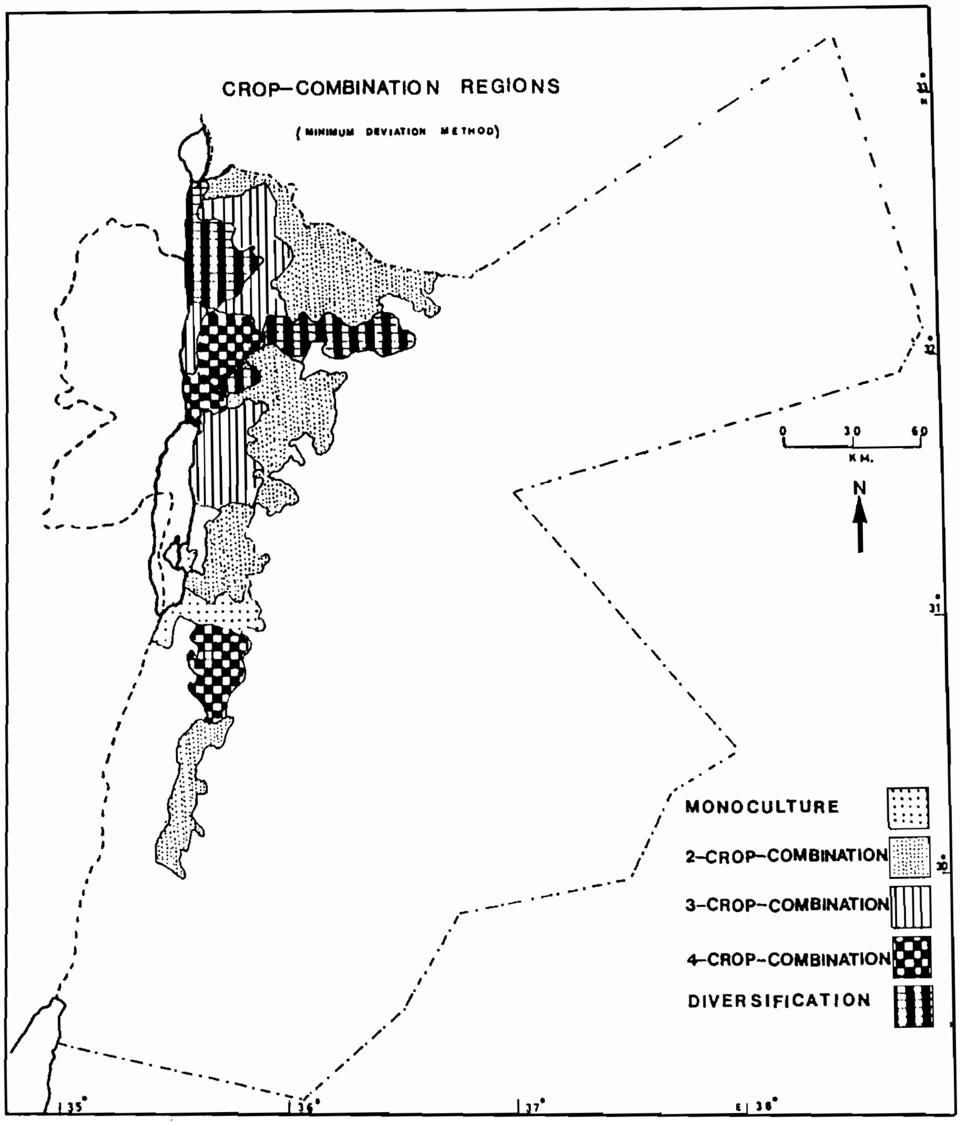
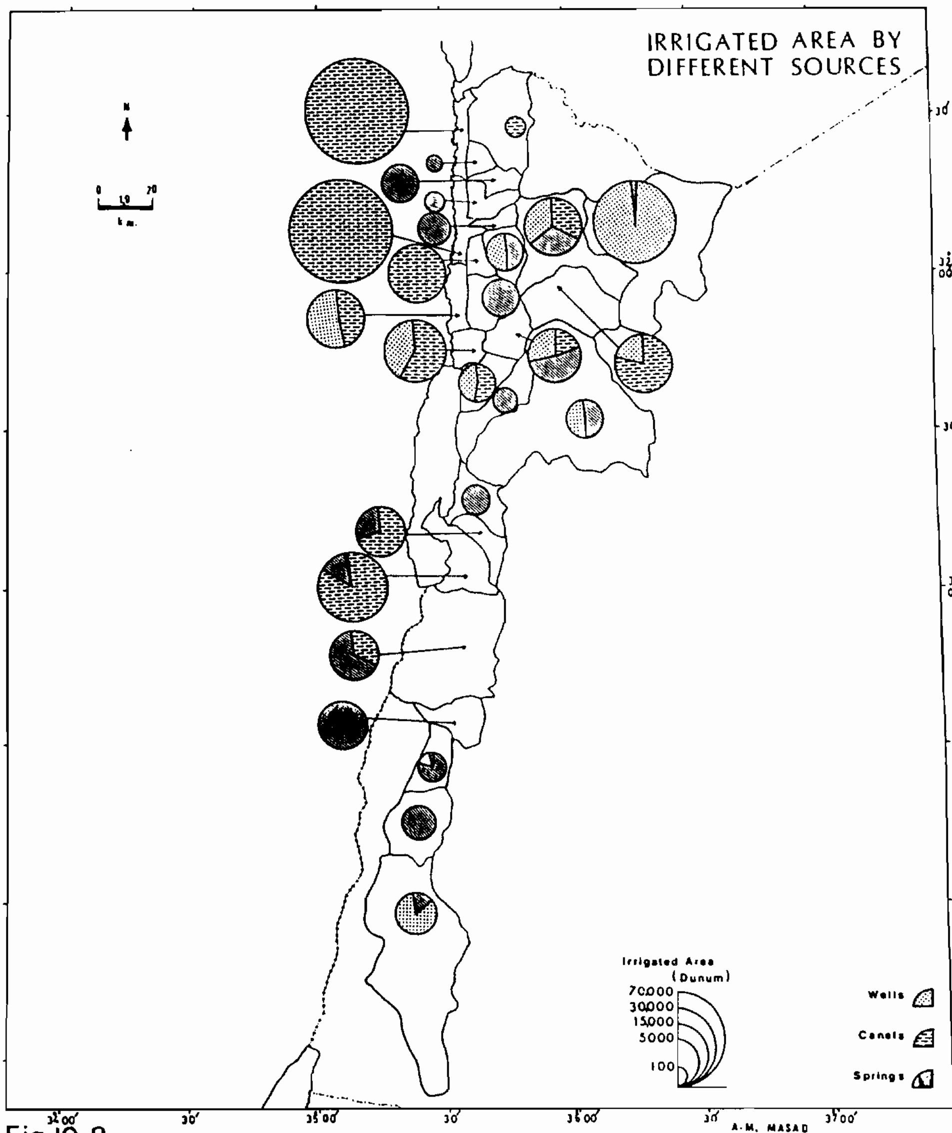


Fig. II.I

A.M.MAS'AD


IRRIGATED AREA BY DIFFERENT SOURCES
Irrigated Area
(Dunum)
70,000
30,000
15,000
5000
100
Wells
Canals
Springs
A.M. MASAD
Fig.10.8

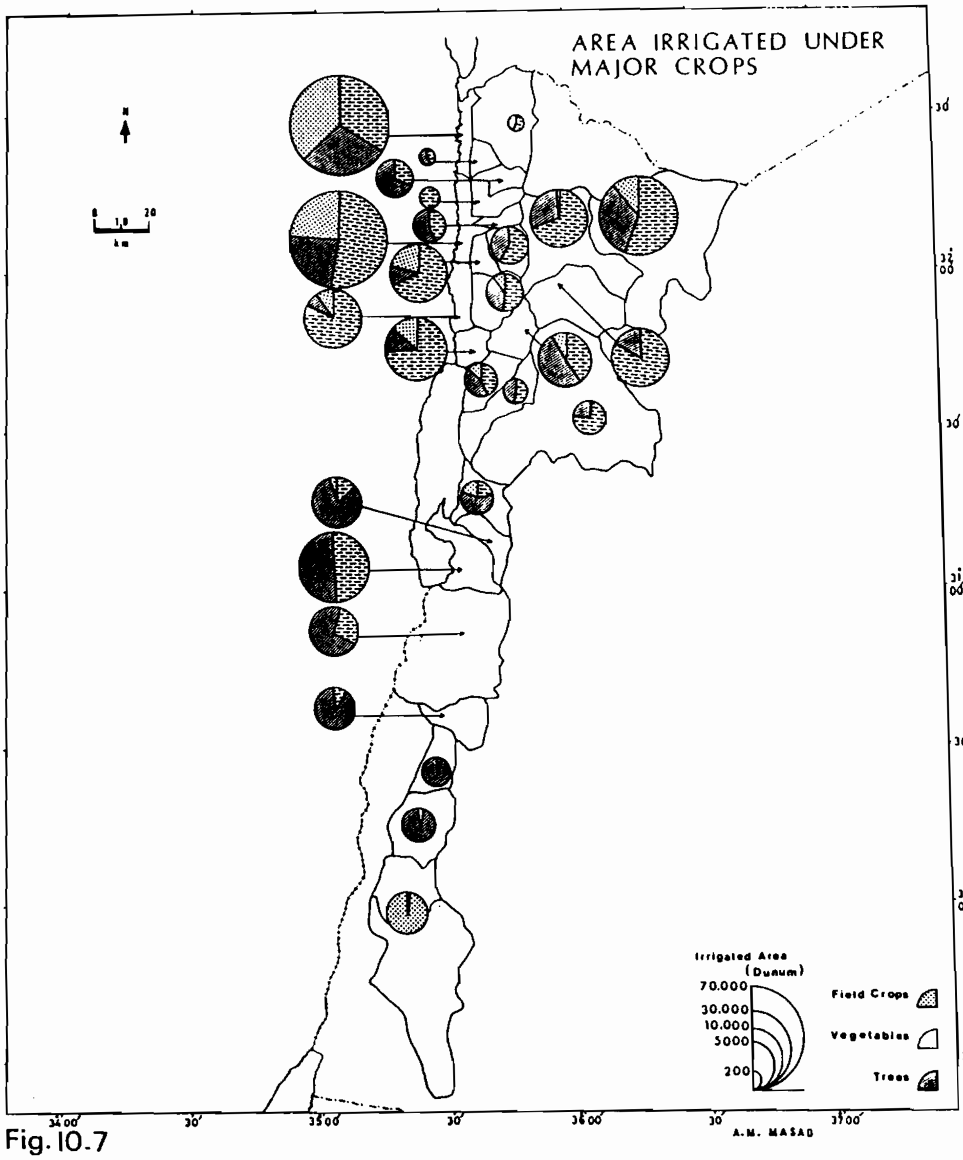
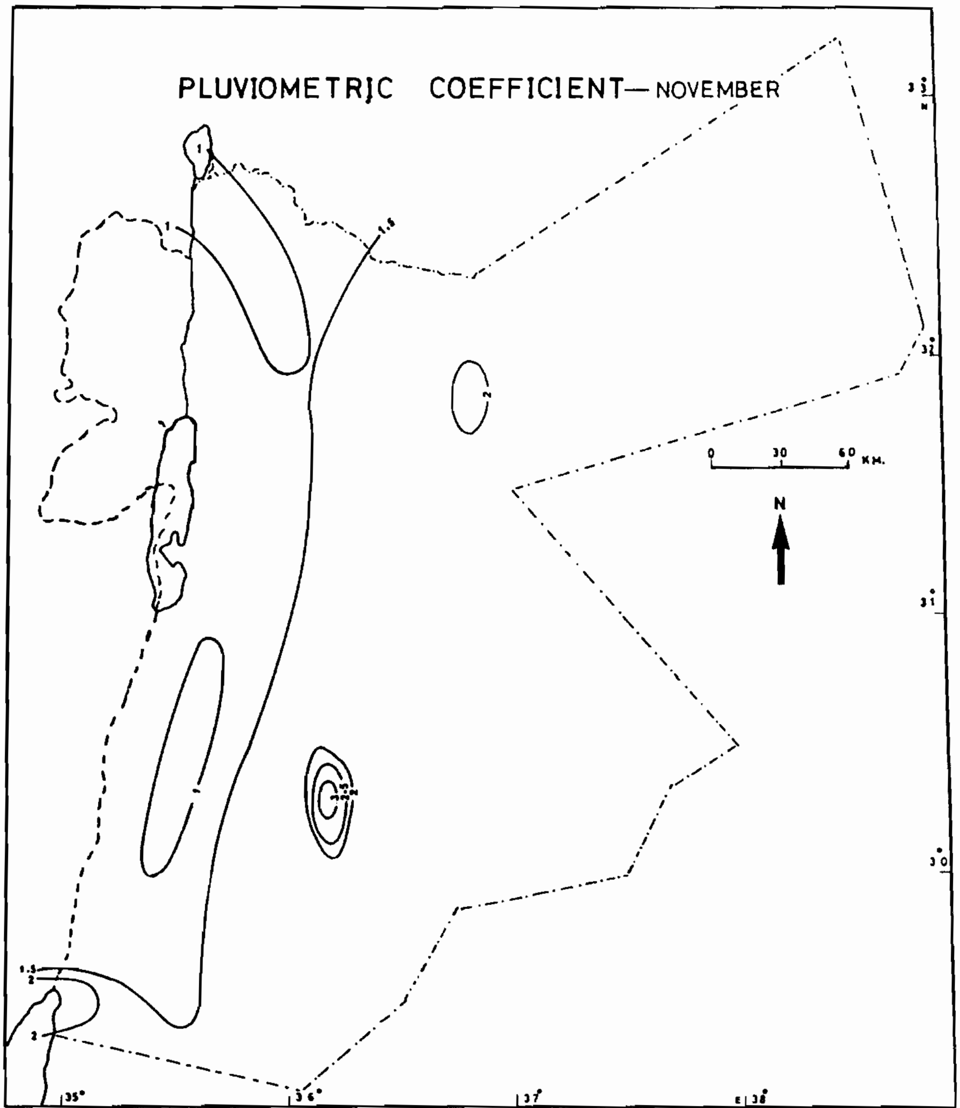

AREA IRRIGATED UNDER MAJOR CROPS
Irrigated Area
(Dunum)
70.000
30.000
10.000
5000
200
Field Crops
Vegetables
Trees
A.M. MASAD

Fig. 10.7


PLUVIOMETRIC COEFFICIENT— NOVEMBER
0
30
60
KM.
N
35°
36°
37°
38°
A. M. MAS'AD
Fig. 10.5

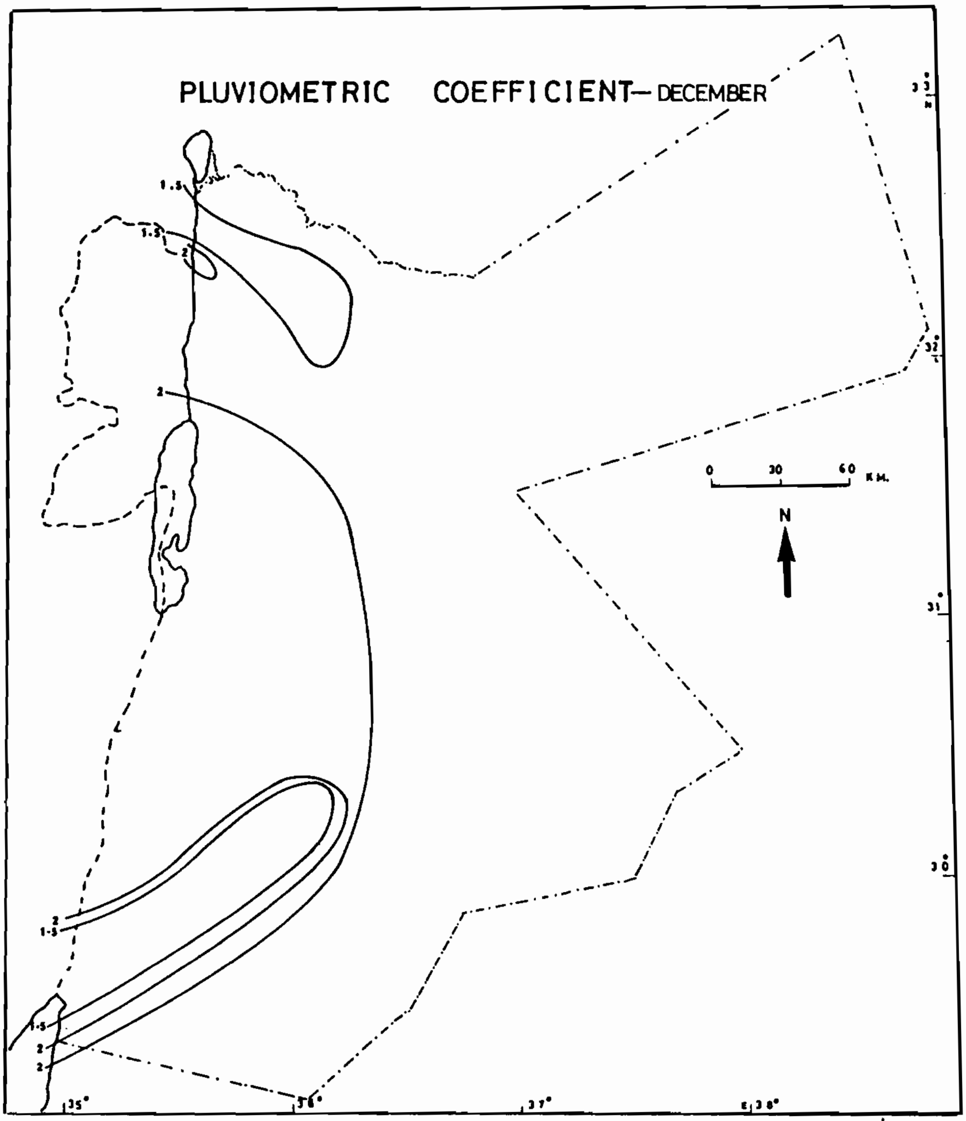



Fig.10.6

A. M. MASAD

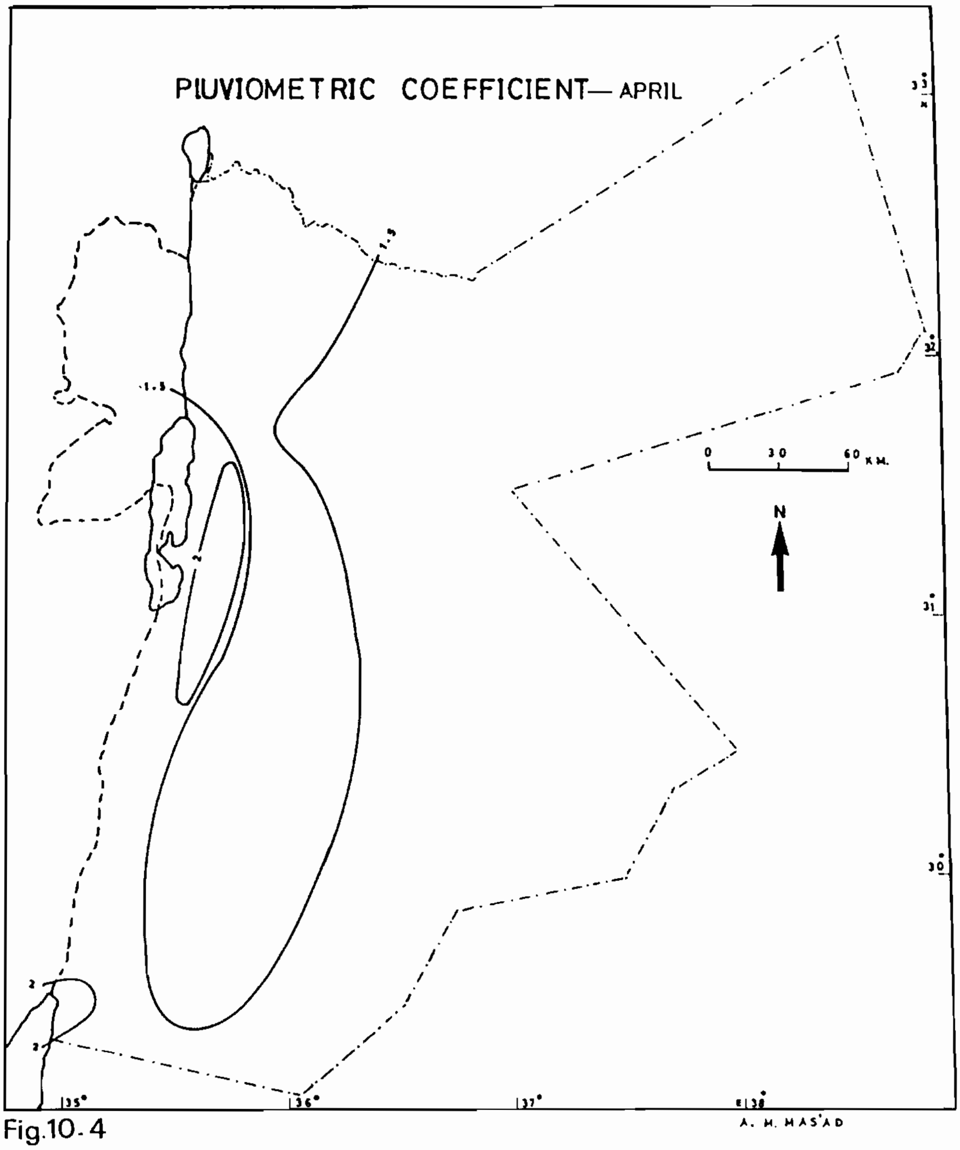
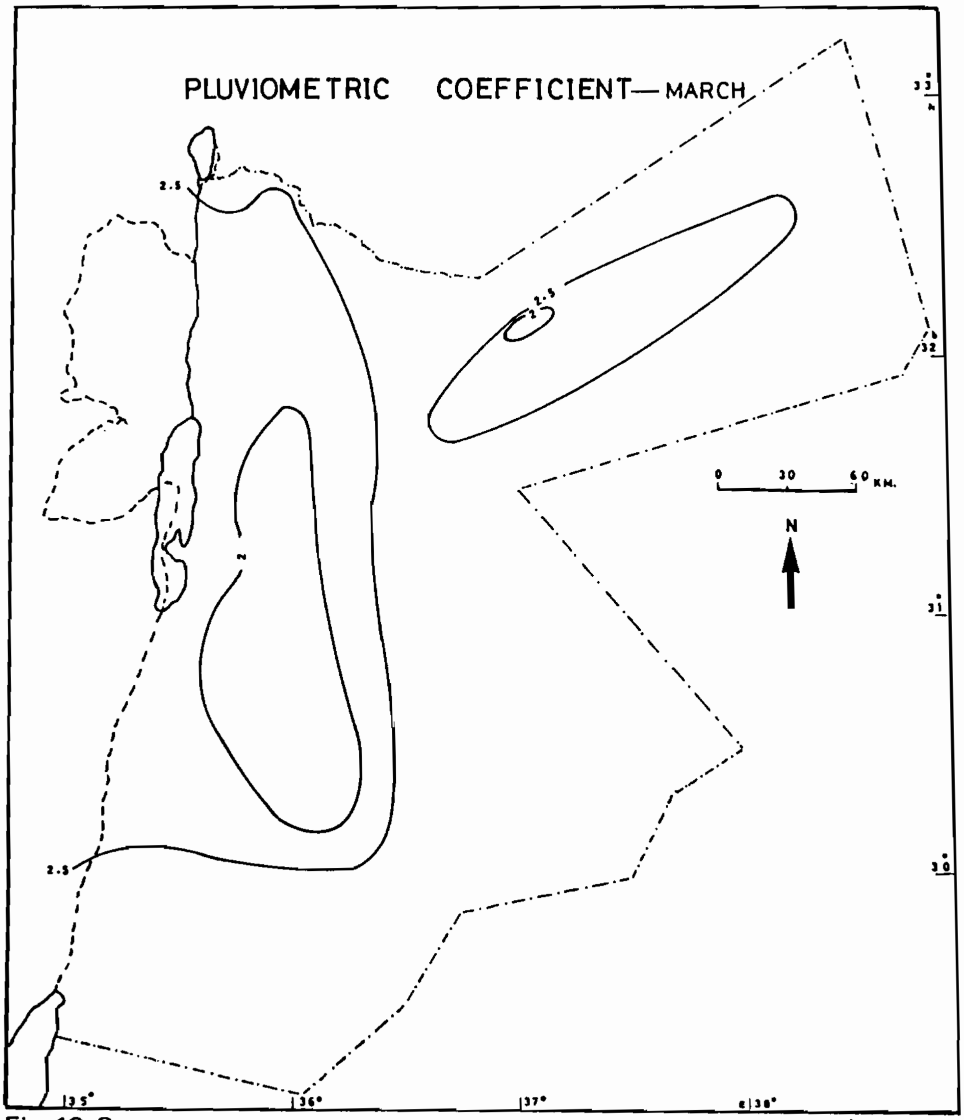


