REPUBLIC OF TURKEY
PRIME MINISTRY

GAP

SOUTHEASTERN ANATOLIA PROJECT
REGIONAL DEVELOPMENT ADMINISTRATION

AGRICULTURAL COMMODITIES MARKETING SURVEY
PLANNING OF CROP PATTERN
AND
INTEGRATION OF MARKETING AND CROP PATTERN STUDIES

VOLUME IV

Annex 5A - 5B

AUGUST • 1992 ANKARA

TİPAŞ Tarım - Turizm - İnşaat
Pazarlama ve Ticaret A.Ş
Ankara - Turkey

AFC Agriculture and Food
International Consulting GmbH
Bonn - Germany

ANNEX 5A

ESTIMATION OF DATA RELATED TO IRRIGATION

ANNEX 5 A: ESTIMATION OF DATA RELATED TO IRRIGATION

CONTENTS Page

List of Tables

5.A ESTIMATION OF DATA RELATED TO IRRIGATION

5A.1 Introduction

The irrigation water requirements of all the crops possibly be grown in the different irrigation projects are needed as input variables for the crop pattern model. The procedures applied are basically those described in the FAO Irrigation and Drainage Paper 24. So the steps involved are as follows:

- Calculation of reference crop evapotranspiration (ETo)
- Calculation of crop water requirements (ETc)
- Calculation of net irrigation requirements (In)
- Estimation of irrigation water requirements (Vi)

In principle the calculations for the 17 irrigation projects of the GAP Master Plan have been conducted individually. But as climatic and/or crop data are not specifically available for each project, some projects have been lumped together so that finally there are 12 results for each crop (main seeding dates) plus a varying number of results because of alternative seeding dates.

5A.2 Calculation of Reference Crop Evapotranspiration (ETo)

The FAO methodology for the prediction of crop water requirements has become known since the mid 1970's, and has developed to an international standard, worldwide applied in irrigation development and management projects.

The effect of climate on crop water requirements is given by the reference crop evapotransporation (ETo) which is defined as "the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water." FAO recommends 4 methods to calculate ETo, depending on the type of climatic data available. Concerning accuracy, the Penman method, modified by FAO, would offer the best results whereas the Blaney-Criddle method, also modified by FAO, ranks last. There was evidence, however, that the FAO modified Penman method was somewhat overpredicting under non-advective conditions. So since May 1990 FAO recommends the Penman - Monteith method as the presently best performing combination equation (FAO Report on the Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements, May 1990, Rome). Climatic data needed for the Penman-Monteith method are: temperature, humidity, wind, and sunshine. So for each of the 17 irrigation projects the nearest climatic station has been identified (Table 5A.1). As not all the stations measure all 4 needed parameters, the missing one has been taken from another nearby station.

Table 5A.1: Climatological Stations Related to the Irrigation Projects

Irrigation Project	Code	Temperature	Sunshine Humidity, Wind	Rainfall
NORTH-GAP				
Siverek-Hilvan	N1	Siverek	Siverek	Siverek
Adiyaman-Kahta Adiyaman-Göksu-Ar.	N2a N2b	Adiyaman	Adiyaman	Kahta
Dicle right bank Dicle right pumped	N3	Diyarbakir	Diyarbakir	Diyarbakir
Garzan	N4a	Batman	Batman	Kurtalan, Beçiri
Batman right bank Batman left bank	N4b	Batman	Batman	Batman
Batman-Silvan	N4c			
SOUTH-GAP				
Bozova pumped	S7	S. Urfa	S. Urfa	Bozova
Gaziantep	S9	Gaziantep	Gaziantep	Nizip
Silopi	S11	Cizre	Cizre	Cizre
Nusaybin-Cizre-Idil	S10	Nusaybin, Cizre	Nusaybin, Cizre	Nusaybin, Cizre
Urfa-Harran	S5	S. Urfa	S. Urfa	Pt. Urfa
Mardin-Ceylanpinar 1st stage Mardin-Ceylanpinar 2nd stage	S6	Ceylanpinar	Ceylanpinar	Ceylanpinar, Kiziltep
Suruç-Baziki	S8	Birecik	Birecik	Yaylak

Source: GAP Proje Sahasinin Meteorolojik Etüdü, DMI, Ankara, 1990

The calculations of ETo have been conducted with the FAO-CROPWAT program, version 5.6 of March 1991 which incorporates already the Penman-Monteith method. Input data and results of ETo for the different irrigation projects are presented in the tables 9.1 to 9.12 of Appendix E, whereas summarizing results are shown in Table 5A.2. Annual ETo-values range from 1222 to 1668 mm whereas the annual effective rainfall (Pe) ranges from 301 to 554 mm. Highest ETo-values occur for July which is the peak month for all irrigation projects in the range of approximately 7 to 9.5 mm/d and with practically no effective rainfall (Pe) whereas the lowest ETo-values occur during December to February (approx. 0.6 to 1.5 mm/d) being completely compensated by Pe.