Fig.10-4


PLUVIOMETRIC COEFFICIENT— MARCH
2.5
2
0 30 60 KM.
N
35°
36°
37°
38°
33°
32°
31°
30°
A. M. MAS'AD
Fig. 10-3

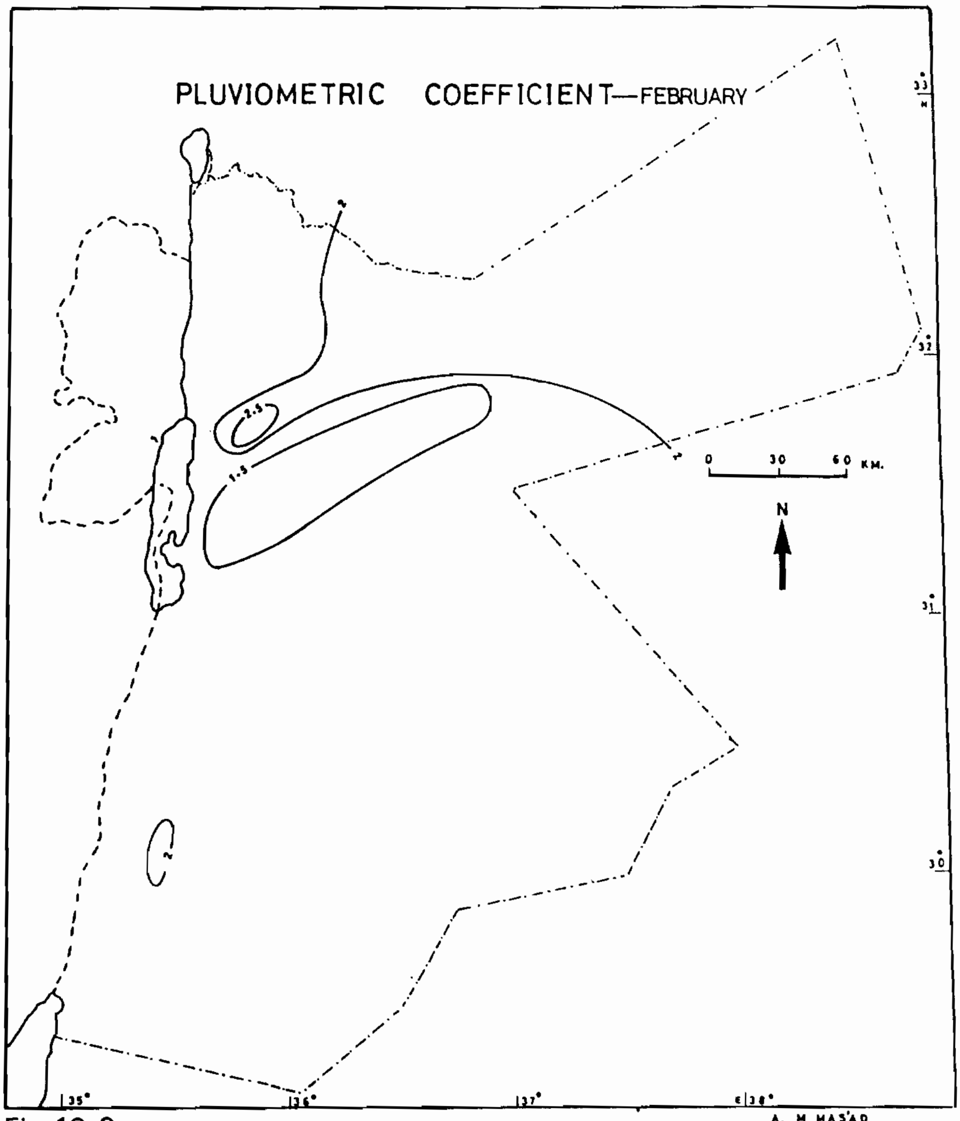

PLUVIOMETRIC COEFFICIENT—FEBRUARY
2.5
1.5
0 30 60 KM.
N
33
32
31
30
35°
36°
37°
38°
A. M. MAS'AD

Fig. 10.2

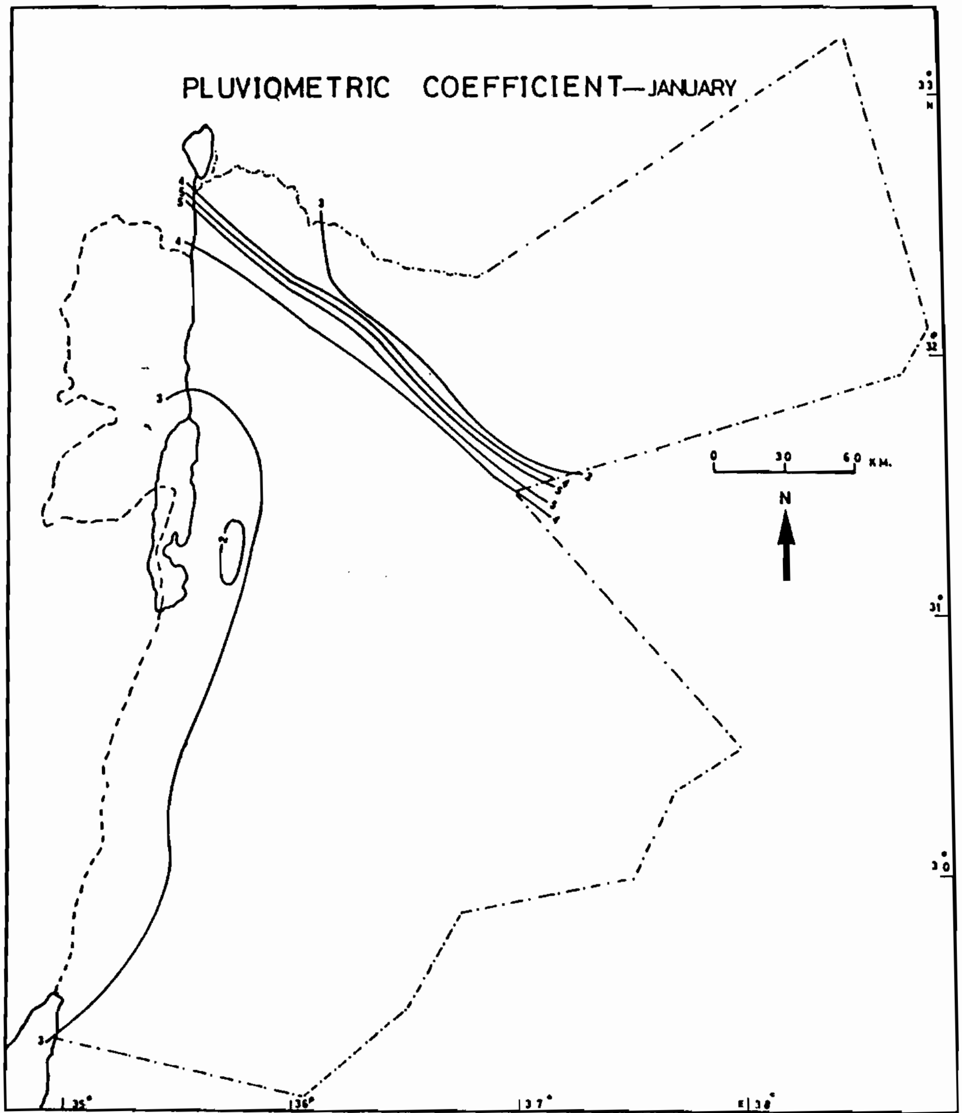


Fig.10-1

A. M. MAS'AD

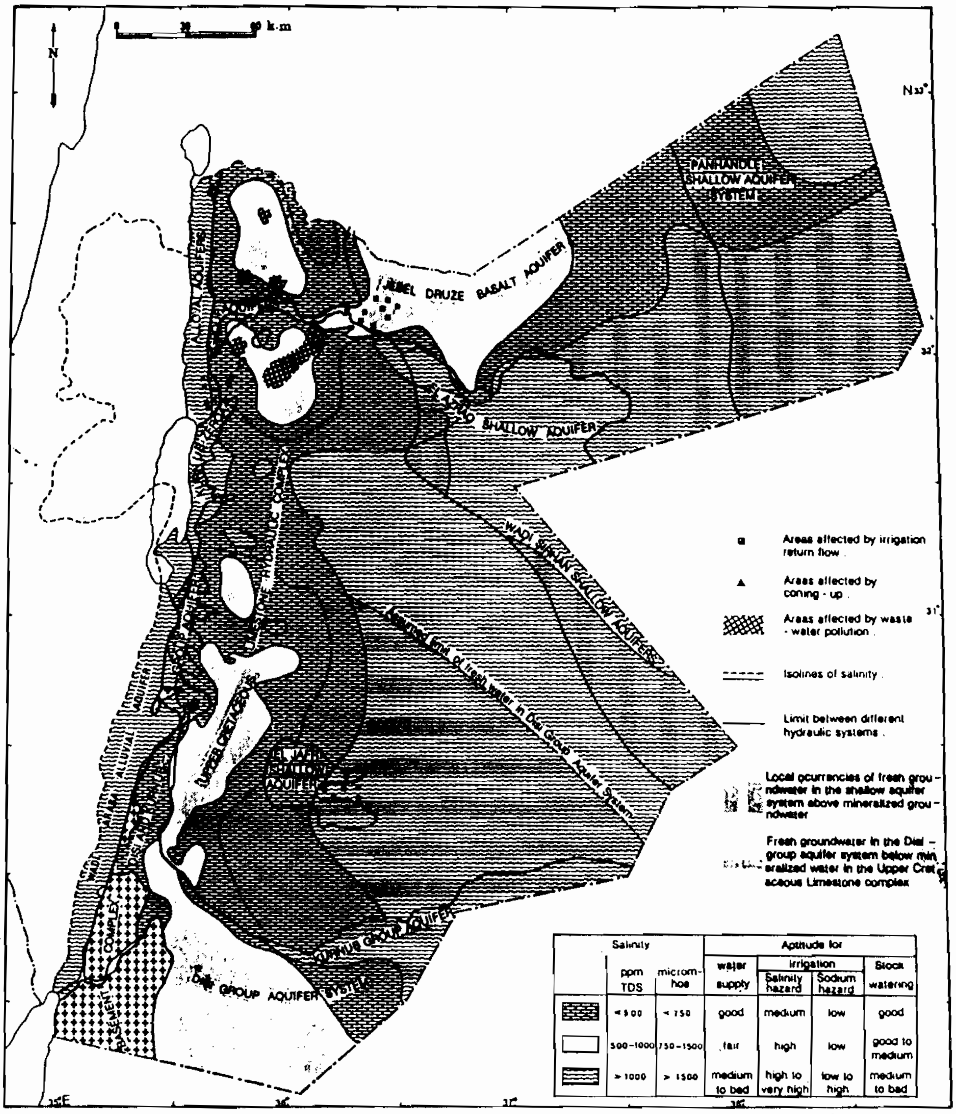

k.m
N
PANHANDLE SHALLOW AQUIFER SYSTEM
JEBEL DRUZE BASALT AQUIFER
AZRAQ SHALLOW AQUIFER
WADI SIRHAN SHALLOW AQUIFERS
UPPER CRETACEOUS
EL JAFR SHALLOW AQUIFER
GROUP AQUIFER SYSTEM
Areas affected by irrigation return flow .
Araas affected by coning - up .
Araas affected by waste - water pollution .
Isolines of salinity .
Limit between different hydraulic systems .
Local ocurrencies of fresh grou - ndwater in the shallow aquifer system above mineralized grou - ndwater
Fresh groundwater in the Disi - group aquifer system below min eralized water in the Upper Cret aceous Limestone complex
Salinity
ppm TDS
microm-hos
Aptitude for
water supply
irrigation
Salinity hazard
Sodium hazard
Stock watering
< 500
< 750
good
medium
low
good
500-1000
750-1500
fair
high
low
good to medium
> 1000
> 1500
medium to bad
high to very high
low to high
medium to bad
A. M. MAS'AD

Fig. 9.4

TOTAL VOLUME OF STORED GROUNDWATER IN THE UPPER CRETACEOUS LIMESTONE AQUIFER COMPLEX ( AJLUN - LOWER BELQA GROUP )

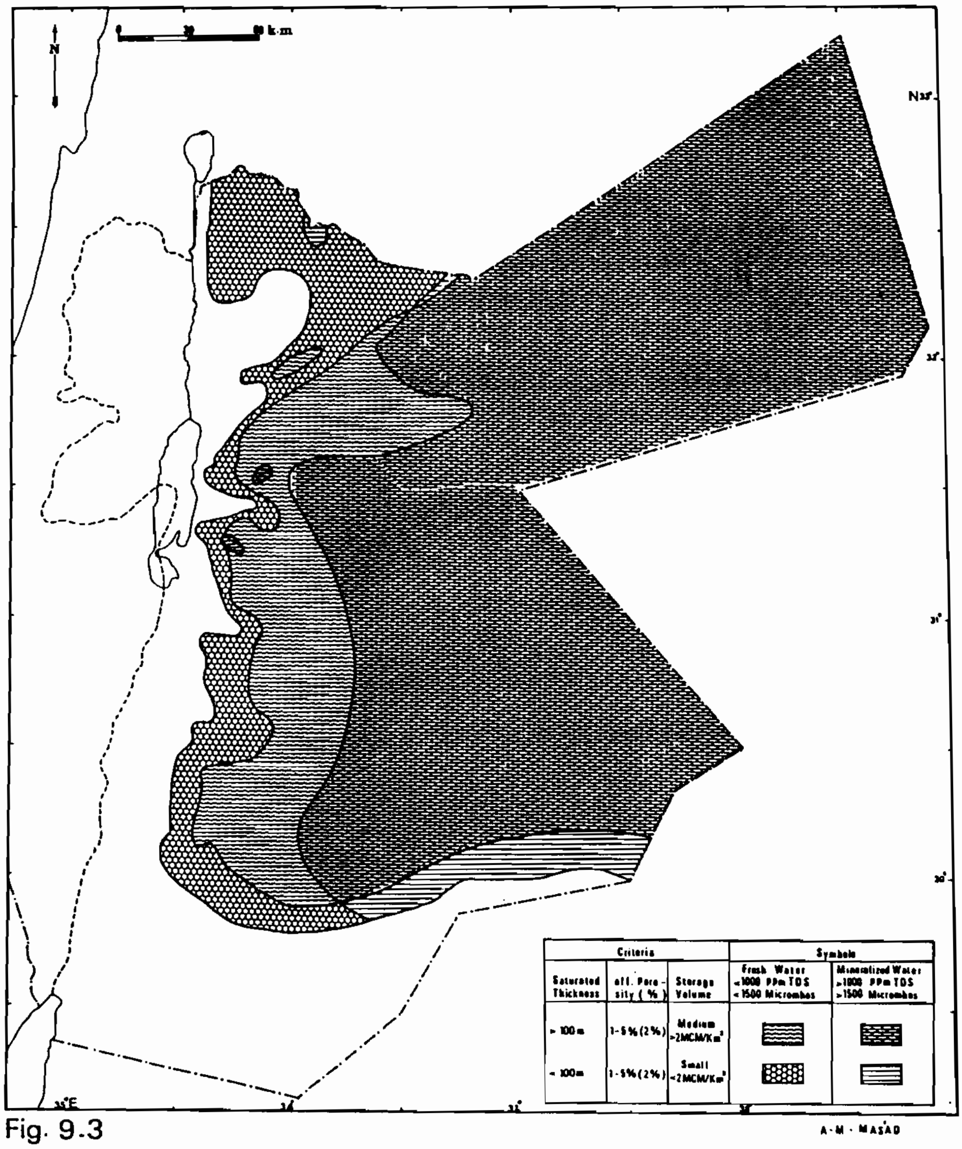



Fig. 9.3

TOTAL VOLUME OF STORED GROUNDWATER IN THE SANDSTONE AQUIFER COMPLEX
( KURNUB - ZARQA - DISI GROUP )