Table 5A.2: Reference Crop Evapotranspiration (ETo) and Effective Rainfall (Pe)

Irrigation Project	Code	ETo (mm/a)	ETo (mm/season)*	Pe (mm/a)	ETo for July (mm/d)
NORTH-GAP					
Siverek-Hilvan	N1	1686	1471	467	9.5
Adiyaman-Kahta	N2a	1548	1366	540	8.9
Adiyaman-Göksu-Araban	N2b	1548	1366	540	8.9
Dicle right + right pumped	N3	1433	1297	433	9.1
Garzan	N4a	1222	1093	523	7.2
Batman right + left	N4b	1222	1093	437	7.2
Batman-Silvan	N4c	1222	1093	437	7.2
SOUTH-GAP					
Urfa-Harran	S5	1646	1464	301	9.6
Mardin-Ceylan. (1st+2nd stage)	S6	1478	1315	350	8.9
Bozova pumped	S7	1646	1464	362	9.6
Suruç-Baziki	S8	1486	1307	361	8.6
Gaziantep	S9	1514	1351	377	8.0
Nusaybin-Cizre-Idil	S10	1381	1240	485	6.7
Silopi	S11	1409	1233	554	7.6

* irrigation season from April to November

5A.3 Calculation of Crop Water Requirements (ETc)

Crop water requirements (ETc) are defined as "the depth of water needed to meet the water loss through evapotranspiration of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment". The effect of the crop characteristics on ETc is given by the crop coefficient (kc) which presents the relationship between ETo and ETc or ETc = kc * ETo.

Values of kc vary with the crop, its crop stage, growing season and the prevailing weather conditions. So the growing season of field and vegetable crops is divided into 4 stages: the initial, crop development, mid season, and late season stage. As the seeding and harvest dates are different for the 2 GAP regions (Güler 1991), the length of the 4 growing stages for the same crop is also somewhat different. These lengths have been modified based on the information provided in the FAO papers 24 and 33 and for some few crops local information was available. The kc-value for the initial stage depends on ETo and the average recurrence interval of irrigation or significant rain. This interval was assumed to be for both regions and all months 7 to 10 days. The ETo-values for each month have been averaged for all irrigation projects to be used in a graph in FAO-paper 24, resulting in identical kc-values for the initial stage for all irrigation projects.

The kc-values for the mid- and late-season stage of each crop depend on minimum relative humidity (RHmin) and wind speed. It was found that for each irrigation project the wind speed is <5 m/s for all months and RHmin (RH at 14.00h) for all projects and all months is >20%, except for July and August. As for June and September RHmin is just slightly >20% an interpolation for the kc-values is applied. All the kc-values for the different crops have been taken from FAO-paper 24.

So for the main seeding dates the same crop coefficients for all irrigation projects can be applied. But as the length of the crop growing season for the same crop is somewhat different in the North- and South-GAP region it was necessary to use 2 crop data sets for field and vegetable crops whereas for perennials only one crop data set has been used (Appendix E 9).

As it is the objective of the crop pattern model to find an optimum crop pattern which is also influenced by climate, soil, land and water availability, management and production criteria, for most (major) crops alternative seeding dates had to be considered. To reduce the number of input data for the model only 1 to 9 additional alternative seeding dates have been selected, principally with a time interval of 15 days. Consequently the kc-values and the length of the 4 growing stages for the same crop had to be modified, separately for the two GAP-regions, giving a large number of additional crop data sets (Appendix E 9).

The calculation of ETo has also been conducted with the FAO-CROPWAT program, resulting in 10 data sets, one for each irrigation project or group of projects with identical ETo-data (Tables B1 to B11 of Working Paper No. II/4.5 of March 1992 show the results for the main seeding dates, although for some projects the data have been modified at a later date).