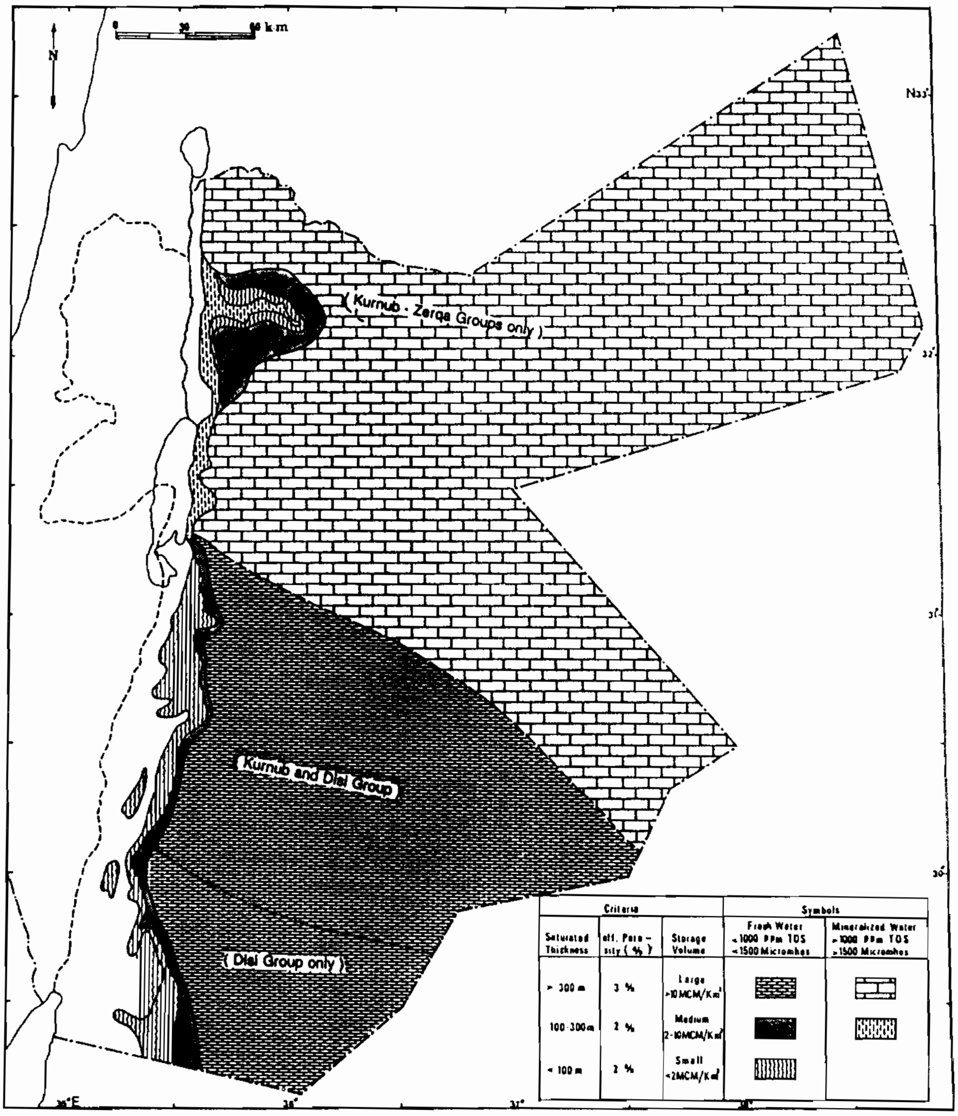



Fig. 9-2

A·M·MAS'AD

TOTAL VOLUME OF STORED GROUNDWATER IN THE SHALLOW AQUIFER COMPLEX

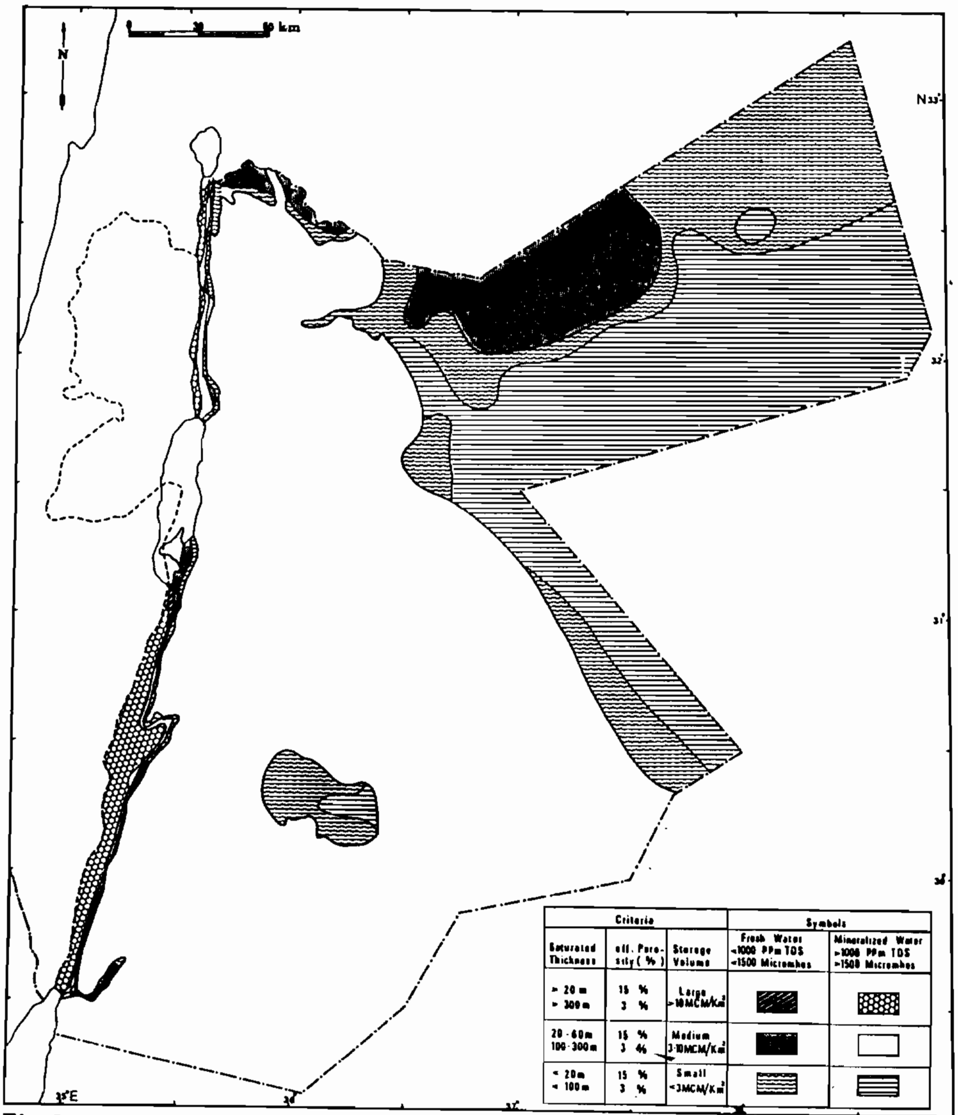


Fig. 9.1

A. M. MAS'AD

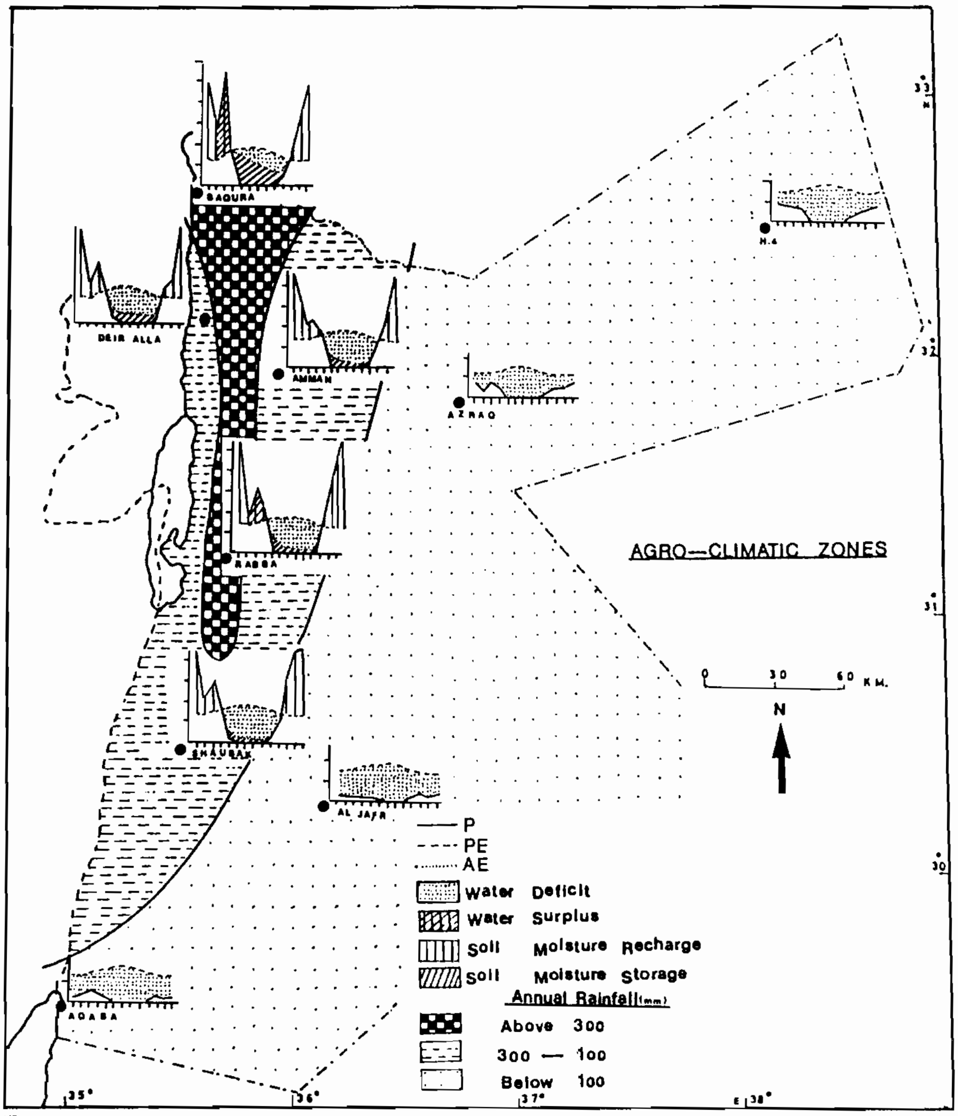



Fig. 8.2

A.M. MAS'AD

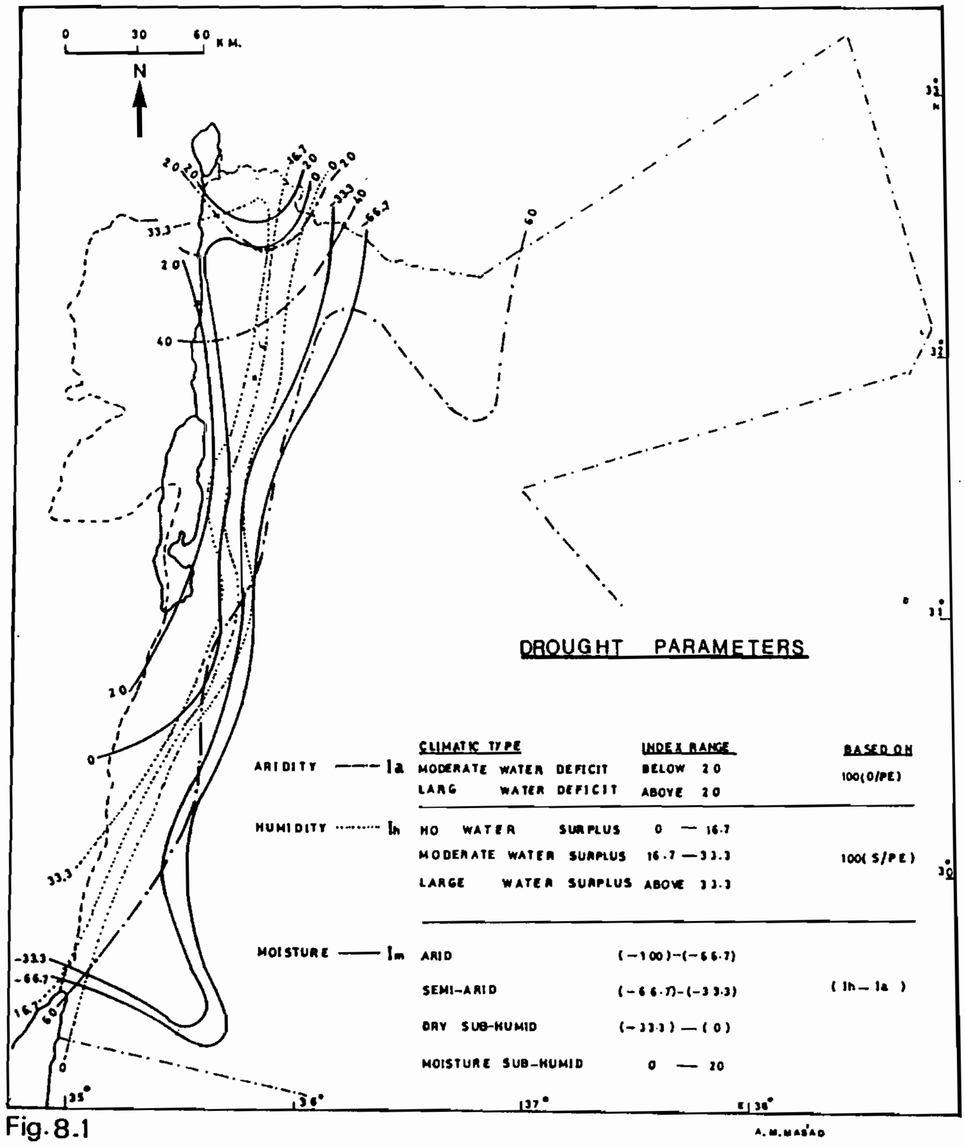

0 30 60 KM.
N
DROUGHT PARAMETERS
CLIMATIC TYPE
INDEX RANGE
BASED ON
ARIDITY Ia
MODERATE WATER DEFICIT BELOW 20
LARG WATER DEFICIT ABOVE 20
100(D/PE)
HUMIDITY Ih
NO WATER SURPLUS 0 — 16.7
MODERATE WATER SURPLUS 16.7 — 33.3
LARGE WATER SURPLUS ABOVE 33.3
100(S/PE)
MOISTURE Im
ARID (−100)−(−66.7)
SEMI-ARID (−66.7)−(−33.3)
DRY SUB-HUMID (−33.3) — (0)
MOISTURE SUB-HUMID 0 — 20
(Ih − Ia)
35°
36°
37°
E 38°
A. M. MAS'AD

Fig. 8.1

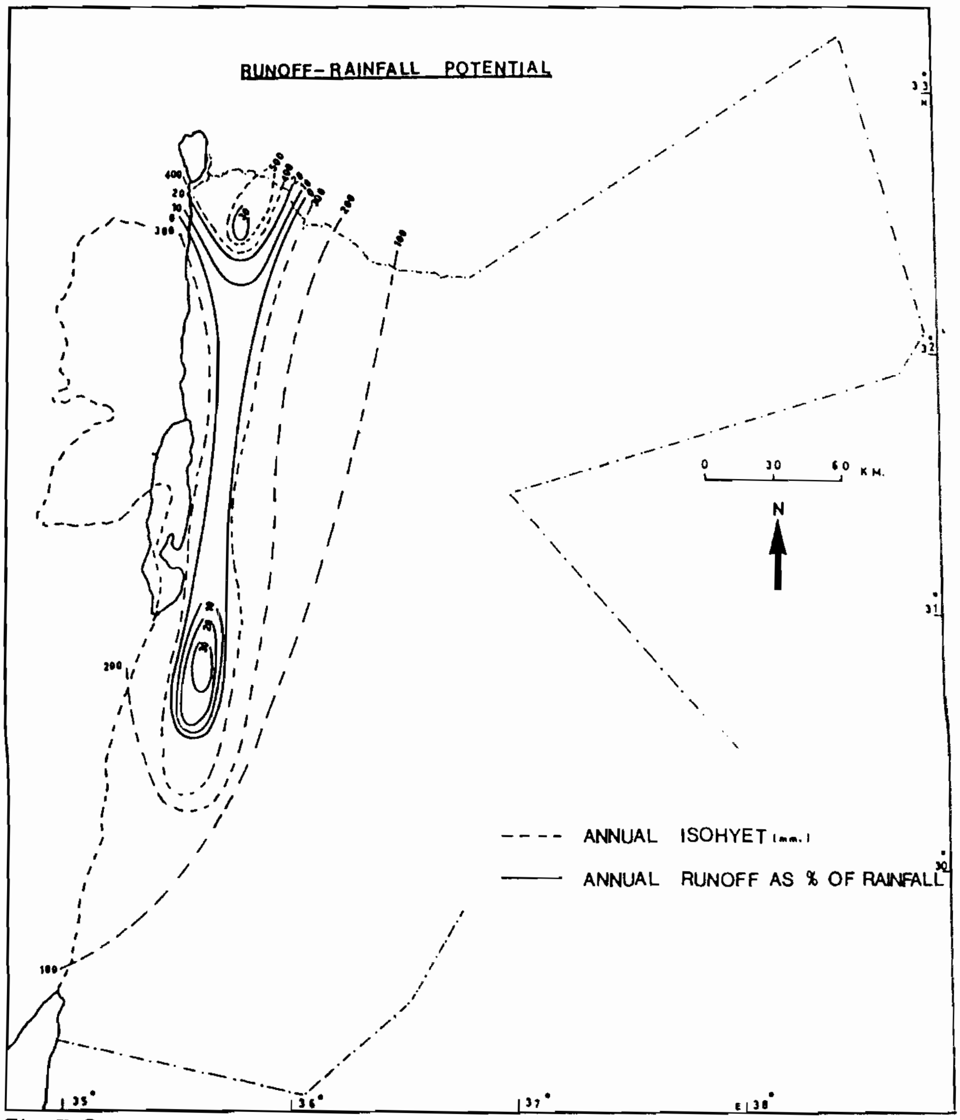
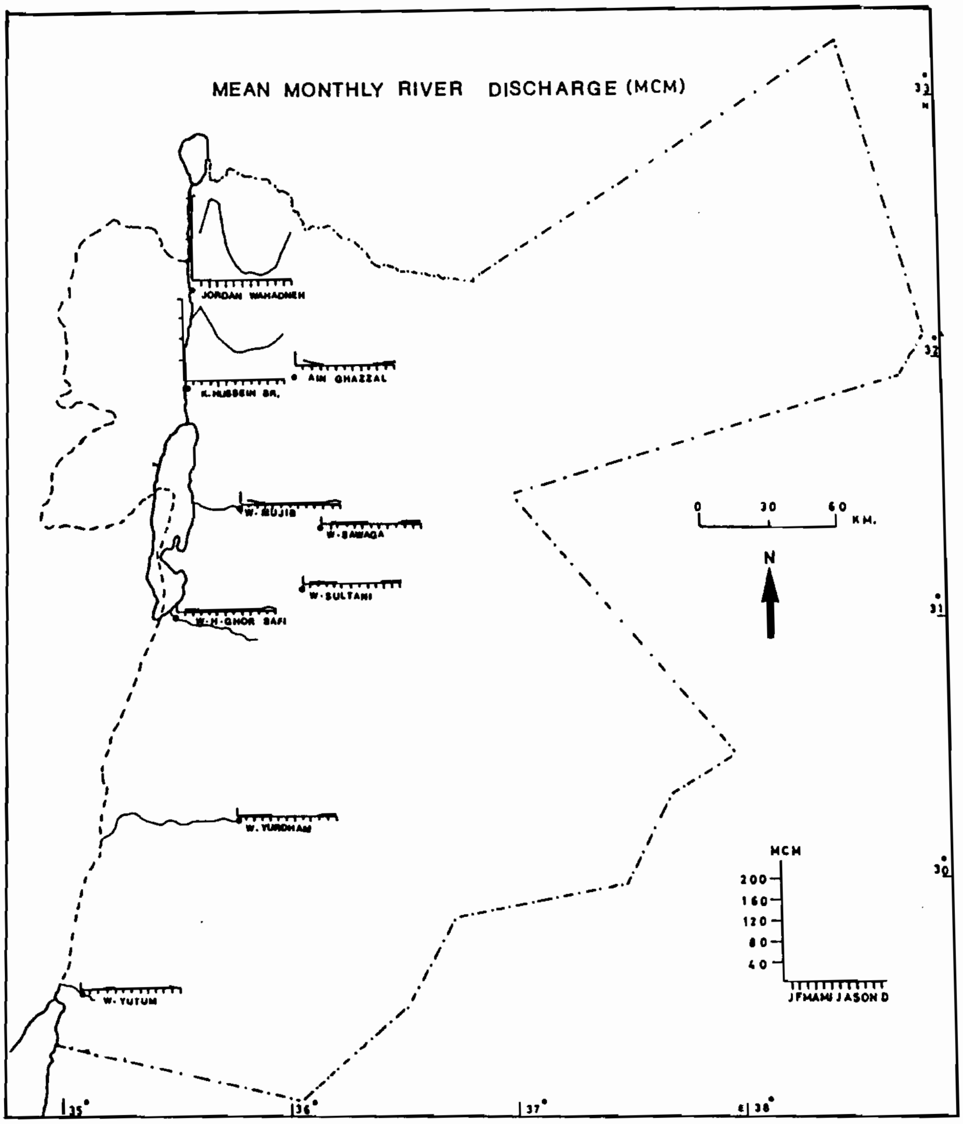

RUNOFF-RAINFALL POTENTIAL
ANNUAL ISOHYET (mm.)
ANNUAL RUNOFF AS % OF RAINFALL
0 30 60 KM.
N
35°
36°
37°
E 38°
33° N
32°
31°
30°
A.M.MAS'AD

Fig. 7.2


MEAN MONTHLY RIVER DISCHARGE (MCM)
JORDAN WAHADNEH
K.HUSSEIN BR.
AIN GHAZZAL
W. MUJIB
W. SULTANI
W.H.GHOR SAFI
W. YURDHAM
W. YUTUM
0 30 60 KM.
N
MCM
200
160
120
80
40
JFMAMJJASOND
35°
36°
37°
38°
33° N
32°
31°
30°
A. M. MAS'AD
Fig. 7.1

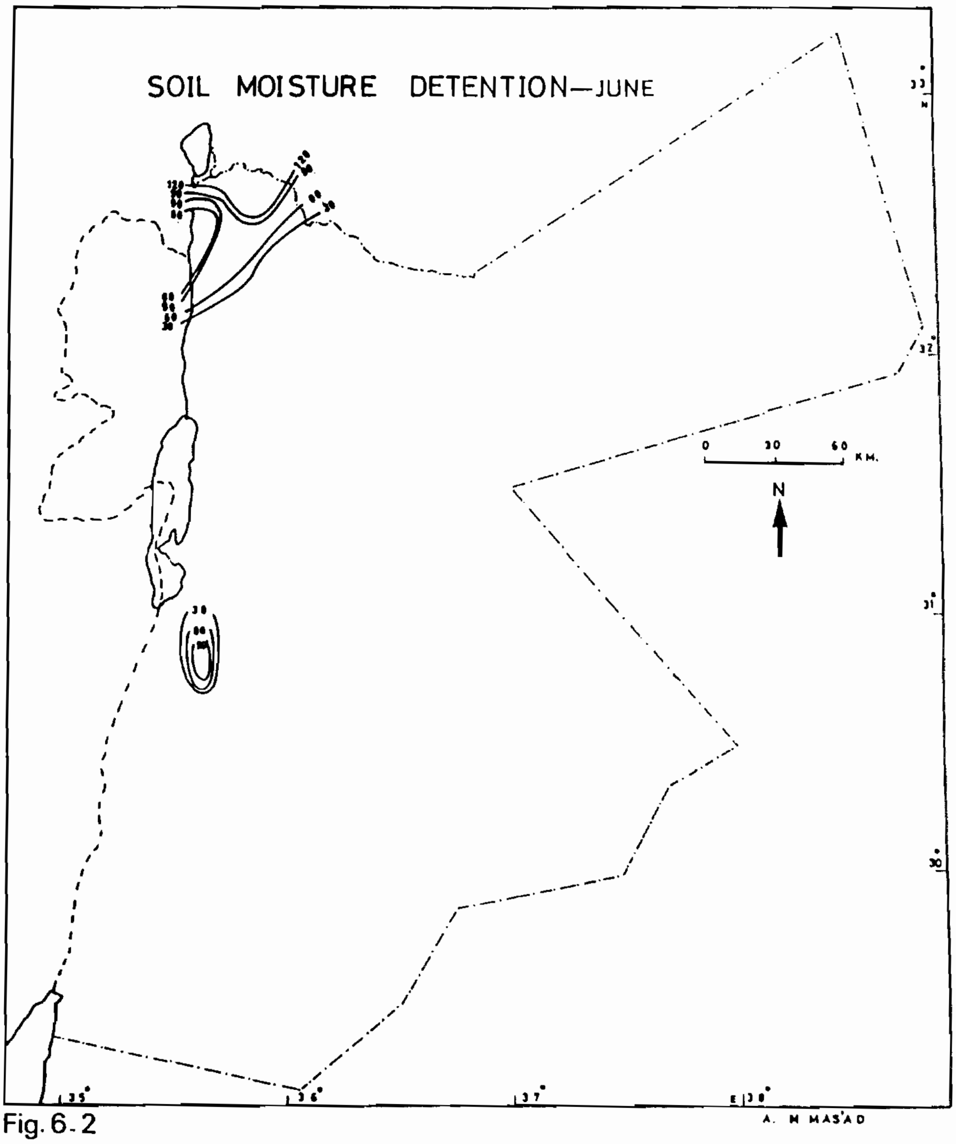


Fig. 6-2

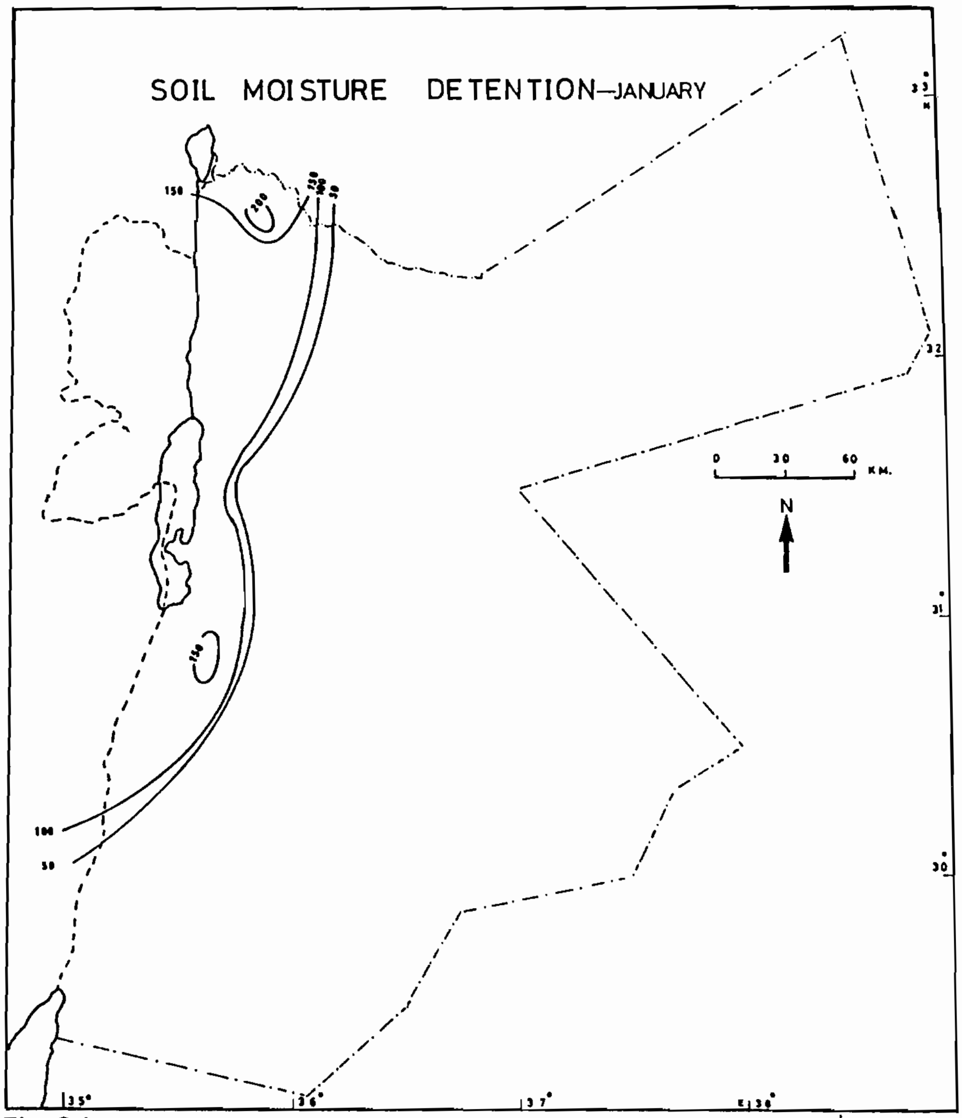
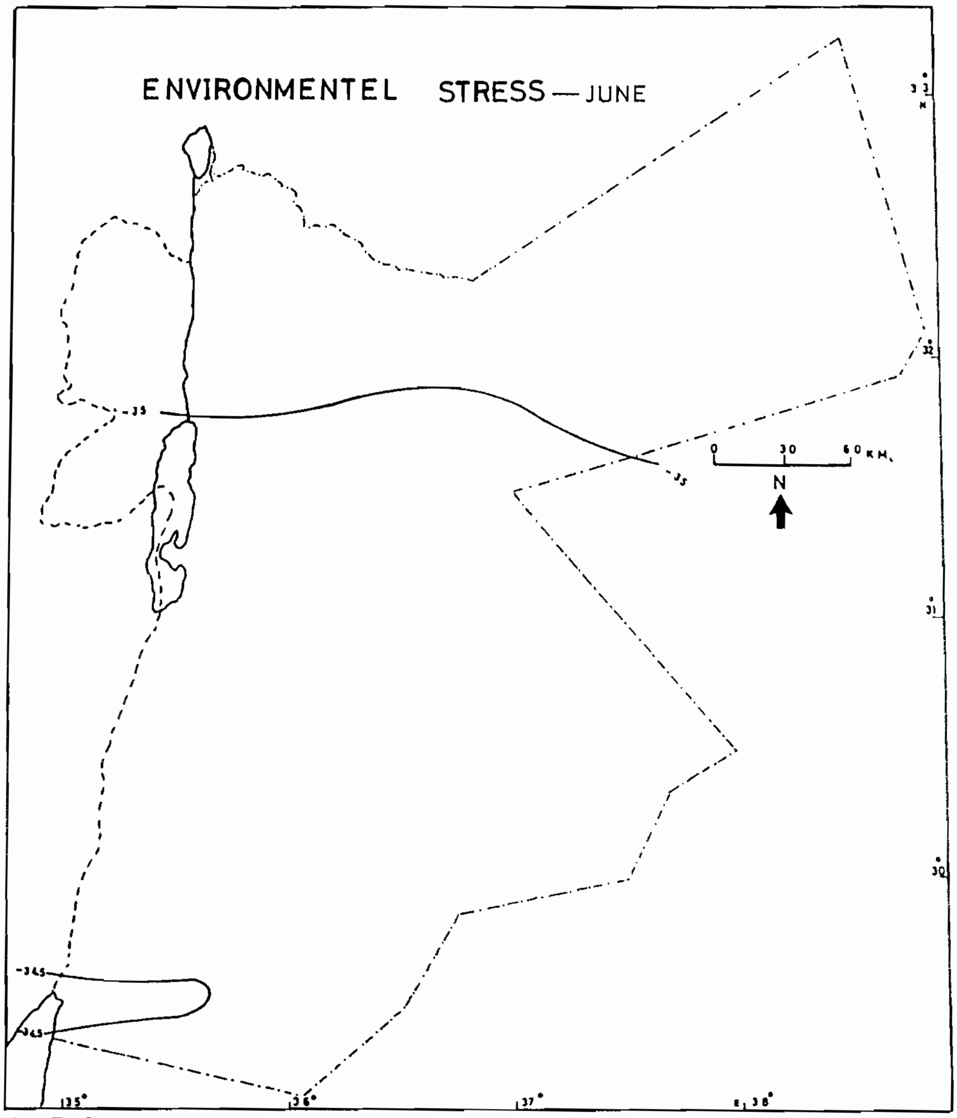