A5.4 Calculation of Net Irrigation Requirements (In)

Part of the crop water requirements can be met by effective rainfall (Pe), groundwater (Ge) and stored soil water (Wb) or

$$In = ETc - Pe - Ge - Wb.$$

In this study Ge and Wb are assumed to be zero. Effective rainfall is calculated on a monthly basis according to the USBR method:

$$Pe = P(125 - 0.2P/125) \quad \text{for } P < 250 \text{ mm and}$$

$$Pe = 125 + 0.1P \quad \text{for } P > 250 \text{ mm}$$

with P = average monthly rainfall (approx. 50% probability).

This approach is similar to that applied by DSI, not taking into account a dependable rainfall (80% probability of excedence). This seems to be acceptable as there is hardly any rainfall from June to September, the critical months because of peak water requirements.

Alternatively the combined effect of dependable rainfall (80% prob. exc.) and estimated losses due to runoff and percolation can be taken into account by the empirical formula developed by FAO/AGLW:

$$Pe = 0.6P - 10 \quad \text{for } P < 60 \text{ mm}$$

$$Pe = 0.8P - 25 \quad \text{for } P > 60 \text{ mm}$$

As there are more rainfall than complete meteorological stations in the GAP region, for nearly each irrigation project another rainfall station has been used (Tables 5A.1 and 5A.2).

The calculation of net irrigation requirements has also been conducted with the FAO-CROPWAT program. The detailed results for the main seeding dates are shown in the tables B1 to B11 (In = IRReq) of Working Paper No.II/4.5 of March 1992 and Table 5A.3 gives a summary, taking also into account the results of alternative seeding dates. For the crop pattern model monthly In-values are used, only for the expected peak period from June to August 10-day-values are used.

Table 5A.3a: Seasonal Net Irrigation Requirements (In) for North-GAP Projects

Range of net irrigation requirements (mm/season)					
Crops*	Siverek-Hilvan N1	Adiyaman N2a+b	Dicle N3	Garzan N4a	Batman-Silvan N4b+c
Alfalfa	1137	1048	995	801	808
Barley$_2$	153-219	145-212	105-164	68-122	68-136
Bean, dry	434	423	375	319	322
Cabbage$_3$	158-309	161-262	104-248	74-193	75-195
Carrot-Winter	148	122	95	56	67
Carrot-Spring	548	530	481	399	403
Cauliflower	462	400	389	324	306
Chickpea$_3$	298-470	289-456	233-392	183-318	197-333
Corn-Grain$_7$	589-789	525-747	522-730	410-585	411-581
Corn-Sillage$_8$	469-761	406-716	394-713	309-568	311-570
Cotton	1104	1027	990	786	790
Cucumber$_2$	783-836	728-785	722-772	573-615	575-617
Eggplant$_2$	1015-1028	931-954	903-923	716-737	720-741
Groundnut$_7$	562-805	494-755	486-751	383-597	385-599
Leek	406	349	337	264	265
Lentil	188	180	136	96	109
Lettuce$_3$	36-57	25-51	14-31	2-12	6-19
Melon	794	747	736	585	588
Occra	1127	1033	1008	807	807
Onion Winter$_3$	588-688	539-644	466-585	372-468	384-479
Onion Spring	754	722	674	549	556
Pepper$_2$	835-945	756-864	740-842	585-668	588-671
Potato, early	528	519	474	396	400
Potato, late	697	668	628	517	520
Rice**	1710	1651	1627	1443	1445
Sorghum-Sillage$_9$	356-745	302-701	287-698	224-556	226-558
Sorghum-Grain$_7$	619-866	546-817	538-803	423-640	425-643
Soybean$_7$	602-783	537-738	535-733	422-585	422-587
Spinach-Spring	98	96	68	57	57
Spinach-Winter$_3$	25-137	13-115	10-106	7-85	7-85
Squash	553	526	510	409	412
Sugarbeet$_2$	1114-1147	1029-1071	1001-1038	798-835	802-838
Sunflower$_2$	984-1001	925-946	905-917	722-740	726-743
Tomato$_2$	1097-1125	1025-1058	1003-1030	799-828	802-832
Watermelon$_2$	667-682	628-646	624-630	497-503	499-506
Wheat$_2$	203-317	196-278	150-280	109-176	109-241

* Indices are meaning the number of alternative seeding dates.
** Including water for nursery on 10% of the area, 200 mm water for land preparation and percolation rate of 4 mm/day; no irrigation during the last month.