Fig. 6.1

A. H. HASAD


ENVIRONMENTEL STRESS — JUNE
-35
35
-345
-345
0
30
60 KM.
N
35°
36°
37°
E 38°
33° N
32°
31°
30°
A. M. MAS'AD
Fig. 5.2

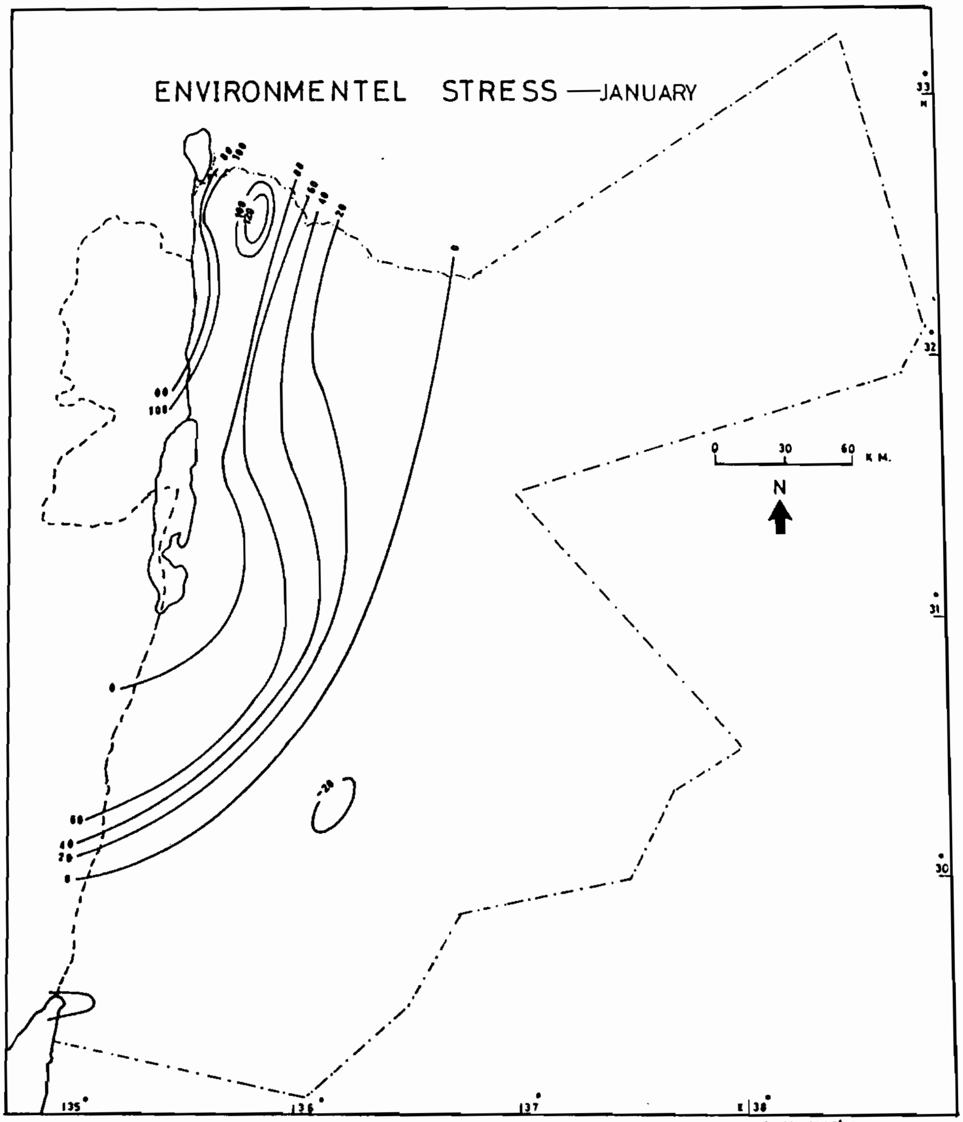



Fig. 5.1

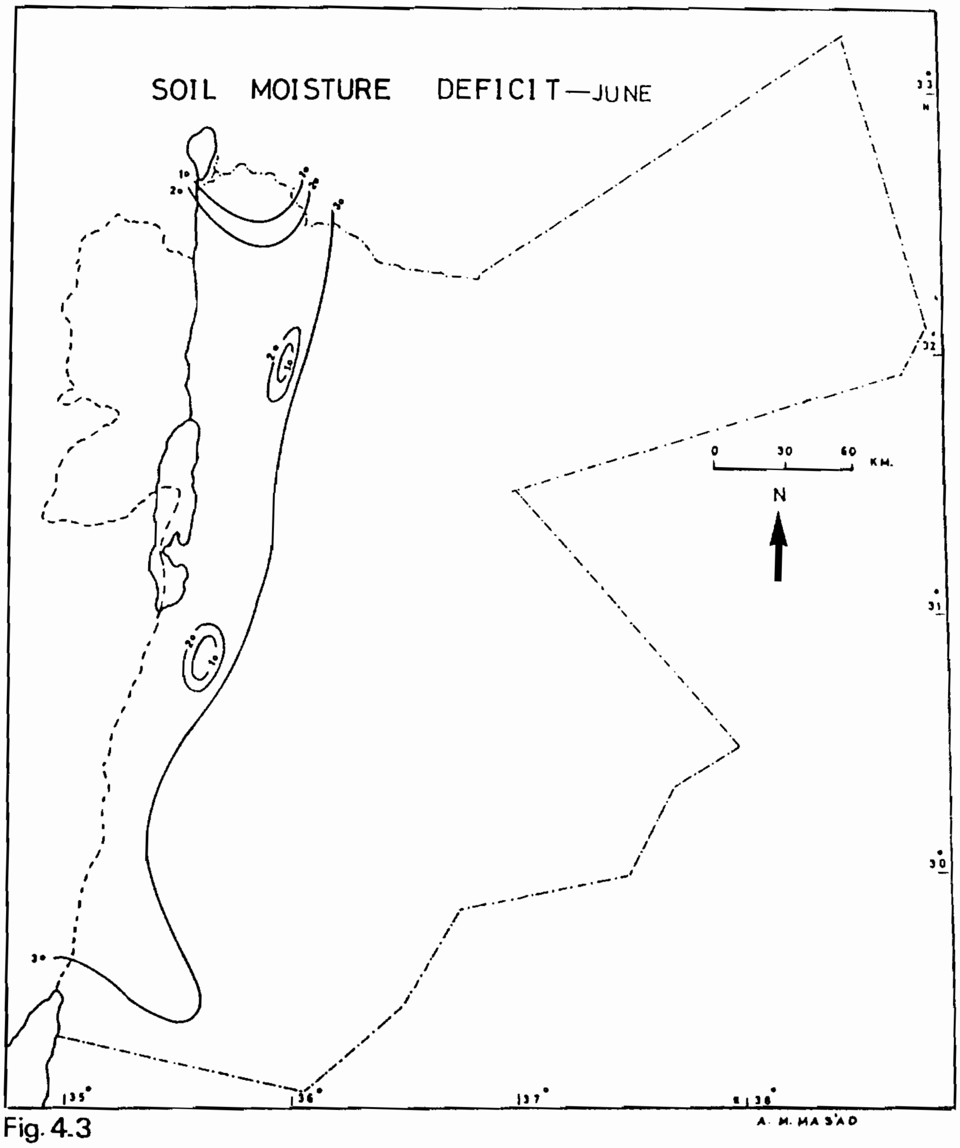
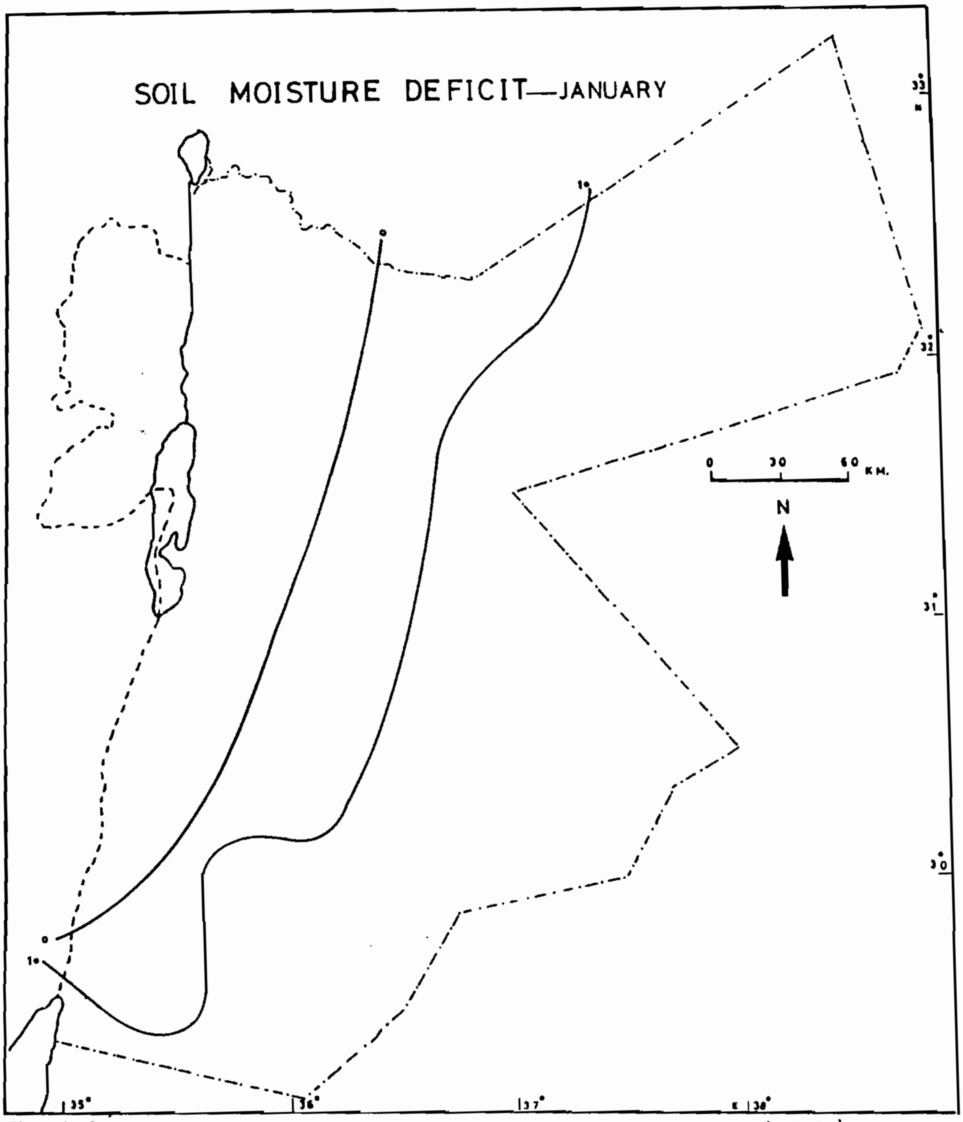


Fig. 4.3


SOIL MOISTURE DEFICIT—JANUARY
0
10
0
30
60 KM.
N
33°
32°
31°
30°
35°
36°
37°
38°
A. M. MASAD
Fig. 4.2

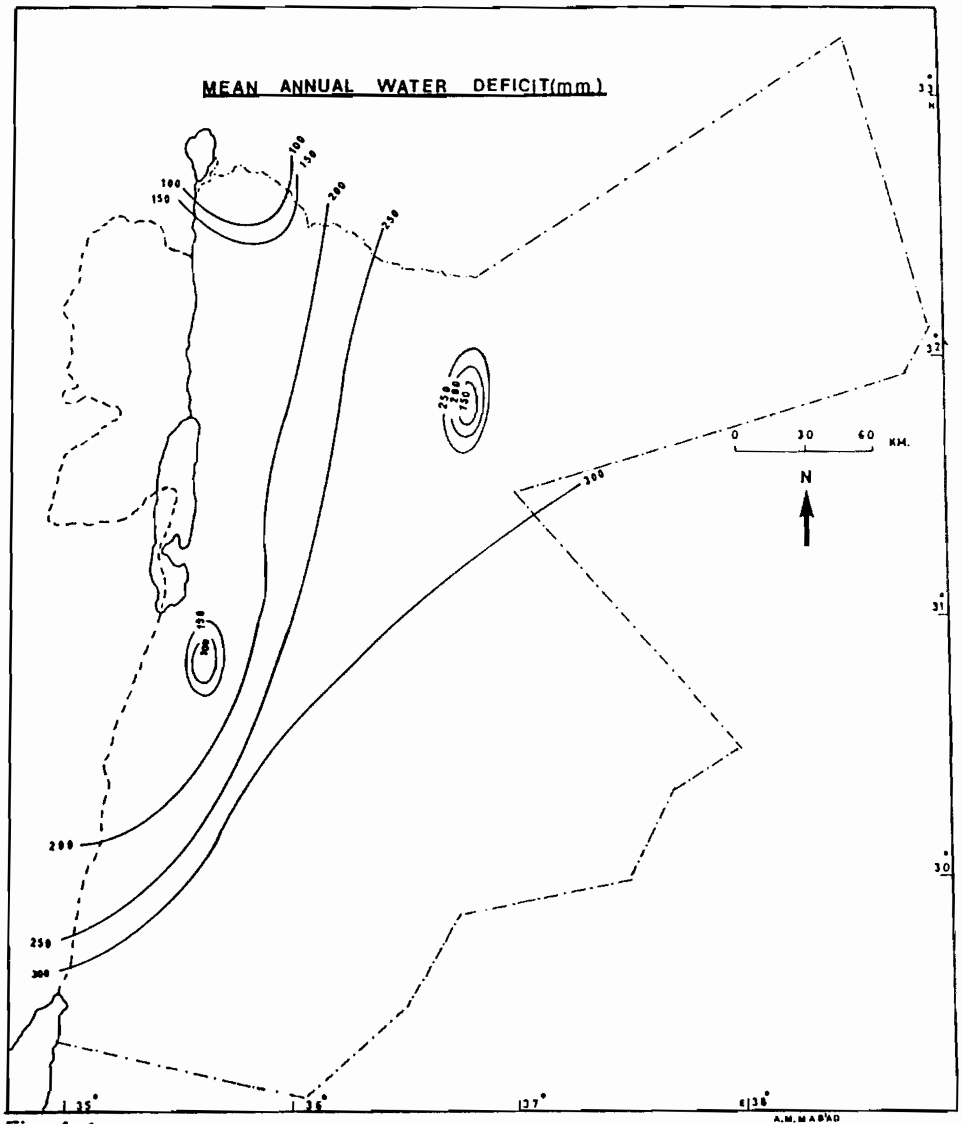


Fig. 4-1

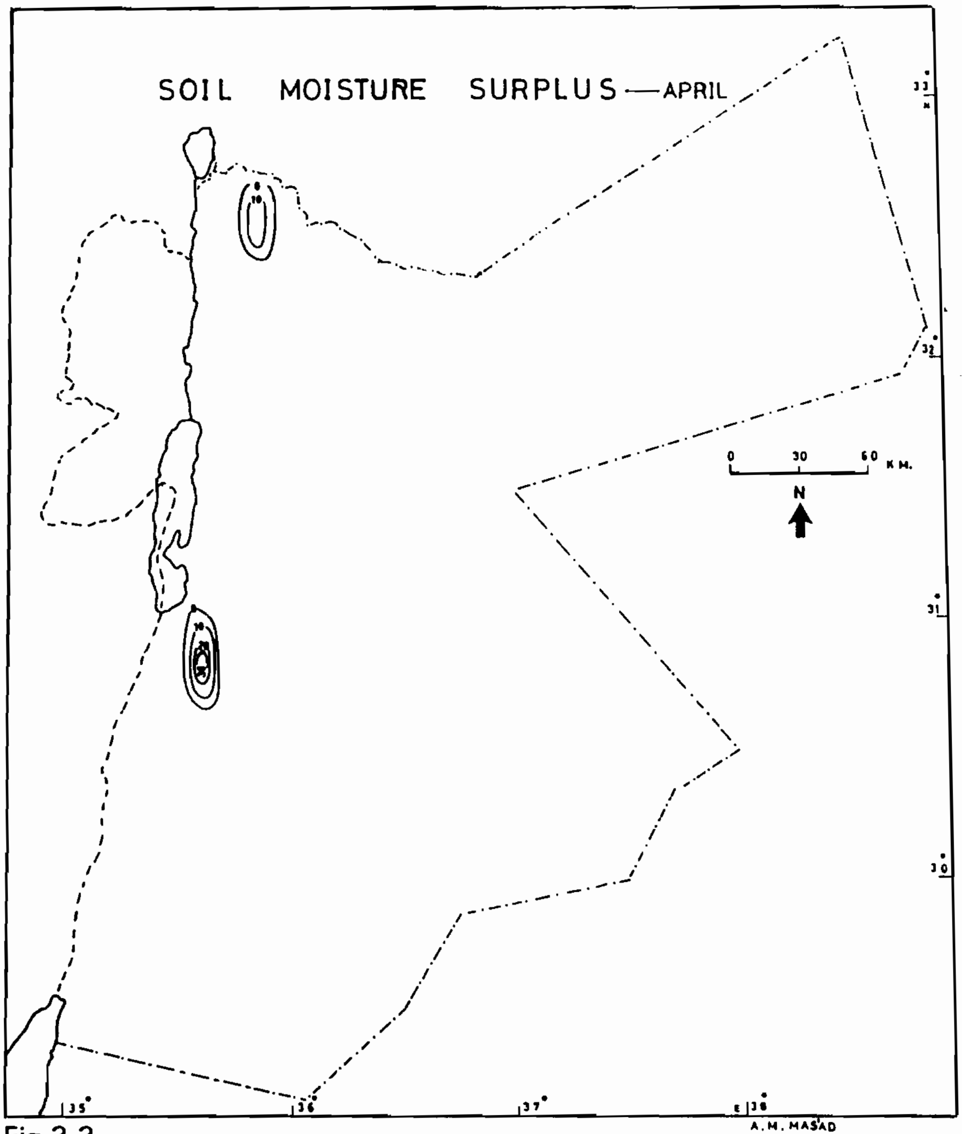
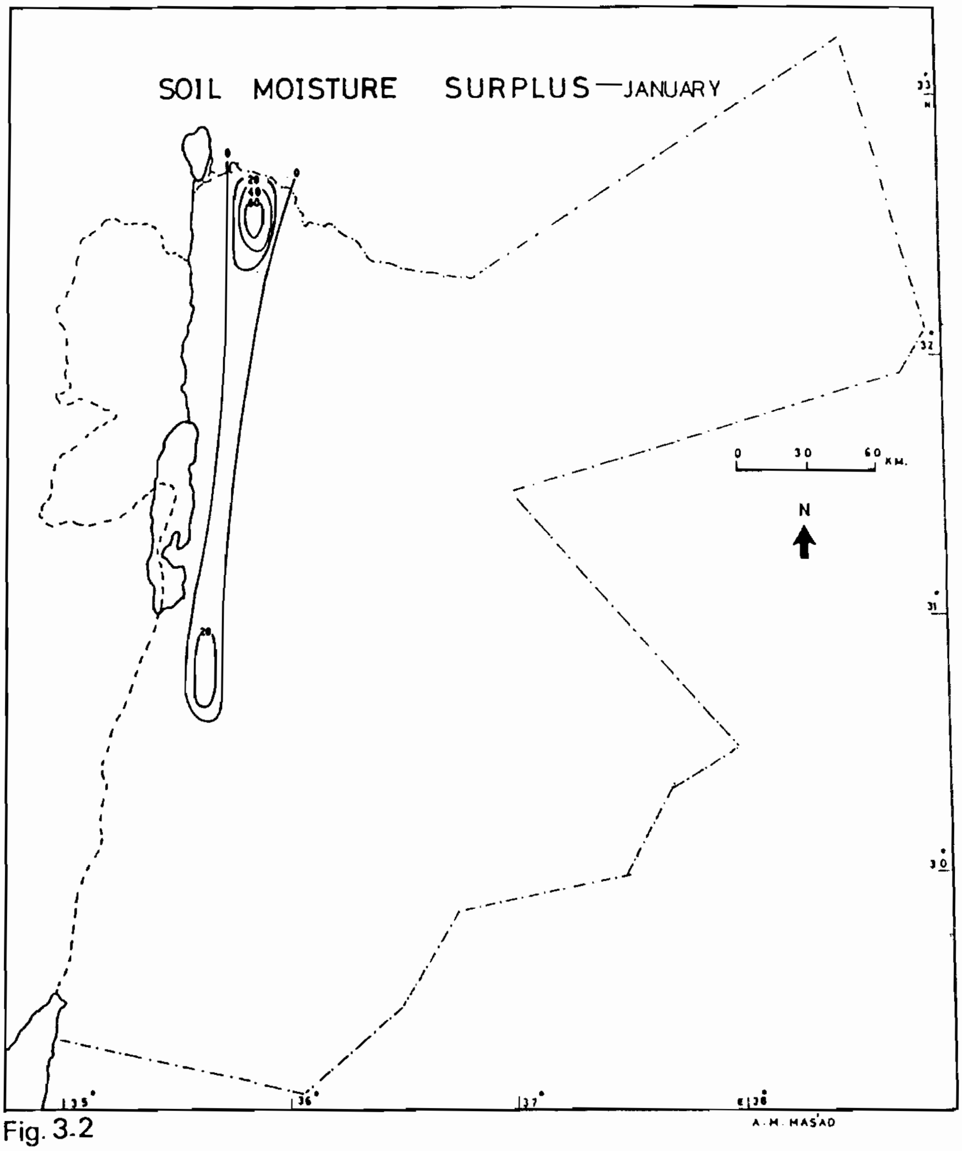
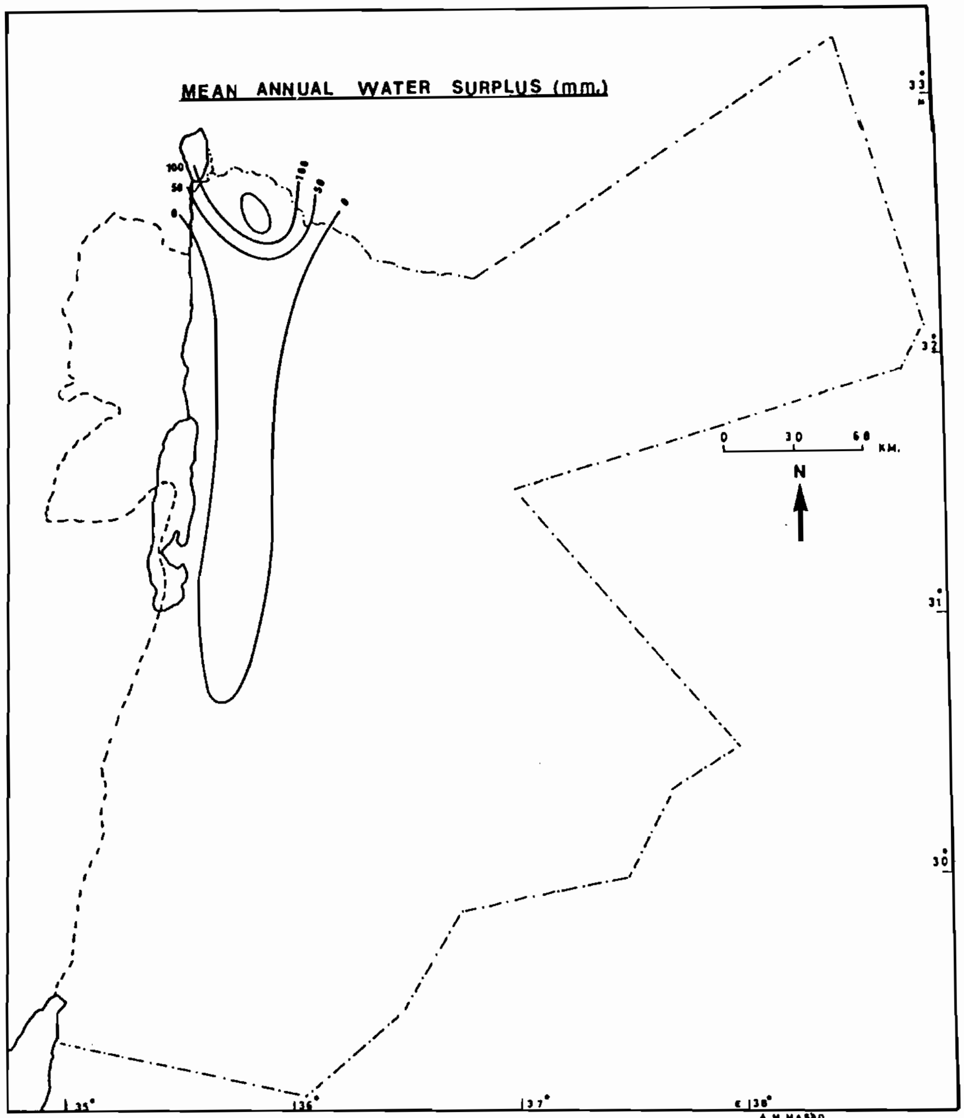


Fig. 3.3


SOIL MOISTURE SURPLUS—JANUARY
0
20
40
60
0
20
0 30 60 KM.
N
33° N
32°
31°
30°
35°
36°
37°
E 38°
A. M. MAS'AD
Fig. 3.2


MEAN ANNUAL WATER SURPLUS (mm.)
100
50
0
100
50
0
0 30 60 KM.
N
A.M.MASRO
Fig. 3.1

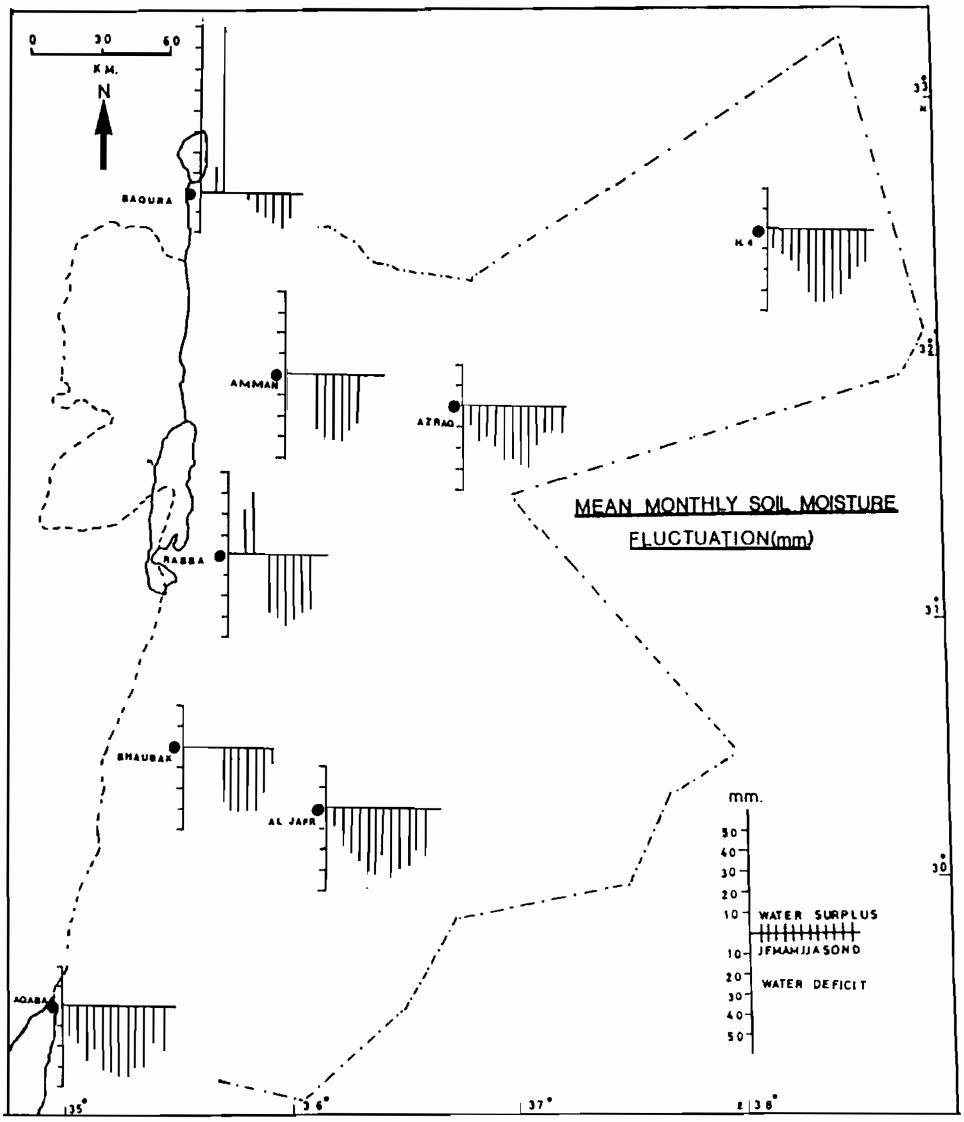



Fig. 2.2

A.M.MAS'AD

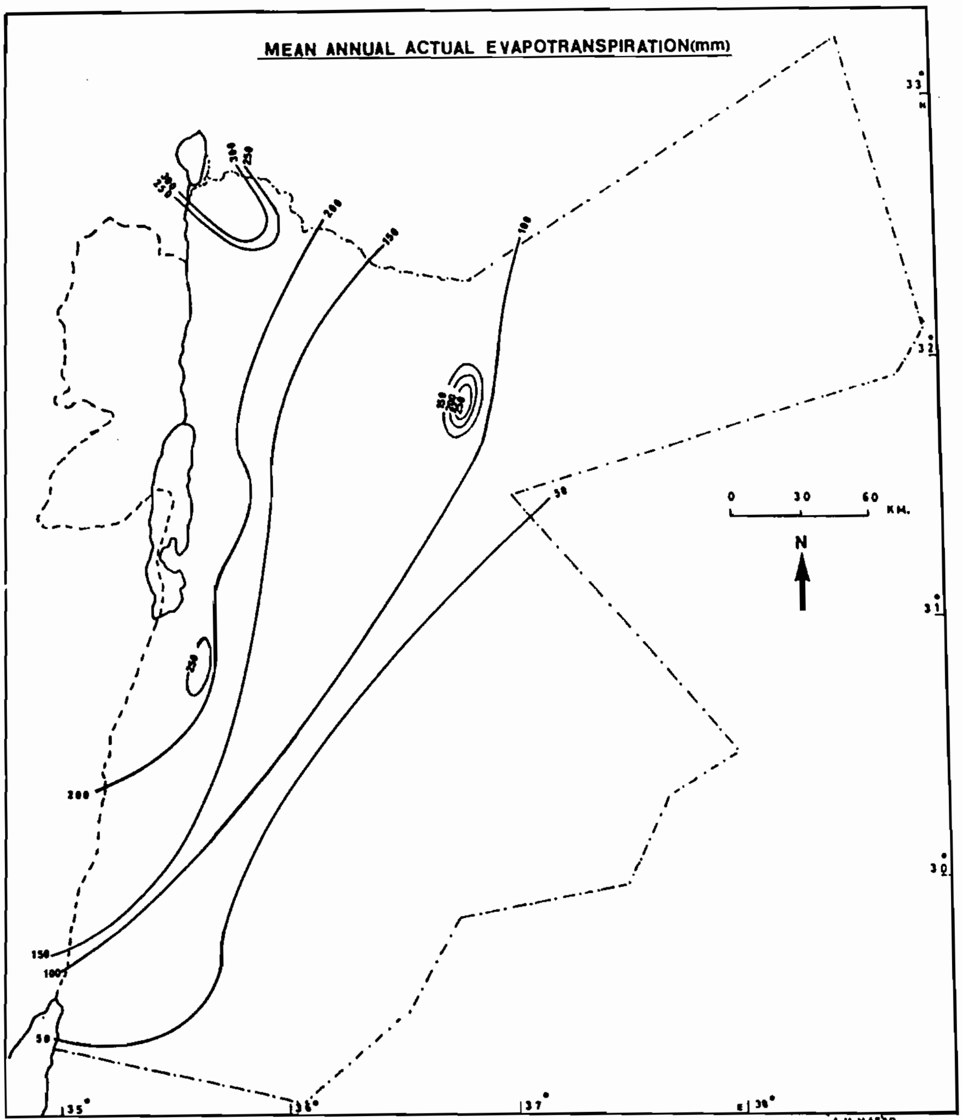

MEAN ANNUAL ACTUAL EVAPOTRANSPIRATION(mm)
0 30 60 KM.
N
200
150
100
50
35°
37°


Fig. 2.1

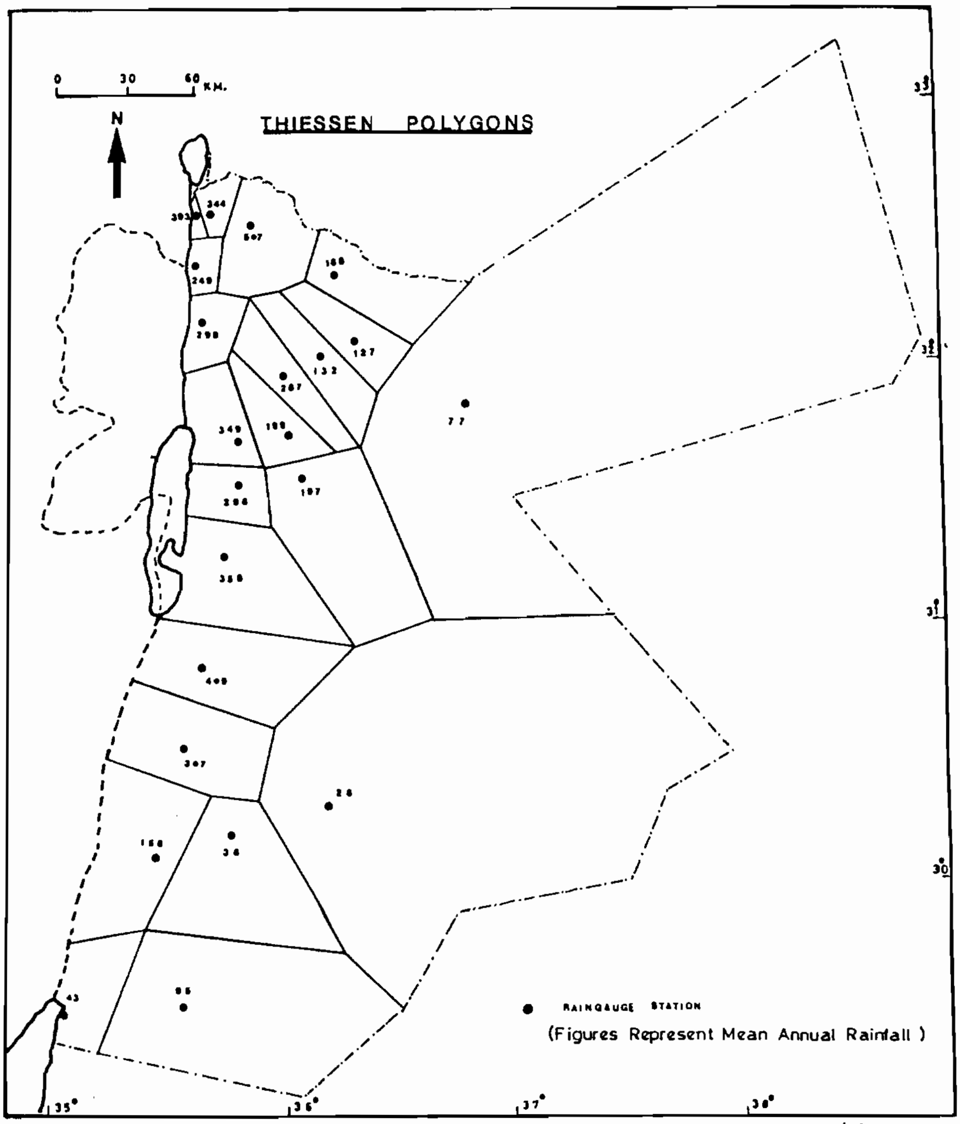



Fig.1

A. H. MAS'AD

# ILLUSTRATIONS

Area: AQABA

Geographical co-ordinates: 29° 31N 35° 00E

Elevation: 2 m.

Water Holding Capacity: 125 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 18.7 | 27.3 | 4 | -23.3 | 7 | 10 | 17.3 | 0 | 0 | 7 |
| FEB | 18.5 | 26.1 | 3.8 | -22.3 | 6 | 4.8 | 21.3 | 0 | 0 | 6 |
| MAR | 22.7 | 30.9 | 13.3 | -17.6 | 5 | 14.3 | 16.6 | 0 | 0 | 5 |
| APR | 21.8 | 32.1 | 7.9 | -24.2 | 4 | 8.9 | 23.2 | 0 | 0 | 4 |
| MAY | 27.6 | 35.1 | 4 | -31.1 | 3 | 5 | 30.1 | 0 | 0 | 3 |
| JUN | 31.01 | 34.8 | 0 | -34.8 | 2 | 1 | 33.8 | 0 | 0 | 2 |
| JUL | 31.8 | 35.7 | 0 | -35.7 | 2 | 0 | 35.7 | 0 | 0 | 2 |
| AUG | 31.9 | 33.9 | 0 | -33.9 | 1 | 0 | 33.9 | 0 | 0 | 1 |
| SEP | 30.6 | 30.9 | 0 | -30.9 | 1 | 0 | 30.9 | 0 | 0 | 1 |
| OCT | 26.8 | 29.4 | 0.1 | -29.3 | 1 | 0.1 | 29.3 | 0 | 0 | 1 |
| NOV | 21.9 | 26.7 | 7.8 | -18.9 | 1 | 7.8 | 18.9 | 0 | 0 | 1 |
| DEC | 16.9 | 26.7 | 2.6 | -24.1 | 1 | 2.6 | 24.1 | 0 | 0 | 1 |
| YEARLY | | 369.6 | 43.5 | -326.1 | | 54.5 | 315.1 | | | |

Area: JAFR

Geographical co-ordinates: 30° 17N 36° 09E.

Elevator: 865 m.

Water Holding Capacity: 125 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 9.4 | 27 | 6.6 | -20.4 | 12 | 17.6 | 9.4 | 0 | 0 | 12 |
| FEB | 12.3 | 26.1 | 2.6 | -23.5 | 10 | 4.5 | 21.5 | 0 | 0 | 10 |
| MAR | 16 | 50.9 | 3.4 | -27.5 | 8 | 5.4 | 25.5 | 0 | 0 | 8 |
| APR | 18.04 | 32.4 | 1.8 | -30.6 | 6 | 3.8 | 28.6 | 0 | 0 | 6 |
| MAY | 21.04 | 35.4 | 1.7 | -33.7 | 5 | 2.7 | 32.7 | 0 | 0 | 5 |
| JUN | 24.6 | 35.1 | 0 | -35.1 | 4 | 1 | 34.1 | 0 | 0 | 4 |
| JUL | 26.1 | 36 | 0 | -36 | 3 | 1 | 35 | 0 | 0 | 3 |
| AUG | 26.1 | 34.2 | 0 | -34.2 | 3 | 0 | 34.2 | 0 | 0 | 3 |
| SEP | 24.2 | 30.9 | 0.1 | -30.8 | 2 | 1.1 | 29.8 | 0 | 0 | 2 |
| OCT | 19.8 | 29.4 | 0.3 | -29.1 | 2 | 0.3 | 29.1 | 0 | 0 | 2 |
| NOV | 13.8 | 26.7 | 7.7 | -19 | 2 | 7.7 | 21 | 0 | 0 | 2 |
| DEC | 9 | 26.4 | 1.3 | -25.1 | 1 | 2.3 | 24.1 | 0 | 0 | 1 |
| YEARLY | | 370.5 | 25.5 | -345 | | 47.5 | 375 | | | |

Area: SHOUBAK

Geographical co-ordinates: 30° 31N 35° 32E.

Elevation: 1365 m.

Water Holding Capacity: 150 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 6.2 | 27 | 88 | 61 | 106.9 | 27 | 0 | 0 | 0 | 106.9 |
| FEB | 7.6 | 26.1 | 39.3 | 13.2 | 120.1 | 26.1 | 0 | 0 | 0 | 120.1 |
| MAR | 12.1 | 30.9 | 59.6 | 28.7 | 34 | 30.9 | 0 | 0 | 0 | 34 |
| APR | 13.7 | 32.4 | 31 | -1.4 | 34 | 31 | 1.4 | 0 | 0 | 34 |
| MAY | 14.9 | 35.4 | 2.8 | -32.6 | 27 | 9.8 | 25.6 | 0 | 0 | 27 |
| JUN | 17 | 35.1 | 0 | -35.1 | 22 | 5 | 30.1 | 0 | 0 | 22 |
| JUL | 18.8 | 36 | 0 | -36 | 17 | 5 | 31 | 0 | 0 | 17 |
| AUG | 20.1 | 34.2 | 0 | -34.2 | 14 | 3 | 31.2 | 0 | 0 | 14 |
| SEP | 18.2 | 30.9 | 0 | -30.9 | 11 | 3 | 27.9 | 0 | 0 | 11 |
| OCT | 15 | 29.4 | 2.6 | -26.2 | 9 | 4.6 | 24.8 | 0 | 0 | 9 |
| NOV | 9.8 | 26.7 | 20.8 | -5.9 | 9 | 20.8 | 5.9 | 0 | 0 | 9 |
| DEC | 7.4 | 20.3 | 63.3 | 36.9 | 45.9 | 20.4 | 0 | 0 | 0 | 45.9 |
| YEARLY | | 370.5 | 307.4 | -63.1 | | 192.6 | 177.9 | | | |

Area: RABBA

Geographical Co-ordinates: 31° 16N 35° 45E

Elevation 920 m

Water Holding Capacity: 150 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 9.5 | 27 | 109.8 | 82.8 | 145.3 | 27 | 0 | 0 | 0 | 145.3 |
| FEB | 11.8 | 26.1 | 33.3 | 7.2 | 150 | 26.1 | 0 | 2.5 | 1.3 | 151.3 |
| MAR | 23.8 | 30.9 | 63.9 | 32.6 | 150 | 30.8 | 0 | 32.9 | 16.9 | 166.9 |
| APR | 16.9 | 32.4 | 46.7 | 14.3 | 36 | 32.4 | 0 | 0 | 8.5 | 44.5 |
| MAY | 20.4 | 35.4 | 0.5 | -34.9 | 29 | 7.5 | 27.9 | 0 | 4.2 | 33.2 |
| JUN | 21.3 | 35.1 | 0 | 35.1 | 23 | 6 | 29.1 | 0 | 2.2 | 25.2 |
| JUL | 23.4 | 36 | 0 | -36 | 22 | 1 | 35 | 0 | 1 | 23 |
| AUG | 24 | 34.2 | 0 | -34.2 | 17 | 5 | 29.2 | 0 | 1 | 18 |
| SEP | 23.6 | 30.9 | 0 | -30.9 | 14 | 3 | 27.9 | 0 | 0 | 14 |
| OCT | 26 | 29.4 | 2.1 | -27.3 | 12 | 4.1 | 25.3 | 0 | 0 | 12 |
| NOV | 14.7 | 26.4 | 31.4 | 5.1 | 17.1 | 26.4 | 0 | 0 | 0 | 17.1 |
| DEC | 10 | 26.4 | 71.8 | 45.4 | 62.5 | 26.4 | 0 | 0 | 0 | 62.5 |
| YEARLY | | 370.2 | 359.2 | -11 | | 195.8 | -174.4 | 35.1 | 35.1 | |

Area: AZRAQ

Geographical co-ordinates: 31° 43N 35° 09E.

Elevation: 715 m.