Table 5A.3b: Seasonal Net Irrigation Requirements (In) for South-GAP Projects

	Range of net irrigation requirements (mm/season)			
Crops*	Urfa-Harran S5	Mardin-Ceylanpinar S6	Bozova S7	Suruc-Baziki S8
Alfalfa	1202	1059	1162	1023
Barley$_2$	141-178	84-133	108-160	80-123
Cabbage$_3$	123-259	80-209	101-244	79-201
Carrot-Winter	133	86	112	67
Carrot-Spring	450	416	445	391
Cauliflower	378	310	361	299
Chickpea$_3$	224-544	163-469	192-512	163-462
Corn-Grain$_9$	477-791	407-736	464-785	389-703
Corn-Sill.$_{10}$	383-773	311-721	366-768	303-689
Cotton$_3$	1035-1105	956-1001	1047-1089	906-961
Cucumber$_3$	745-780	702-713	749-773	659-682
Eggplant$_3$	1054-1095	939-969	1030-1061	904-941
Groundnut$_8$	564-799	492-740	552-793	468-706
Leek	337	272	318	263
Lentil	147	115	141	91
Lettuce$_3$	32-91	11-51	19-69	10-43
Melon	752	709	781	663
Occra	1133	1045	1132	988
Onion Winter$_3$	426-541	324-454	379-497	322-443
Onion Spring	599	561	636	523
Pepper$_2$	939-946	844-863	924-938	812-824
Potato, early	510	457	487	449
Potato, late	630	566	606	556
Rice**	1466	1395	1503	1378
Sorghum-Sillage$_{10}$	357-791	292-736	341-783	282-709
Sorghum-Grain$_9$	467-842	395-781	453-836	379-751
Soybean$_8$	562-768	504-716	559-763	474-686
Spinach-Spring	40	35	52	17
Spinach-Winter$_3$	18-97	7-72	9-87	6-71
Squash	453	424	485	403
Sugarbeet$_3$	1057-1143	962-1033	1059-1126	926-994
Sunflower$_3$	913-1043	837-954	911-1028	805-916
Tomato$_3$	1008-1071	919-976	986-1055	883-940
Watermelon$_2$	621-652	601-606	642-644	555-586
Wheat$_2$	198-244	142-208	169-235	141-188

* Indices are meaning the number of alternative seeding dates.
** Including water for nursery on 10% of the area, 200 mm water for land preparation and percolation rate of 4 mm/day; no irrigation during the last month.

Table 5A.3c: Seasonal Net Irrigation Requirements (In) for South-GAP Projects

	Range of net irrigation requirements (mm/season)		
Crops*	Gaziantep S9	Nusaybin-Cizre-Idil S10	Silopi S11
Alfalfa	1066	927	934
Barley$_2$	99-151	39-82	28-72
Cabbage$_3$	85-214	81-200	78-199
Carrot-Winter	95	57	99
Carrot-Spring	426	357	357
Cauliflower	316	291	291
Chickpea$_3$	181-482	108-387	98-383
Corn-Grain$_9$	410-720	375-629	380-637
Corn-Sillage$_{10}$	320-704	296-615	297-623
Cotton$_3$	950-993	833-868	843-879
Cucumber$_3$	691-710	598-619	604-628
Eggplant$_3$	939-972	822-842	831-851
Groundnut$_8$	491-725	445-635	450-644
Leek	279	257	257
Lentil	132	65	55
Lettuce$_3$	11-60	3-21	1-16
Melon	725	620	627
Occra	1037	909	920
Onion Winter$_3$	350-467	271-379	262-374
Onion Spring	600	504	505
Pepper$_2$	840-857	744	753
Potato, early	464	397	400
Potato, late	572	490	495
Rice**	1441	1330	1338
Sorghum-Sillage$_{10}$	299-724	277-627	278-634
Sorghum-Grain$_9$	400-768	365-669	368-678
Soybean$_8$	498-700	445-612	452-620
Spinach-Spring	51	22	19
Spinach-Winter$_3$	7-77	6-76	5-74
Squash	457	390	394
Sugarbeet$_3$	979-1027	844-895	853-907
Sunflower$_3$	845-944	726-817	734-826
Tomato$_3$	911-967	783-836	792-846
Watermelon$_2$	597-598	512-516	518-522
Wheat$_2$	161-228	90-152	80-143

* Indices are meaning the number of alternative seeding dates.
** Including water for nursery on 10% of the area, 200 mm water for land preparation and percolation rate of 4 mm/day; no irrigation during the last month.