Water Holding Capacity: 75 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 11.3 | 27 | 14.8 | -12.2 | 1 | 14.8 | 12.2 | 0 | 0 | 1 |
| FEB | 13 | 26.1 | 7.6 | -18.5 | 1 | 7.6 | 18.5 | 0 | 0 | 1 |
| MAR | 17.9 | 30.9 | 13.8 | -17.1 | 1 | 13.8 | 17.1 | 0 | 0 | 1 |
| APR | 20.7 | 32.4 | 11.6 | -20.8 | 1 | 11.6 | 20.8 | 0 | 0 | 1 |
| MAY | 23.3 | 35.4 | 1.2 | -34.2 | 1 | 1.2 | 34.2 | 0 | 0 | 1 |
| JUN | 26.7 | 35.1 | 0 | -35.1 | 1 | 35.1 | 0 | 0 | 0 | 1 |
| JUL | 27.9 | 36 | 0 | -36 | 1 | 0 | 0 | 0 | 0 | 1 |
| AUG | 27.9 | 34.7 | 0 | -34.2 | 1 | 34.2 | 0 | 0 | 0 | 1 |
| SEP | 27.2 | 30.9 | 0 | -30.9 | 1 | 30.9 | 0 | 0 | 0 | 1 |
| OCT | 22.4 | 29.4 | 3.1 | -26.3 | 1 | 29.4 | 0 | 0 | 0 | 1 |
| NOV | 15.7 | 26.4 | 3.4 | -13 | 1 | 13.4 | 13 | 0 | 0 | 1 |
| DEC | 9.7 | 26.4 | 11.7 | -14.7 | 1 | 11.7 | 14.7 | 0 | 0 | 1 |
| YEARLY | | 370.2 | 77.2 | -293 | | 293.7 | 130.5 | | | |

Area: H 4

Geographical co-ordinates: 32° 30N 38° 12E

Elevation: 686 m

Water Holding Capacity: 75 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | Ro | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 7.7 | 26.7 | 14.7 | -12 | 1 | 14.7 | 12 | 0 | 0 | 1 |
| FEB | 10.8 | 25.8 | 13.1 | -12.7 | 1 | 13.1 | 12.7 | 0 | 0 | 1 |
| MAR | 15.9 | 30.9 | 13.2 | -17.7 | 0 | 13.2 | 17.7 | 0 | 0 | 1 |
| APR | 19.7 | 32.4 | 11.4 | -21 | 1 | 11.4 | 21 | 0 | 0 | 1 |
| MAY | 24.6 | 35.7 | 5.7 | -30 | 1 | 5.7 | 30 | 0 | 0 | 1 |
| UN | 26.4 | 35.4 | 0 | -35.4 | 1 | 0 | 35.4 | 0 | 0 | 1 |
| JUL | 28.1 | 36.3 | 0 | -36.3 | 1 | 0 | 36.3 | 0 | 0 | 1 |
| AUG | 28.7 | 34.5 | 0 | -34.5 | 1 | 0 | 34.5 | 0 | 0 | 1 |
| SEP | 25.9 | 30.9 | 0 | -30.9 | 1 | 0 | 30.9 | 0 | 0 | 1 |
| OCT | 21.0 | 29.4 | 4.6 | -24.8 | 1 | 4.6 | 24.8 | 0 | 0 | 1 |
| NOV | 16.1 | 26.4 | 7.6 | -18.8 | 1 | 7.6 | 18.8 | 0 | 0 | 1 |
| DEC | 8.5 | 26.1 | 8.9 | -17.2 | 1 | 8.9 | 17.2 | 0 | 0 | 1 |
| YEARLY | | 370.5 | 79.2 | -291.3 | | 79.2 | 291.3 | | | |

Area: BAQURA

Geographical co-ordinates: 32° 37N 35° 37E.

Elevation: - 197 m.

Water Holding Capacity: 200 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 13 | 26.7 | 96 | 69.3 | 179.8 | 26.7 | 0 | 0 | 0 | 179.8 |
| FEB | 15 | 25.8 | 58 | 32.2 | 200 | 25.8 | 0 | 12 | 6 | 206 |
| MAR | 17 | 30.9 | 110 | 79.1 | 200 | 30.9 | 0 | 79.1 | 6 | 206 |
| APR | 22 | 32.4 | 31 | -104 | 199 | 32 | 0.4 | 0 | 40 | 239 |
| MAY | 24 | 35.7 | 1 | 34.7 | 167 | 33 | 2.7 | 0 | 20 | 187 |
| JUN | 29 | 35.4 | 0 | -35.4 | 140 | 27 | 8.7 | 0 | 10 | 150 |
| JUL | 32 | 36.3 | 0 | -36.3 | 116 | 24 | 12.3 | 0 | 5 | 121 |
| AUG | 31 | 34.5 | 0 | -34.5 | 97 | 19 | 15.5 | 0 | 3 | 100 |
| SEP | 30 | 30.9 | 0 | -30.9 | 83 | 14 | 16.90 | 101 | 84.1 | |
| OCT | 26 | 29.4 | 10 | -19.4 | 76 | 17 | 12.4 | 0 | 0 | 76 |
| NOV | 32 | 26.4 | 28 | 106 | 77.6 | 26.4 | 0 | 0 | 0 | 77.6 |
| DEC | 14 | 26.1 | 59 | 32.9 | 110.5 | 26.1 | 0 | 0 | 0 | 110.5 |
| YEARLY | | 370.5 | 393 | +22.5 | | 301.9 | 68.9 | 91.1 | 91.1 | |

Area: DEIR ALLA

Geographical co-ordinates: 32 12N 35° 37E.

Elevation: 224 m

Water Holding Capacity: 250 m.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 14.8 | 26.7 | 91.1 | 64.4 | 123.9 | 26.7 | 0 | 0 | 0 | 123.9 |
| FEB | 17.8 | 25.8 | 39.8 | 14 | 137.9 | 25.8 | 0 | 0 | 0 | 137.9 |
| MAR | 19.9 | 30.9 | 59.6 | 28.7 | 166.6 | 30.9 | 0 | 0 | 0 | 166.6 |
| APR | 23.7 | 32.4 | 32.7 | 0.3 | 90 | 32.4 | 0 | 0 | 0 | 90 |
| MAY | 26.3 | 35.7 | 2.3 | -33.4 | 79 | 13.3 | 22.4 | 0 | 0 | 79 |
| JUN | 30.6 | 35.4 | 0.07 | -35.3 | 68 | 11.07 | 24.3 | 0 | 0 | 68 |
| LUL | 31.6 | 36.3 | 0 | -36.3 | 59 | 9 | 27.3 | 0 | 0 | 59 |
| AUG | 32.1 | 34.5 | 0 | -34.5 | 51 | 8 | 26.5 | 0 | 0 | 51 |
| SEP | 31.5 | 30.9 | 0.68 | -30.2 | 45 | 6.68 | 24.2 | 0 | 0 | 45 |
| OCT | 27.6 | 29.4 | 2.25 | -27.2 | 41 | 6.25 | 23.1 | 0 | 0 | 41 |
| NOV | 22.08 | 26.4 | 30.7 | 4.3 | 45.3 | 26.4 | 0 | 0 | 0 | 45.3 |
| DEC | 15.9 | 26.1 | 40.3 | 14.2 | 59.5 | 26.1 | 0 | 0 | 0 | 59.5 |
| YEARLY | | 370.5 | 299.5 | -71 | | 222 | 147.9 | | | |

Area: Amman Airport

Geographical co-ordinates: 31°59N 35° 59E.

Elevation: 766 m.

Water Holding Capacity: 150 mm.

| | Tc° | PE | P | P-PE | ST | AE | D | S | RO | DT |
|---|---|---|---|---|---|---|---|---|---|---|
| JAN | 8.7 | 26.7 | 90.6 | 63.9 | 89.8 | 26.7 | 0 | 0 | 0 | 89.8 |
| FEB | 11 | 25.8 | 39.7 | 13.9 | 103.7 | 25.8 | 0 | 0 | 0 | 103.7 |
| MAR | 15.8 | 30.9 | 49.4 | 18.5 | 122.2 | 30.9 | 0 | 0 | 0 | 122.2 |
| APR | 17.4 | 32.4 | 36 | 3.6 | 35 | 32.4 | 0 | 0 | 0 | 35 |
| MAY | 20.1 | 35.7 | 1.9 | -33.8 | 28 | 8.9 | 26.8 | 0 | 0 | 28 |
| JUN | 24.4 | 35.4 | 0 | -35.4 | 22 | -6 | 29.4 | 0 | 0 | 22 |
| JUL | 24.8 | 36.3 | 0 | -36.3 | 17 | 5 | 31.3 | 0 | 17 | |
| AUG | 26.2 | 34.5 | 0 | -34.5 | 14 | 3 | 31.5 | 0 | 0 | 14 |
| SEP | 24.1 | 30.9 | 0 | -30.9 | 11 | 3 | 27.9 | 0 | 0 | 11 |
| OCT | 20.6 | 29.4 | 3.1 | -26.3 | 9 | 5.1 | 24.3 | 0 | 0 | 9 |
| NOV. | 14.4 | 26.4 | 23.3 | -3.1 | 9 | 25.3 | 1.1 | 0 | 0 | 9 |
| DEC | 9.3 | 26.1 | 43 | 16.9 | 25.9 | 26.1 | 0 | 0 | 0 | 25.9 |
| YEARLY | | 370.5 | 287 | -83.5 | | 198.2 | 172.3 | | | |

**Abreviations:**

TC° . Mean air temperature.

PE mm : Potential evapotranspiration.

P mm : Precipitation

ST mm : Storage.

AE mm : Actual evapotranspiration.

D mm . Moisture.

S mm : Moisture surplus.

RO mm : Water runoff

DT mm : Total moisture detention.

**APPENDIX**

Water Balance Parameters of Representative Station in Jordan with rainfall. But a new cropping pattern based on scientific vegetable plantation has opened a new era for the economy of Jordan.

Because the surface water supplies are not available easily, emphasis on use of groundwater has increased considerably. As seen from the pattern of water consumption the deficit is very high, and so that amount that has to be drawn from under ground resources to meet the demand is also high. A coordination in the use of surface and groundwater is essential to avoid waste and ensure optimal use of water. The annual water demand indicate the importance of a rational water resources strategy which allows to satisfy domestic water supply in the first priority from the total water demand. Domestic and industrial water is closely related to a control of water quality and water pullution. There is no significant use of water purposes other than domestic, industrial and irrigation. The development of water resources for irrigated agriculture, as a basic component of Jordan's economy, is given a high rating. There is no connection between the produced / consumed water and the number of people supplied, as the increase in the amount of water supplied is higher than the growth of population.

The analysis shows that the western hilly side of Jordan depicts good water availability low deficiency and fair volume of runoff. Hence from the hydrological point of view this region may be taken to possess considerable agricultural potential where two or three crops in a year may be raised. The eastern and southern limits of the hilly tracts present a simearid of climate and protected agriculture can be raised.

In Jordan, depending upon the value of agriculture production in relation to annual average of rainfall, ali the crops have been discussed. We have on one hand the water loving crops, and on the other hand the adjustable crops. These crops differ also in their capacity to stand the shortage of moisture in the root zone which can lead to the wilting of the crops. As such, changing the cropping pattern is important in the rational utilization of water resources. Even though a certain part of the season or a whole season may go dry, crops can still thrive on the basis of the reserve water that may be available in the soils supplemented by additional irrigation.

Consideration of the cropping season of Jordan should begin with consideration of the cropping pattern and the moisture storage capacity of the soil. The effect of these factors has great importance particularly in the choice of the crops in the non-rainy season. It is necessary to consider the rainfall and the potential evaportanspiration of the cropped area. Based on Thornthwaite method, the value of potential evapotranspiration has been used as an index of thermal efficiency and we can conclude that all Jordan has megathermal climate.

On the basis of the agro-hydrological envionment, we have carried out the western zone which implies a fairly low need supplementary irrigation, while in the rest of the country, the low rainfall necessitates a high need for supplementary irrigation. In these regions of erratic and scanty rainfall, agriculture is a gamble have seen, the actual run-off was almost 50% of the total rainfall. It was, therefore, decided to consider the actual deficit higher than the computed deficit. The basic reason is that Thornthwaite's formula extremely exaggerates the potential evapotranspiration during the rainy season. In this study, data collection poses a serious problem especially in places where the theoretical results are to be compared with the actual results.

In the hilly zone of Jordan, particularly in the north, there is a fair balance between water surplus and deficiency. Both are small, but the region has got the advantage of the location where additional water supply from the surplus areas in Syria has been carried out. Though both the surplus and the deficit are small, but if we consider the annual distribution of these parameters, it is found that the surplus period is not longer than 3-4 months. In this season, the water supply can exceed the water needs, the excess in water supply will go into soil moisture storage to be available to the crops in the following season. That water which exceeds the water holding capacity of the soil will go as runoff. Throughout the non-rainy season the water deficit more or less remains high.

In our study, the values of potential evapotranspiration had been used as the main parameter to determine the water need of Jordan and to estimate the irrigation water requirements (65). We have dealt with the drought as a period during which moisture need exceeds the moisture supply, and we have treated the water deficit as the difference between the potential evapotranspiration and the actual evapotranspiration.

The anomally between the computed discharge and the actual discharge can be explained in many ways. Though the potential evapotranspiration may exceed precipitation there is always an excess rain (PE) which is equal to (P-F) where P is the intensity of rain and F is the rat of infiltration. This may cause surface runoff as the excess rain is bound to find its way to drainage lines.

In certain cases, why for a given value of rainfall (x) the different districts do not show the same agricultural productivity. The most plausible answer is that rainfall is not the only determinant of agricultural productivity. There are several other variables also operating positively as well as negatively. The agricultural productivity will be more than the average in districts where the positive factors dominate, and also than the average where the negative factors dominate. Thus the residual (y - y") becomes a very meaningful indicator which shows the nature and intensity of operation of the factors in determining (y) other than the independent variable alrady taken in the model.

## SUMMARY OF FINDINGS AND CONCLUSIONS

The study on the whole has satisfied its basic objectives:

1. Determining the available water resources of Jordan and assessing the hydrological potential by using the water balance technique (63).

2. Evaluation of the water resources of Jordan together with the determination of cropping pattern and crop regime, has given an idea about the need and possibility of irrigation.

3. Potential evapotranspiration in this study has established itself as a tool for the determination of the water surplus and runoff.

In the light of detailed investigation reported in this study, the utility of water balance theory in the study of the environmental hydrolgy has been tested (64). We find that the formula has given a satisfactory result in case of non-availability of complete meteorological information and can be safely used.

In theoritical terms, Thornthwaite's formula fails to determine the run-off for the southern and eastern arid zones. As we

The slope of this regression line (b) which is also known as regression coefficient (62), shows the estimated average change in (y) with resect to (x).

Thus from the regression equation we can say that the relationship between agriculture productivity and rainfall is such that a milimeter change in rainfall by and large cause an increase of x kg. in the agricultural productivity.

The result indicates towards the fact that a great deal of agricultural productivity in Jordan depends on rainfall.

When in a regression equation different values of x are put, we get the corresponding estimate values of y. These estimated values are the mean values of the given value of x. For an example, suppose in few districts the rainfall (x) is equal, that does not mean that there productivity (y) will also be equal. Each such district will have different values of y. The mean of all these different values of y would be equal to the estimated values y. Even if no two values of x are same, y maintains average position.

Hence, residual mapping has been used as a tool to identify and regionalise the areas having negative and positive impact over agricultural productivity (y), when the effect of rainfall (x) is removed. With the help of these maps we can easly find out the more effective spatial variables for further explanations of the variations in the dependent variable y.

Because the number of observations are small, we may not get sufficient observation in each category. As the number of observation increase the plus and minus residuals are expected to be distributed equally, such that a large number of observations will fall between O-medium negative and O-medium positive. Relatively smaller number of observations will be fall in between medium negative to high negative and medium positive to high positive and there will be few outlines in below very high negative and very high positive. (Fig. 12.7).

the total fruit area. The area occupied by citrus trees estimated about 31716 Dunoms or 7.6% of the total fruit area. Among vegetables, Eggplant and Tomato are the main two crops intered the crop association. All these crops accounts 58% of the total cropped area.

When the delineation of crop regions is based on the first two crop, (13) crop combination regions can be distinguished. It will be seen from the figures that the crop combination regions of Jordan become higher in number if the three crops are taken into consideration and consequently will be higher by taken the first four or five crops into account. (Fig. 11.2).

The cropping pattern throughout Jordan are determined by three climatic factors, the incidence of rainfall, the relative humidity and the temperature, which are controlled the sowing and harvesting seasons. Besides, the availability of the irrigation also helps in modifying the crop composition in Jordan Valley. Since there is a great deal of variation in rainfall and the availability of irrigation, there appears a mosaic of cropping pattern in Jordan (Fig. 11.3).

## RESIDUALS FROM REGRESSION OF AGRICULTURAL PRODUCTIVITY ON RAINFALL

In order to explain the different regions of Jordan by the Rainfall, the variables chosen are:

1. Value of agricultural production in Kg/dunun (Y).
2. Annual average rainfall of the districts in mm (X).

This conclusion may further be given as:

$$Y = a + bx$$

Where: $$b = \frac{\begin{array}{c} \lesssim x\,y - \dfrac{x \lesssim y}{n} \\ n \end{array}}{x^2 - \dfrac{(\ x\ )^2}{2}}$$

$$a = y'' - bx''$$

Information about cropping intensities was scarce, mostly they are based on information for a limited area. The determination of the cropping intensity was different mainly in the area under vegetables. Tree crops are perenial (100% intensity), while areas under field crops were assumed to be follow in summer and have a 100% cropping intensity during winter. Considering that in vegetable - areas about 25 - 30% of the land is kept follow, the maximum vegetable cropping intensity either in summer or winter could be in the order of 75%.

Occasionally, double cropped areas have occured when trees still young and non-baring frequently vegetables are planted in between. When ever this was known, 50% of the area have been allocated to vegetables and 50% to trees and the total area may have been counted once for vegetables and once for trees. Land under vegetables wheat rotation actually appears twice in the computations, once under the area of field crops, and again as under vegetables, but here with a cropping intensity of 75% in summer only.

## CROP COMBINATION REGIONS:-

The climatic water balance has imposed a sharp constraints on the cropping pattern in Jordan. The cropping zones must take into consideration the combinational analysis and the relative position of the crops which can explain the impact of water rsources availability on the crops heirachy and the economy of the region.

The statistical approach applied in the delineation of crop regions brings to light the important crops which inter the crops association. It has been ascertained that according to Weaver's method (61), minimum deviation methods, five crop combination regions may be recognized. (Fig. 11.1).

Wheat area estimated at 1060715 Dunoms or 62% of the total cereal area. Olive is the second in rank in the crop combination regions of Jordan, occupied about 242177 Dunoms or 58.4% of

A medium - term projections assume the public irrigation schemes in 1985 will cover about 47.000 dunums, in addition to about 112.500 dunums under private schemes. Compared to the present situation the area of irrigated lands would be extended by about 75%. Accordingly the average annual water demand is estimated to require a water production of about 730 MCM. In line with the project and adopted assumptions, 455 MCM would have to be diverted from river flows and about 200 MCM to be pumped from groundwater resources, while spring flow diversions for obvious reasons would remain in the present order of about 75 MCM. Some 350 MCM of the average annual demand of irrigation water result from the development programmes for irrigated agriculture in Jordan Valley. (Fig. 10.8).

Absence of relevant records made it difficult to estimate how much water the different crops were receving under the conditions prevailing in the various areas and seasons (59). Vegetables probably are irrigated with priority and at more regular intervals than orchards trees or fields crops. For barley and wheat, irrigation is primarily applied through flooding of the fields; usually once for storage of soil moisture and leaching of the top - soil, and when rainfall is normal 2 - 3 times in April / May. Orchards are irrigated between April and November depending on the availability of water.

## CROPPING INTENSITY:-

In Jordan, the major problem was the determination of the cropping intensities in the irrigation areas. Generally the crop rotation includes a follow period of one or more growing seasons; thus, only a certain percentage of the area is cultivated. In vegetable areas each year about 25 - 30% is kept follow. It depends on the availability of irrigable land and may last for two or even three sasons. In the vegetable wheat rotation, the wheat crop is sometime left out for one year (60).

It seems that 80% of all losses from irrigation would return into the ground or surface water. this equals to roughly one third of the gross irrigation water supply. The rest is assumed to evaporate in adjacent areas through natural vegetation. Most of the losses that return are caused by deep percolation of water below the root zone. It seems that under average year conditions, the following estimate of annual water use would have to be taken into account for irrigation in Jordan:

| | |
|---|---|
| From groundwater | 102 MCM |
| From spring flows | 75 MCM |
| From rivers | 178 MCM |
| TOTAL | 355 MCM |

Related to the irrigated areas, this water use would correspond with an average:

| | |
|---|---|
| From groundwater | 14,160 $m^2$/h. |
| From spring flows | 15,000 $m^2$/h. |
| From rivers flows | 8,300 $m^2$/h. |
| TOTAL | 37,460 $m^2$/h. |

The development of water resources for irrigated agriculture, as a basic component of Jordan's economy, is given a high rating. Present irrigation schemes - both public and private - are scattered throughout the country and cover a total areas of about 336,000 dunums (57). The average annual water use in the order of 405 MCM. Most of this volume (230 MCM) is taken from river flows, 100 MCM are pumped from groundwater and some 75 MCM originate from spring flow diversions (58).

suspended or inhabited. Consequently, the productivity and yield of these crops will be affected. As a result, Olives and Grapes plantation areas mainly concentrated in the mountainous regions which receive at last 250 mm of annual rainfall.

**IRRIGATION:-**

Most of the irrigated lands are situated in areas with a mean annual rainfall varying from 150 - 350 mm. Monthly effective rainfall is balances against the monthly evapotranspiration of a particular crop (54). In a dry year, there is hardly any rainfall in the desert regions as well as in the southern Ghors aand southern part of the valley. In a normal year, rainfall varies between 50 - 100 mm of which most was considered effective. However, this effective rainfall is almost negligible compared with the large consumptive water requirement in these regions. (Fig. 10 1 - 10. 6).

The northern highlands with significant irrigated agriculture is affected by strong local variations of annual rainfall. The annual mean values range from 250 - 300 mm at Amman / Zarqa to 600 mm at Ajlun. In this region the storage of the affective rainfall as soil moisture was supposed to be important (55).

The southern highlands, southern mountains and northern Jordan valley have rainfall characteristics similar to the northern highland. In various areas such as Zarqa, Ajlun and the southern Ghors, it appeared that 25 - 30% of the area used for irrigated vegetable was kept fallow, either because of water shortage or to facilitate a second crop in winter or summer. (Fig. 10.7).

The consumptive irrigation water requirement is the difference between potential evapotranspiration and the estimated effective rainfall. Based on these consideration, it was assumed that the average of 70% of the net irrigation requirements is at present supplied to irrigated crops. Some crops might get more, but others such as trees or barley might get even less (56).

crop production in all such areas of the country where crop production suffers due to scarcity and / or irregular distribution of rainfall (48). Any drop in the rainfall amount leads to reduction in crop yields and production. In other words, the availability of water in the right quantity and at the right time is essential for good plant growth and yield (49). Both the amount of water as well as the time may differ in different crop plant. Thus what may be true for one crop not necessarily be so for other crop. When we talk of the amount of water, our concern is both the shortage as well as the excess (50). However more often we come across situations when water supply is short of the need in Jordan (51), it is only during the rainy season that there may be excess water. A general picture is that reduction in rainfall amount leads to reduction and finally stopping of the synthetic processes. On the other hand, the degradative processes become relatively more active (52).

Accordingly, the area under cereal crops have been controlled by the amount of rainfall since these crops mostly rainfall crops. In wheat and barley, deficiency of water is known to reduce tillering and the fertility of spikes. When these crops were grown under normal water - stressed conditions, there was reduction of yield to varying degrees. In the north, we had the maximum stability in yield and production. Barley also showed greater stability in yield and production where the water stressed conditions increased. It is apparent that the productivity of these crops is higher in the areas of more than 250 mm of rainfall (53).

The relationship of growth of olives and grapes with time is normally sigmoid in nature. The initial growth rate is slow but once a few leaves have emerged they start photosynthesizing and contributing to the development of more leaves and branches. Accordingly, the evapotranspiration demand increases. The root go deeper and draw moisture from the lower regions. Depending upon the time when rainfall is in short supply, the crop may enter the state in which cell division and cell growth would be either

3. 20 l/c/d in the large cities and towns as households needs.
4. 30 l/c/d in the other towns and communities with the assumption that large quantities of water will be used for watering gardens.

## WATER POLLUTION:-

The importance of the water quality and of water pollution controls is increasing steadily in present water resources development. The results of population growth and industrial development are reflected in the deteriorating water quality of the previously unaffected raw water resources (47). In some areas of Jordan such as the Amman / Zerqa region, the situation can be considered as alarming and joint efforts should be recommended to prevent it from becoming worse.

The analysis of water samples taken from Yarmouk River and East Bank Wadis do not indicate any significant pollution. The surface water is suitable for drinking purpose. The water of the Jordan River is not usable of the salinity of the return flow from the irrigated area. A heavy content of trace elements in the samples taken from the Zarqa River indicates pollution from chemical and domestic effluents especially at Awajan bridge downstream of the industrial area of Ruseifah. Extremely high contents of manganese, iron and lead. This applies mainly to periods with a low base flow in the dry season.

The analysis of the samples from the Dead Sea east shore wadis indicate a relatively high total dissolved solids content, although it is below maximum permissible level. The salinity of water samples from Wadi Hasa and Wadi Mujib could be explained by the salinity of the springs in these areas.

## WATER AND AGRICULTURE:-

Rainfall is one of the most important inputs in an assured related to the annual flood volumes.

| | |
|---|---|
| Yarmouk River | 0.3% |
| Lower Zarqa River | 1.0% |
| Wadi Wala, Upper Zarqa River | 1.0% |
| Wadi Mujib, Wadi Dhuliel | 1.5% |
| Southern Riftside catchment | 2.5% |
| Wadi Sawaga, W. Jordan, Upper Hasa | 2.5% |
| Jordan Riftside catchment | 3.0% |
| Small "flash flood" catchments | >3.0% |

The total sediment transport has to be taken into account with regard to the storage capacities of reservoirs in the river basin (46). The potential sedimentation will be reflected in the operational conditions and the lifetime of the reservoirs.

**WASTE WATER:-**

The waste water of the domestic and industrial consumers is that portion of the water supply which is discharged into sewers or individual waste water disposal units. The remainder is used up to satisfy miscellaneous household, commercial, municipal and industrial needs. In Jordan, where disposal through sanitary sewage systems is not common practice, the determination of the waste water quantities for consideration in the water balances should be based on the assumption that these quantities will remain in the terrestrial water circulation either as groundwater or as surface water. The feasibility of their further usage should be determined individually for each particular community or large industrial consumers, considering the specific conditions.

It has been assumed that the following portion of the municipal water consumption are used up:

1. 10% of the technical water losses.
2. 50% of the consumption of commerce and small industries.

**SEDIMENTATION :-**

The available sediment record provide information for only a limited number of catchment areas. Some of them represent corditions which seems to be characteristics for many of the ungaged areas in Jordan.

In Yarmouk River, it appears that suspended local concentration generally remain insignificant (1%) even during most of the flood flow stages. Occasionally larger concentration were observed (2% - 5%) presumbly effected by heavy local storm rainfall in part of the catchment. There is no significant sediment transport during the dry season.

In Zarqa River Basin, it seem to provide a comparative information on the effects of rather different catchment characteristics. They refer to sub-catchments in the upper hill region (Wadi Abdoun, Wadi Um ed Dananeer) to the Wadi Dhuliel area bordering the desert region, and they indicate the development of suspended sediment local along the course of the Zarqa River.

In Jordan River side wadis, few data are available from the east bank wadis joining the Jordan river. They are results of random samples, they cannot be taken as a fully representative information on sediment discharge during flood flows.

There are a large number of records on sediment loads at the gaging stations of the Wadi Mujib and Wadi Hasa River Basins. These basins represent the hydrological and catchment character-stics of a significant part of the Jordan territory along the east bank of the Dead Sea and the Wadi Araba Valley. Dry season flows are small or non - existent, and flash floods are the typical form of runoff in the rainy season.

The following percentage rates of annual sediment volumes

1990. The calculation of the actual water consumption has been made separately for the following groups of water supply system:

1. City of Amman.
2. City of Zarqa.
3. Other towns supplied by their own system.
4. Water supply corporations system.
5. Unpiped supplies.

The result are always given as average values and they are defined as "Water quantities produced".

For a better analysis of water utilization, a breakdown of the total water quantities produced has been made, the main components being as follows:

1. Domestic use.
2. Use by commerce and small industries.
3. Industrial use from public network in the cities of Amman & Zarqa.
4. Water losses and / or quantities uncounted for.

Accordingly, the increase of water consumption does not follow the increase of the water production. There is no connection between the produced / consumed water and the number of people supplied, as the increase in the amount of water supplied is higher than the growth of the population.

The municipal water supply system in koperation are supplied by groundwater which is pumped either from deep wells or from springs, and in small cases stored in small reservoirs.

The volume of water uncounted for i.e. the difference between the quantities produced and those billed, amount to about 50% in the city of Amman, about 35% in the towns operating their own water supply system and between 20% - 30% in water suply corporation's grouped system with an average of 28%.

The total production in 1980 on the base of information from the water supply authorities can be divided between the consumer groups as follows:

| | |
|---|---|
| Cities and Towns | 22.9 MCM |
| Small Communities | 5.8 MCM |
| Various other consumers | 1.7 MCM |
| Industry | 10.0 MCM |
| Population not connected to piped system | 5.3 MCM |

Therefore, about 28.7 MCM of water was supplied to a population of about 1.55 million by mean of piped water supply system.

Where the unpiped supply consumers are concerned, it has been assumed that they use water from both ground and surface water sources.

Two classes of industries can be distinguished with respect to water supply:

1. Industries supplied by public networks.
2. Industries operating their own raw water supplies.

The first are mostly small enterprises with negligible water consumption while the second are important industries such as phosphate mines, a cement factory, textiles factories, a refinery, etc. which require large quantities of water for the technological processes. They normally operate deep wells in the vicinity of the works.

In view of the limited capacity of the raw water sources under operation and the rapid increase of population in the country, several projects for development of new sources are under way, most of them being part of the National Development Plan 1986 -

There is no significant use of water purposes other domestic / industrial water supply and irrigation. The hydro - power plans envisaged at the KING TALA DAM and at the projected Magarin reservoir will presumably be operated in coordination with the priorities and water requirements of irrigation and domestic water supply schemes.

**WATER SUPPLY SYSTEM :-**

In Jordan, all communities have been divided into two groups; those are connected to piped water supply system and those without supply (45). The first group has been subdivided into:

1. Cities and large towns such as Amman, Zarqa, Irbid & Aqaba.
2. Communities with a population of 50,000 - 3,000 inhabitants.
3. Communities with less than 3,000 inhabitants.

The water supply by the piped system originates mainly from groundwater sources such as deep wells or springs. Based on the data, the communities with a piped supply have been classified in the appropriate consumer groups, and the number of people served in each area has been established up to 1980:-

| Communities | NO | Total population | | | | Population Served by | |
|---|---|---|---|---|---|---|---|
| | | | % | Piped | % | Un-piped | % |
| More than 100,000 | 3 | 910 | 47 | 910 | 100 | - | 0 |
| 100,000-10,000 | 14 | 269 | 13 | 250 | 93 | 19 | 7 |
| 10,000-3,000 | 71 | 305 | 16 | 142.7 | 47 | 162.3 | 53 |
| less than 3,000 | 712 | 468 | 24 | 239 | 52 | 229 | 48 |
| TOTAL | 800 | 1,952 | 100 | 1541.7 | 80 | 410 | 20 |

Consideration of hydropower potentials is of secondary importance and aspects related to water use for navigation do not exist. However long - term plans may have to take account of water requirements for the maintenance of adequate water quality and minimum flows in river courses of areas which require particular standards of environmental protetion. At present situation (1984), the annual water production-primarilly from groundwater resources for the water supply of communities and industries is in the order of about 190 MCM. Related to the population number, this figure proves the considerable deficiencies, particularly in the existing systems for domestic water supply. Assuming proper water supply conditions, the potential present water demand would require a water production of about 200 MCM / year.

Corresponding to the pattern of the population density, the Amman - Zarqa area requires about 65% of the annual water production. The supply gap, in the most of the areas are obvious and have been identified as objectives of major concern for the allocation of water resources and for the implementation of water supply projects. The annual water demand indicate the importance of a well - coordinated water resources strategy which allows to satisfy domestic water supply in the first priority from the total water demand to about 190 MCM / year. The previous figures for water demand for domestic and industrial purposes reflect the present low standard of the domestic water supply. Domestic and industrial water is closely related to a control of water quality and water pollution. Data on the quality of the stream flows are scarce and still inconsistent, but they indicate the particular pollution hazards resulting from uncontrolled waste water discharges and waste deposits along the river courses at major communities and industrial centres. In Amman, there is hardly any treatment of sewage. Returnflows of treated sewage contribute significantly to the very necessary maintenance of acceptable water quality in the river courses, and they are to be considsered as potential future water resources in addition to the natural annual water resources.

east. However, within these regions of overall highly mineralized groundwater, an acceptable water quality still exist (42).

Increasing salinity due to induced pumpage of salt water underlying fresh groundwater is mainly a problem of groundwater management. Also, the alkalization and salinization of the groundwater caused by infiltration of irrigation losses (leaching requirements) is a man-made deterioration of groundwater which cannot be avoided to a certain extent if agricultural production is to be improved (43). Therefore, groundwater abstration for irrigation purposes should be located upstream of the irrigated area and extensive irrigation should be planned upstream of existing groundwater use for public water supply.

The most dangerous effects on groundwater quality derive from human settlements and related activities coused by sinkholes and cesspools of houses and even hospitals, reverse wells used by factories to deliver toxic waste water into the underground, tank leakages of petrol stations, surface waste water infilirating into the aquifer. Under confined conditions, no restrictions are necessary at the ground surface, only the use of wells for toxic waste water infiltration is to be prohibited. In the vicinity of springs or wells, stronger regulations are needed than in the recharge areas as a whole, large communities are to be connected to sewage plants and cesspools of private houses are to be strictly prohibited within an area where the groundwater flow takes less than 50 days to reach the spring or the wells protected.

**PRIORITY FOR WATER USE :-**

The formulation of strategies for the allocation of the water resources may be confronted with the problem to set priorities for the use of water if the available resources are limited.

Water use and demand in the Jordan result dominantly from the requirements of domestic and industrial water supply and from irrigation agriculture (44).

seasonal decline in the summer due to irrigation abstractions and a recovery in the winter, which does not come up to the former water level, thus forming a steplike decline.

**Chemical Analysis:-**

Most of the groundwater samples of Jordan are of the Ca bicarbonatetype, with increasing salinity, Sodium and Magenesium become the dominant cations, and cloride the main anion. Sulphate content is generally low except in the Jordan Valley and Wadi Araba where the evaporite sediments of the Lisan marl contribute to the groundwater salinity. Due to the Ca bicarbonate content, the alkalinity hazard remains low even if the salinity hazard is considerable high (41). Only the areas of Jafr and parts of the Jordan Valley that affected by recycled irrigation water have a higher alkalinity hazard. (Fig. 9.4).

The suitability of the groundwater for agriculture can be shown by the total salinity. in this matter, Jordan consists of four regions of good water quality in terms of salinity.:

1. The mountain regions of Ajlun - Amman in the north.
2. Karak - Ras en Naqb in the south.
3. The extreme north extending from the Syrian Jebel Druze southwards to the Azraq and Wadi Dhuleil regions.
4. The extreme south extending northwards from the Um Sahm mountains to the Qa'Disi - mudawwara region.

These regions are identical or closely connected with the main recharge areas of Jordan.

The regions of poor groundwater quality are the central axis of th Jordan Valley and the Wadi Araba in the West, the whole eastern region except the extreme north and south, and a connection between these regions, extending from the Dead Sea to the northwest of Amman. At a Surface elevation between 600 and 675 m above sea level, the valley floor extends in a southwest to northeast direction at a length of 8 km and a width of about 3 km.; Due to its fertile soil, the area is extensively used for agriculture, the low rainfall rate (400 mm per year as average), indicates the need for irrigation. The high population density makes exploitation of groundwater resources necessary for the water supply. Groundwater can be found in layers of sand. Sandstone and dolomite belonging to the lower Kurnub Group and the Zarqa Group (40). This lower groundwater body is tapped by numerous wells in the area. More than 3 MCM/year is pumped from these wells for irrigation and drinking purposes. Water quality is good (mostly less than 700 ppm TDS), but increasing salinity seems to occur at greater depths. The water level is between 120 and 150m below surface in most of the wells. There are some wells where the water level encountered during the drilling was different than after the pump tests, pumpage of loose sand and a decrease in yield occured at some wells due to improper well design. Some wells have a low yield due to the small thickness of the water-bearing sandy layers.

The Sama Sdud area extends in almost triangular shape north of Mafraq between the railway line Mafraq-Dera'a and the Syrian border. The main topographic features is the valley of the Wadi Dhuleil which drains from the south and southeast to the north, but only sporadically during occasional floods. The area lies east of the region where regular rain-fed agriculture is possible. It receives less than 150 mm per year rainfall. The prospering agricultural activity is due to high-yield wells in a narrow strip along the main wadi. Population density is low, but there is an international cooperation project for industrial settlement at the border with Syria. This will create an increase in demand for water, in addition to the needs of agriculture. Groundwater exploitation started in the early sixties after first productive wells had been drilled. Water level measurements in the area show a

MCM/a of the groundwater inflow is thought to be evaporated from the salt (the Azraq playa) and its environs. The groundwater is brackish in some areas due to the salt deposits within the playa.

The squifer at Qatrana is a part of the Amman-Wadi Sir system. The static water level is go to 100m below the surface. In some parts of the area the overlying sediments are permeable enough that surface water can infiltrate to the groundwater table. 50% of the area under irrigation is underlain by marls and shales. In the rest of the irrigated area, it is assumed that 30% of the irrigation water recharges back to the groundwater (38).

In the Shoubak-Ras en Naqab area acquifer is a part of Amman-Wadi Sir formation. A groundwater divide, on a line through Shoubak, Wadi Musa and Ras en Naqab, separates the area of investigation from the Wadi Arabs in the west. Several flexures and faults extending from north to south govern the groundwater flow, the recharge area is in the western part.

The groundwater contour lines are considerably influenced by the flexures and faults. Generally, the water flow is to the east. Only at Wadi Musa and north of Skoubak is the groundwater flow influenced by outflow westward to Wadi Araba.

In Qa' Disi-upper Wadi Yutm area, the thickness of the sandstone group varies from 400m in the Qa' Disi area up to 1000m to the east, the aquifer is unconfined in the western part; the system is confined in the eastern part by the overlying Khreim and Balqa groups.

The depth to the water table varies greatly due to the large variations in the topography. In the large flat areas around Qa' Disi and near Mudawwara, the depth to the water table is about 80m or less (39).

The Baq'a region is a relatively flat depression some 15 km western highlands and the eastern desert, the water quality normally is still acceptable, and the groundwater is not too deep below the surface. The only problem is the relatively low permeability of the aquifer and the small gradient of the groundwater, resulting in a very small amount of groundwater flow. Thus, if the groundwater resources is exploited, most of the water pumped will be taken from storage, and only after along period of groundwater mining, spring or base flow in the riftside wadis will be reduced.

In Wadi Dhuliel area, there is little natural recharge from the ground surface into the aquifer. The exploitation of groundwater in this area has increased over the years (37). A total withdrawal of 22 MCM/a, was estimated for 1972. The estimation for 1976 was 30 MCM/a or more.

The available groundwater resources in the Amman - Zarga area are estimated to be about 20 MCM/year. As the estimated amount of natural recharge in the area is 25 MCM/year, the amount is considered to be extractable even if there is no artificial or induced recharge. Any return to groundwater would increase the outflow of the area rather than the technically exploitable amount of water.

In Azraq Basin, the aquifer system is composed of plateau basalt overlying carbonate rock in the north, chert-limestone in the west chalk in the south and coars clastics in the east. The aquifers are shallow and the groundwater is unconfined except in the Azraq playa area, the thickness of the saturation zone of the aquifer ranges from 60m on the center of the basin to zero at the boundaries. The aquifer system from a closed basin and in recharged mainly by underflow from the north through the basalts from the Jebel Druze (2.6 MCM/a) and by rain water infitration (8 MCM/a) within the area. There are groundwater discharge at springs in the Shishan area (11.3 MCM/a), the Druze area (2.6 MCM 3a) and at seeps (4.5 MCM/a. The balance of 12

Jordan possesses significant groundwater resources of good quality. Due to the mechanism of the water circuit, groundwater resources having a great annual replenishement are of good quality in terms of natural salinity also. Groundwater stored in deep aquifers flowing slowly or nearly stagnant with low recharge rates is usually unsuitable for water supply or irrigation purposes.

Nearly all of groundwater resources of Jordan are found in hard - rock aquifers where the water moves in fissures and joints. Because of the low porosity of these aquifers, the velocity of the groundwater flow is high and the purifying and absorbent activity of the acquifer is low. (Fig. 9.1 -9.3).

In the western highlands, the total groundwater budget is met almost entirely by discharge from springs from aquifers of the Ajlun series. In the southern part of the Jordan Valley, the Wadi Dhuleil and Sama Soud area, they show the strong response of the water table level to the seasonal variation of pumpage for irrigation. Conversely in the Karama area, the large decline of the water level has showed down or even stopped. In the Wadi Dhuleil and in Sama area, the water level continues to fall each year; the water table rises during winter, but does not reach the level of the previous year, in dictating that the groundwater recharge to the areas by infiltration or underground inflow does not come up to the amount removed. In other regions distant from groundwater abstraction, water level remains constant with time, apart from small fluctuations due to meteorological effects (36).

In some regions it is quite obvious that the groundwater potential has decreased during the past few years. Water level declines in observation wells in the southern Jordan Valley, Sama Sdud and Dhuleil area, since all the water flowing underground is part of the total water circuit, a decision has to be made about how the water resources are to be used in all regions where important groundwater abstractions take place or are planned.

In most of the areas lie in the transaction zone between the water from precipitation and runoff which is part of the mean annual groundwater budget, and moves downward in an unconfiend aquifer and reapear at the surface in the discharge area.

2. Return flow of used water,

   - Irrigation losses into the aquifer.
   - Waste-water infiltration.

3. Artificial recharge of surface water,

   - Dam losses into the aquifer.
   - Additional recharge by flood spreading or other methods.

   Artificial reacharge is rare.

4. Subsurface in flow other aquifers or areas. In some subareas, spring discharge measurements are considered to comprise nearly the total groundwater discharge.

The sum of the mean spring discharge of these areas equals the total recharge if there is no positive or negative under flow and if evapotranspiration and pumped discharged from short-term groundwater are zero (34).

The general equation for the groundwater balance can be written as follows (35) : Recharge + Import + Change of storage = Discharge + Export.

The most important part of the total groundwater discharge in area is the water reapearing as surface flow in the area. The sum of this estimated amount and the base flow discharge is called the total natural base flow.

Thus surface water and groundwater resources are identical to a certain extent and may not simply be added. Accordingly, the base flow or spring flow as well in the list of water resources used for planning purposes is considered to belong to the surface water resources only. The term of available groundwater resources is the part of the technically exploitable resources of an area which is thought to be abstractable and usable without medium and short-term dangerous affects.

neighbouring states in the north through two of its major rivers and through infiltration in the high rainfall areas of northern hills which finds its way into the plains of Jordan.

Particular attentioin was paid to a realistic interpretation of the relationship between groundwater exploitation and base flow discharge in the river cources (33). On the average, from the total amount of annual groundwater recharge in Jordan of about 580 MCM, some 250 MCM seem to be available as annual groundwater resources, in addition to the streamflow and the stored groundwater. The volume of stored groundwater is estimated to be in the order of about 12000 MCM. Locally, water retained in depths greater than 150m below groundwater may prove to be exploitable additionally for specific purposes.

Ultimately the recharge of groundwater in Jordan equals the sum of discharging quantities. The total discharge of a groundwater can be subdivided as follow:

1. Discharge into surface runoff (base flow),
   - Spring discharge (measured).
   - Spring discharge and seeps (unmeasured).

The base flow measured at the gauging stations includes the total discharge of springs an seeps.

2. Pumped discharge from wells:
   - Withdrawals from aquifers which are directly connected with discharge springs (short term groundwater).
   - With drawals from aquifers which are distantly connected with there discharge (long term groundwater).

The recharge into groundwater can be subdivided as follows:

1. Natural recharge, from the surface.
   - Direct recharge based on precipitation.
   - Direct recharge from surface runoff into aquifer.

Long term mean annual natural recharge is the amount of

In the Wadi Araba North Region, all the perennial base flows which originate from Springs and groundwater discharge in the major rift side catchments apparently are used at present. Most of them serve local small scale irrigation schemes. It is to be noted that the Population Centres of this area are primarilly located in the upper regions of the riftside catchments. The major communities are connected to water supply schemes which import water from resources outside the area.

The Wadi Araba south/Wadi Yutum region, does hardly avail of water resources. Accordingly, the present water use is small (less than 3 MCM/year) and concentrated in the Aqaba Area, which is supplied through mining of every limited groundwater resources stored in the lower Wadi Yutum region.

The southern desert and Jafr Basin (32) indicate some surplus of annual water resources, groundwater primarilly. More significant regarding future development, however are the stored groundwater resources.

In Azraq Basin, almost 1700 MCM of stored groundwater, there seems to be surplus of about 40 MCM of annual resources, they include some 12 MCM of flood flows, which presumably are not directly exploitable.

The area of Wadi Sirhan Basin and Wadi Hammad Basin are without any importance regarding water resources and water use.

**GROUNDWATER RESOURCES:-**

Groundwater assumes great importance in areas where the drainage frequency is less and the number of perennial streams is small. Jordan has a few rivers, which even if harnessed, can irrigate only a limited part of Jordan. The rest of the country has to depend on groundwater resources. It must be mentioned that whether surface water or groundwater, the ultimate source of both is rainfall. In the event of scarcity of rainfall, the groundwater potential could be as precarious as the surface water. Fortunately, Jordan not withstanding low rainfall, receives water from the are primarily originating from uncontrolled floods. Additionally, some 6 MCM have been estimated as unused groundwater flow.

The comparative review identifies the Zarqa River Basin as a region which requires particular attention. The greater Amman - Zarqa area is the center of domestic and industrial water use in Jordan. A part from flood flows, the available annual water resources are used to a large extent throughout the river basin. Locally (Wadi Dhuliel area), the water production result from a considerable mining of stored groundwater resources. The Dead Sea Riftside Wadis outlines the northern catchments (north of the Wadi Mujib gorge) as a region with a considerable surplus water. These are dominantly base flows originating from springs and discharge of groundwater. The present water use in the area is small compared to the resources. This can be attributed to the difficult topographic exploitation of the flows. Taking spring flows with quality constraints out of consideration, some 18 MCM of the surface flows (including floods) and about 3 MCM of the groundwater are estimated as the present water resources in the northern catchments.

In the southern subareas the situation is different. There is a significant water use in irrigation areas. Groundwater is hardly being exploited. The computations (31) indicate a surplus of about '8' MCM of surface flow and it does not seem that these surplus resources can fully be considered for future development.

The wadi Mujib Basin is a major surplus area. Less than 10 MCM are at present exploited for purposes of domestic water supply and irrigation, while the average annual surface water flow is estimated to be in the order of 78 MCM, in addition to considerable groundwater resources which include more than 1100 MCM of groundwater stored in the region.

Wadi Hasa Basin allows a conclusion similar to that drawn for Wadi Mujib Basin. The estimated annual water resources, compared to their present utilization indicate that more than 30 MCM are still available for development and annual use.

Particular attention was paid to a realistic interpretation of the relationship between the existing system of drainage basins and river catchments. The Yarmouk Area is the most important region of potential water resources for Jordan. Considering the rights of other water users in Syria and the Yarmouk Triangle and the estimated present diversion (Approx. 125 MCM) of irrigation water for the Jordan Valley, on the average, some 200 MCM of annual surface flows are still available for exploitation; additionally at least some 98 MCM of local groundwater flow and some 600 MCM of stored groundwater. As regard the rights of water users outside Jordan, no final information could be obtained. The Present water use (7.7 MCM) in the Yarmouk Area is small compared to the resources. Present water requirements could be fully satisfied through an improved exploitation of the considserable groundwater resources in the area.

The situation in the Jordan Valley is completely different. Apart from some 120 MCM of ground water with acceptable quality the water resources of the valley region are not suitable for exploitation. Some irrigation schemes, covering about 14,300 hectares of agricultural lands in the valley, depend almost entirely on water directed from the adjacent areas (Yarmouk Basin, Rift-side Wadis and Zarqa River Basin). Practically, all the present water use in the Jordan Valley is related to irrigtion.

The northern riftsidse wadis show a considerable surplus of water resources. On the average, some 40 MCM annually could be exploited in addition to the estimated present water use. About 14 MCM of these excess resources originate from the surface flow of the Wadi Arab Catchment, and about 4 MCM could certainly be controlled through a more coordinated operation of the Zeglab Reservoir. Some 7 MCM are related to a potential ground water exploitation along the foot hill areas.

The surplus of water resources in the southern riftside wadis is small. It appears, however that surface flows not used at present eastern plateau, it varies from 12°c in the west to 8°c in the east. The rainfall occurs mostly in winter and the heaviest period recorded in December and January (27). There are two main seasons in Jordan; Summer extend from May to September, and Winter season which extend from November to April, the Summer season is drў and hot, while the Winter is mild and rainy.

Usually the hydrological water year extend from October to December, and it varies in various regions of Jordan. Rainfall records seem to explain a decreasing trend in rainfall amount in the last years. The cumulative departure from mean rainfall shows a certain tendency to return to the mean (28).

The pattern of the hydrological areas was developed from the existing system of drainage basins and river catchments (29). The pattern of hydrological areas turned out to be an adequate base for the comparative review of resources and demands. Assuming average annual rainfall condition (30), the Jordan catchments (including the Syrian area of the Yarmouk River basin) would receive a rainfall volume of about 8,065 MCM. About 75% or 6000 MCM of this annual rainfall can be related to Jordanian territory. The corresponding total annual streamflow of about 880 MCM is small compared to the rainfall volume and characteristics for the particular conditions of the surface water resources in Jordan. Its to be noted that 400 MCM of annual streamflow are to be attributed to the resources in the Yarmouk River at Adasiya. They originate primarily from catchments in Syria. Thus only 480 MCM can be considered as annual resources of the streams in Jordan. The analysis indicate that considerable parts of these flows result from groundwater discharge rather than from direct rainfall runoff during the annual rainy season between November and May. No consideration was given to the flows in the Jordan River. The estimates of potential annual streamflow reflect the general tendency of decreasing resources, when comparing the catchment from the north to the south of Jordan.

excess rainfall exceeds the water holding capacity of the soil, the surplus water will go into the runoff. This is the only season in which water storage and water surplus occurs. However, the south and eastern parts remain deficit areas throughout the rainy season, though the water deficit decreases. Rainy months vary from 3 -4 months in high mountains of Ajlun and Balqa, to 2 - 3 month in the Jordan Valley, which it is only 1 - 2 months in the southern and eastern desert. The two main rainy months are December and January. Spring is a soil moisture utilization season and there is no surplus, but moisture deficit occurs.

**SUMMER SEASON:-**

This is the dry season negligible soil moisture, low actual evapotranspiration and high water deficit. It extends from May to September approximately.

**SURFACE WATER RESOURCES:-**

Out of 89,411 sq.km, the area of Jordan, about 80% belongs to the arid zone, with desert basins of restricted drainage. This area can be divided into four topographic unit:

1. Rift Valley.
2. Eastern Hills.
3. Eastern Plateau.
4. Southern Desert.

Accordingly, most of the weather elements constituting the climate lend themselves to description of west - east trends, the climate range from Mediterranean to desert. Only the rift valley and eastern hills belong to the semi - arid climate.

The mean temperature in the dry season varies from 28°c in the west to 32°c in the east. In the wet season, the average temperature rises in the Jordan Valley and falls towards the occur in the non rainy season, the water deficit is the result of rainfall variability and irrigularity. The climatic water balance shows water surplus in the rainy month and low water deficit in the following months as well as substantial run-off rate. Here agriculture should be supported by irrigation if necessary in the needs of the individual years and crops. It should be adjustable irrigation.

2. The Jordan Valley, has the driest climate and experienced water deficit in different degrees, it increased towards the south. Here agriculture should be supported by substantial and if possible by Perennial Irrigation.

3. The arid zone in the east and the south. This region experienced water deficit in high degrees. Water deficit is the result of the low rainfall and high evapotranspiration. The climate water balance shows no surplus in any season. Here agriculture in some pockets should be supported by perennial irrigation based on groundwater resources.

Water balance parameters for Jordan shows a uniform drought pattern over the country, and this indicate that the water deficit is the dominant. But how large the water deficit is? Since the aridity index for the country is above 20, Jordan should be considerd a large water deficit region.

After considering the Potential Evapotranspiration and Actual Evapotranspiration (26) values for every month, it was possible to trace two main seasons:

**WINTER SEASON:**

In general this season spreads from November to April. In this season the rainfall can exceed potential evapotranspiration. The excess in rainfall will go into soil moisture storage and it will be available to the crops in the following months. In case the

According to moisture regime, large areas of the country are semi - arid and the southern and eastern parts are classified as arid zone. The negative values of the moisture index are found all over Jordan with the exception of a few stations in the north.

The moisture index (25) is used to delimit the moisture regions of Jordan, and is detremined by whether the water deficiencies and surplus are large, moderate or small.

1. The arid climate occurs in a large areas of the country, where the values of moisture index are higher than (66.7) and the values of the aridity are higher than (60), while the value of the humidity index is zero.
2. The semi-arid climate occurs in the rest of the country where the values of moisture index ranges from 33.3 to 66.7, and the aridity index varies from 40-60. The humidity for this region is less than 16.7.
3. Dry sub-humid climate occurs in eastern hilly tracts of Jordan. The values of moisture index are between 0 to -33.3, while the aridity index is below 60 and above 20, which is still classified under the large water deficit region according to Thornthwaite's classification. The humidity index varies from 16.7 - 33.3, and it is considered as a region of moderate water surplus.

Moisture sub-humid climate occurs in small area in the north where the values of moisture index ranges between 0-20, while the aridity index is below 20. The humidity index is above 33.3. (Fig. 8.1).

Consequently, Jordan can be divided into three agroclimatic zones: (Fig. 8.2).

1. In the high mountains of Ajlun and Balga, the water deficit

## DROUGHT PARAMETERS:-

Thornthwaite's formula has been equipped with a number of ratios and indices to use in climatic classification (24). The moisture ratio is used to obtain the relative humidity and aridity. Humidity and aridity indices are used in determining the climatic type of Jordan.

The humidity index is a ratio between water surplus and water need, and the aridity index is a ratio between water deficit and the water need. Both the retios expressed in terms of percentage:

Ih = 100 S/PE.
La = 100 D/PE.

Where Ih = is a humidity index.

S = Surplus.
PE = Potential Evapotranspiration.
Ia = Aridity index.
D = Deficit.

In the event of total absence of rainfall all the time, the aridity index will be 100%, but for the humidity index to become 100%, the water supply must be twice that of the water need, and the water surplus should be equal to PE. Because water supply and the water need are based on different climatic parameters and independent of each other, the water surplus does not equal to water need.

The water surplus of one month may prevent water deficiency in the other month. Thornthwaite, (1948), emphasized that six inches of water surplus in one season will compensate for ten inches of deficiency in another. That's why he considered the ratio of the humidity index higher than the aridity index.

workable basis for estimating the influence by agriculture and urbanization on soil water related.

Soil water detention are of particular interest to farmers who practise irrigation or systematic soil moisture conservation. Soil salinization may have a natural origin influenced by high groundwater tables, but it can be produced artifically by irrigation. (Fig. 6.1-6.2)

**STREAM FLOW:-**

The volume of rainfall over the country is computed by multiplying each station's rainfall by its area. Accordingly the total volume of rainfall has been estimated at 12129.4 mcm. Out of this, the runoff is of the order of 880 mcm. It is to be noted that large portion of this runoff are to be attributed to the resources in the Yarmouk River at Adasiya. They originate primarily from catchments in Syria, and the analysis indicate that considerable parts of these flows result from ground water discharge rather than from direct rainfall runoff, during the annual rainy season between November and May. The estimated potential annual stream flow reflect the general tendency of decreasing resources, when comparting the catchments from the north to the south of Jordan. (Fig. 7.1)

In the northern areas, the computed difference between rainfall and stream flow correspond to about 20% of the calculated potential evapotranspiration. Higher values refer for Wadi Umm ed Dananeer and Wadi Abdoun, where the percentages reach 28% and 25% respectively, the groundwater recharge seems to be high. The lowest values refer to the southern desert regions, where only two percent of the annual potential evapotranspiration seem to be satisfied by the available precipitation. It should be further considered that the calculated surface flow in these areas is most likely percolating to the ground water. (Fig. 7.2) icant for soil moisture storage, percolation, and infiltration - runoff characteristics.

2. The stage of weathering of geological deposits and the extent of decay of organic matter help to determine basic soil features such as clay content, humus content, clay mineralogical composition and depth of soil formation.

All these influence the soil moisture detention. The increase of plant available from coarse to fine textured soils is very well shown in the following table (23):

| Soil texture | Permeability mm/hour | Total pore space (%) | Apparent specific gravity (g/cm3) | Moisture at field capacity (volume %) | Moisture at permanent wilting (volume %) |
|---|---|---|---|---|---|
| Sandy | 25-250 | 32-42 | 1.55-1.8 | 9-22 | 3-11 |
| Sandy loam | 12-25 | 40-47 | 1.4-1.6 | 14.29 | 6-13 |
| Loam | 8-20 | 43-49 | 1.35-1.5 | 24-39 | 11-18 |
| Clay loam | 2-15 | 47-51 | 1.3-1.4 | 30-43 | 14-21 |
| Silty clay | 2-5 | 49-53 | 1.25-1.35 | 34-47 | 16-23 |
| Clay | 1-10 | 51-55 | 1.2-1.3 | 37-51 | 18-25 |

3. Topographic features as a landscape are usually indicate on general soil maps by contour lines. From this and the system of surface water flow, the drainage pattern and slope position of soils can be interpreted. It is normally safe to conclude that soils on hillslopes are less deeply developed and contain less fine material than those in low-laying land, and any drainage impediment is more likely to occur in the lowland area.

4. Finally, the effects of land use and improvement have to be considered. Land use maps combined with soil maps provide a

and 400 mm in Naur to a maximum of 1800 mm in Ghor Safi and 1600 mm in Aqaba (Fig. 4.1)

After considering the potential evapotranspiration values for every month, it was possible to trace the following pattern of water deficit. From November, when the rainfall starts, the zero line of water deficit moves towards the east. In January, this line moves further towards the east and divides the country into the western deficit free zone and the eastern deficit zone. In April, the zero line moves again towards the west and there is no surplus, but moisture deficit in various degrees occurs. May to October are dry months with negligible soil moisture, low actual evapotranspiration and higher water deficit. (Fig. 4.2 - 4.3)

**WATER STRESS:-**

The water stress is the differences between the income from rainfall and the expenditure from potential evapotranspiration (22) which shows the parts of the country which has a positive values on a monthly base. The positive values (P-PE) in the western part indicates the amount of excess water available during the concerned period for soil moisture recharge and runoff. The negative values indicates the amount by which the rainfall short of the supply to the potential water needs of the crops. In summer months, the crops reach the peak consumptive stage, and the water stress is the lowest, so the additional source of moisture will be from dew. But in the arid zone in the east and south the dew formation is negligible and has no contribution to soil moisture where the water stress increase. (Fig. 5.1 - 5.2)

**WATER DETENTION:-**

The following factors are relevant for studies of the water detained in the soil:-

1. Both parent material and geomorphology of the site are signif-

The comparison of seasonal march of rainfall and potential evapotranspiration shows that the rainfall is greater than potential evapotranspiration from December to March in the north, and there is a fair balance between the water surplus and deficiency, both are small, but the area has got the advantage of location where a good amount of water resources originate primarily from catchments in Syria. Towards the south and the east the rainfall never exceeds the potential evapotranspiration and the deficit become higher with absence of any type of soil moisture recharge.

**WATER SURPLUS :-**

Most of the country has no water surplus. A small area of winter water surplus is found in the mountains of Ajlun and Balga. The areas of more than 500 mm of rainfall are the areas of 200 mm water surplus which is mainly a few pockets in the nort of the country. (Fig. 3.1).

There is no prolonged water surplus period in Jordan and is confined to a few months extending from January to April and covers a limited areas. The first surplus is noticed in the month of January when the Northern hilly tracts receive the early rains in excess of the potential evapotranspiration. There after, there is a progressive shifts of zero line of water surplus, towards the east, in these months, the excess in rain will go into soil moisture storage and it will be available to the crops in the following months. In the case of excess rainfall exceeds the water holding capacity of the soil, the surplus water will go into runoff which mainly concentrated in small pockets in the western zone of the country. Summer months are a soil moisture utilization season and there is no surplus but moisture deficit occurs. (Fig. 3.2 - 3.3).

**WATER DEFICIT:-**

Annual moisture deficit Varies from 350 mm in Ras Muneif needed for evapotranspiration or storage in the soil, is ultimately lost as runoff. This is not immediate for it takes some time for the water to move down to the groundwater table and through the soil to emerge again in surface streams or rivers. The rate of runoff is higher in the northern hilly zone of the country depends on the size of the water shed, its slope and the type of the soil in this region which the water must move (20). It is assume that 50% of the surplus water available in any month is actually is lost by runoff, while the remaining 50% is held over and added to available surplus in the next month. Surplus and Run off are totalling the same amount on an average annual but the monthly distribution of each of them is different. (Fig. 2.3).

## DEW AS A SOURCE OF MOISTURE :-

Dew formation is considered as an additional moisture source for winter crops in Jordan. In January the crops in the rabi tracts reach the peak consumptive stage (21), and the water stress (P-PE) is the lowest in this month, so the additional source of moisture will be from dew which ranges from 0.5 - 0.7 mm. But in the arid zone of south and east Jordan, dew formation is negligible and has no contribution to soil moisture where the water stress increase.

## SEASONAL VARIATIONS OF WATER BALANCE PARAMETERS:-

## POTENTIAL EVAPOTRANSPIRATION:-

In July the monthly potential evapotranspirtion reaches about 800 mm in the southern desert where as in the north the monthly values does not exceed 350 mm. As it is illustrated, average PE in Jordan is less than 50 mm in the mountainous regions. It increases to more than 70 mm in the southern parts to reach 300 mm in the Badia. The average annual PE varies from 2000 mm to 4600 mm.

through evapotranspiration under the optimal conditions of soil moisture and vegetation where the water supply is unlimited. It indicates the optimal water need for irrigation and it is considered a varying factor which varies from region to region depending on the factors to the region that influences evaporation and transpiration (16). It is independent of rainfall and can be equal, higher or lesser than the rainfall. This is because that the factors controlling the PE are not the same for rainfall.

PE equals the AE in the period when rainfall is greater or equal to PE. The difference between PE and AE during certain period is an indicator of how much of water supply is necessary to facilitate normal growth to prevent drought (17). In Jordan as a normal condition, AE never exceeds PE but it falls considerably below it due to shortage of water supply in the soil. Precipitation is greater than PE from December - March, and this period decreases by going towards the south and reaches only 2 - 3 months from Dec. to Feb. Again this period decreased rapidly by going towards the east and the south - east where the rainfall never exceeds the PE (18). (Fig. 2.1)

In the period of higher rainfall than the PE, the soil remains at field capacity, and some water is added to surplus. In Jordan, April is the first month in which the rapid rise of PE which exceeds the supply of water from rainfall, and the rainfall has failed to supply the water needs (19). Some of this need is supplied by the water stored in the upper layer of the soil, but ultimately this amount of water is not supplied by rainfall. As the soil dries, water is not available from the upper soil layers and nothing is removed from the soil to help supply the need. This is, therefore, the water deficit which is the highest in June, July and August all over the country. (Fig. 2.2).

In general, the surplus water, that moisture over what is

10. Moisture deficit, which is the difference between actual evapotranspiration and potential evapotranspiration.

11. Moisture surplus, which is any excess rainfall after the soil moisture storage reaches the water holding capacity.

12. Water run off which is considered as 50% of the surplus water, and the other 50% is detained on the water - shed and made available for run off during the next month (14).

13. Moisture detention is total water stored within the soil.

The hydrological characteristics of Jordan are delimited by the above paremeters. The most useful aspect of these parameters is that no data other than temperature and rainfall are required. Since these are more readily available data than the river discharge. The water yield in the country has been computed by taking the mean annual values of different water balance parameters :

$$P = AE + S \quad (1)$$
$$D = PE - AE \quad (2)$$
$$AE = PE - D \quad (3)$$
$$S = P - (PE - D) \quad (4)$$
$$RO = S/2 \quad (5)$$

Where p = Precipitation (income).

AE = Actual evapotranspiration.
S = Surplus.
D = Deficit.
PE = Potential evaptranspiration (expenditure).
RO = Runoff.

**WATER BALANCE PARAMETERS:-**

Potential evapotranspiration is the main parameter to determine the water need of the country. It is the water loss from an extensive, closed cover of the homogeneous vegetation that never suffers from a lack of water (15). It is the maximum loss of water

The basic procedures in computation of the water balance of Jordan is to work out the following steps (10):

1. The heat index (i) correspond to mean monthly temperature.

2. Unadjusted potential evapotranspirations using the necessary Thornthwaite's tables.

3. Adjusted potential evapotranspiration (11) its the adjustment of the daily values of potential evaporation for month and day length by multiplying the proper correction factor (12).

4. Rainfall: The mean monthly values of rainfall for the stations based on 50 years data are considered and the average depth of rainfall over the area is calculated according to the Theissen's method (13). This method is a means of weighing the precipitation at gauge in proportion to their representative areas. Each gauge is assumed to represent all points closer to it than any other gauge. A Thiessen network is constructed for the country by locating the stations on the map and drawing the perpendicular bisectors to the liens connecting the station. The polygons thus formed around each station are the boundries of the affective area assumed to be controlled by the station. The volume of rainfall over the stations is computed by multiplying each station's rainfall by its area. (Fg. 1).

5. Rainfall minus potential evapotranspiration to determine the periods of moisture excess and deficiency.

6. Accumulated potential water loss gives an estimate of the moisture stored in the soil at the end of the negative period, (P-PE).

7. Soil moisture storage, obtained from the tables available.

8. Change in soil moisture storage, which shows the difference in the amount of soil moisture storage from one month to the next.

9. Actual evapotranspiration is the real or the measured amount of evapotranspiration at any time.

mating potential evapotranspirations (7). This relations is based on three parameters:

1. Mean temperature.
2. Length of the day.
3. The latitude of the place.

The computation of potential evapotranspiration by Thornthwaite was a means of showing the income from rainfall and its distribution through evapotranspiration and runoff, the reserve which is the storage in the soil, the water deficit and the water surplus in the process of running off. The input data used for computing the water balance of Jordan are:

1. Mean monthly temperature.
2. Mean monthly rainfall.
3. Information on the water holding capacity of the depth of soil, and
4. Necessary conversion and computational tables.

A large number of stations have no recorded temperature data, and adjustment calculations are made to get the mean, monthly and annual temperature for the concerned stations. The precipitation data are available for all the stations under study, as published by the Jordan Meteorological Department. For computing the water holding capacity of the soils of the country, two different factors have been considered:

1. The soil type and texture.
2. The vegetation grown on the surface.

The relation between the above two factors is the depth of the root zone. Measurements of the water holding capacity of the soils in Jordan are not available for many places, and the estimating of water holding capacity had been done from indirect evidence of the natural vegetation (8), and soil maps (9).

The tables for use in the computation of the water balance have been prepared for value of water holding capacity varies from 75 - 250 mm.

## INTRODUCTION

When talking about Jordan, I have in mind the two circles in which one should be active, these are water and agriculture. In this regard, the rate of development is very important. It's not enough to say that Jordan is doing better than the others. What has been done in these fields have to be adjusted to suit the great changes that are overwhelming this area, geographically, geopolitically and geoeconomically. While talking about Jordan also, I have in mind the river, the kingpin, which determine the climate, the soil and the very atmosphere of all this area. A round have sprung up over the centuries, great culture, relegion and empires.

Indeed, water as a relatively scarce resources, (1) many problems surround its exploitation or supply, the reconciliation of local values with national needs, the desirability of working out overall strategy rather than a series of short-term policies, and the organizational and psychological constraints in securing adequate future amount (2). The longterm organizational barrier to a national approach to the exploitation of Jordan's water resources was the existence of several water supply undertaking. The psychological barrier is to be found in the public's unwillingness to bear the real coast of a level of water consumption. In Jordan, the local versus national clash of interest derives from spatial dichotomy between the supply and demand for water (3). The conflict between local and wider interest and between short and long-term solutions may be highlighted from the north of the country.

## METHODOLOGY

The main climatic constraints in crops regime is potential evapotranspiration (4) which represent the water need. It defines the degree of moisture or dryness of climate in which crops are raised. Thornthwaite (5) gaven an empirical relations (6) for esti-

**ABSTRACT**

The rainfall availability and optimal use of water have always been important to agriculture, particularly in areas which are deficient in water. Among the many countries in the Middle East, Jordan is one which has sizable part of its land under arid and semi arid conditions and the farmers have to adjust the crop pattern and regime to suit the water availability conditions.

The present paper attempts of an appreciation of the actual water availability and the possible adjustment of crops to these conditions, to understand the conditions of water availability, water balance approach has been adopted. After a thorough review of available literature it was found that basically the Thornthwaite's formulas of book keeping procedures are satisfactory and fit very well within the Frame-work of the water balance approach. Therefore, it was chosen in this study for the determination of water surplus, water deficit, soil moisture detention, water run off and environmental stress. Almost, every process occurring in plants is affected by the water balance parameters which have a great impact upon the environment.

The study has basically two main objectives; to determine the available water resources of jordan by applying a physically and theoretically valid technique which were universally applicable, then to probe into the current cropping pattern and to examine through an evaluation of its water resources, the agro-hydrological environment.

## CONTENTS

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