Table 5A.3d: Annual Net Irrigation Requirements (In) of Perennials (mm/a)

Irrigation Project	Code	Almond, Apricot, Peach, Pear, Pecan, Plum, Nectarine weed free, clean cultivation	Apple, Cherry, Sour Cherry weed free, clean cultiv.	Grape, Pistachio weed free, clean cult.
Siverek-Hilvan	N1	973	1075	713
Adiyaman	N2a+b	900	992	660
Dicle	N3	859	946	633
Garzan	N4a	684	757	503
Batman	N4b+c	691	763	506
Urfa-Harran	S5	1042	1146	764
Mardin-Ceylan.	S6	917	1009	674
Bozova	S7	1004	1106	732
Suruç-Baziki	S8	880	970	647
Gaziantep	S9	928	1014	675
Nusaybin-Cizre-Idil	S10	793	875	584
Silopi	S11	800	881	588

5A.5 Estimation of Irrigation Water Requirements (Vi)

Other than for meeting the net irrigation requirements (In), water may be needed for leaching accumulated salts from the root zone and to compensate for water losses during conveyance, distribution and application. This should be accounted for in the irrigation water requirements (Vi). Leaching requirements (LR) and project irrigation efficiency (Ep) are included as a fraction of net irrigation requirements:

$$Vi = In / (Ep(1-LR))$$

As there is sufficient precipitation during the winter months possibly accumulated salts during summer time will be leached by this rain water. Assuming also good natural drainage conditions and a deep ground water table (at least during the first decades), LR is set to zero. In the case of ground water used for irrigation, especially downstream of extensive irrigation areas, salt conditions should be monitored.

Project irrigation efficiency (Ep) is normally subdivided into 3 stages, each of which is affected by a different set of conditions:

Conveyance efficiency (Ec) : ratio between water received at all inlets to blocks of fields (all farm or group inlets) and that released at the project headworks (Vi).

Field canal efficiency (Eb) : ratio between water received at all field inlets and that received at all inlets to blocks of fields.

Field application efficiency (Ea) : ratio between irrigation water directly available to the crop (In) and that received at all field inlets.

Project irrigation efficiency (Ep) : ratio between irrigation water made directly available to the crop (In) and that released at the project headworks (Vi), or Ep = Ea * Eb * Ec.

Factors affecting conveyance efficiency (Ec) are among others, size of the irrigated acreage, size of rotational unit, number and types of crops requiring adjustments in the supply, canal lining and the technical and managerial facilities of water control. Field canal eff. (Eb) is affected primarily by the method and control of operation, type of soils in respect of seepage losses, length of field canals, size of the irrigation blocks and the fields. Field application eff. (Ea) is much dictated by the operation of the main supply system in meeting the actual field irrigation requirements as well as by the irrigation skill of the farmers. It also depends on the irrigation method, soil type, depth of application per irrigation and flow rate per ha farm plot. In case of gravity irrigation Ea especially depends on field layout and land grading, whereas sprinkler irrigation is heavily depending on climate (hot and dry or humid and cool).

For the crop pattern model the Ep-values given in the Working Paper 15 of the GAP Master Plan will be used for the first alternative (Ep=0.45 to 0.54) with an average for all irrigation projects of 0.50, Table 5A.4. In the GAP Master Plan there are given even higher Ep-values for sprinkler irrigation (Ep=0.72) and especially for drip irrigation (Ep=0.85). These high values may only mean Ea, but Ec and Eb have to be considered, too (and are basically identical to those for gravity irrigation, unless small irrigation areas can be operated independently with their own source of water within (wells) or very close to their irrigation area). If these independent small sprinkler and/or drip systems can't be established , a reestimation of the irrigation efficiencies for all the projects seems to be necessary.

A rough estimation shows that Ep= approx. 0.35 to 0.52 for gravity irrigation projects, Ep= approx. 0.35 to 0.62 for sprinkler irrigation projects and Ep= approx. 0.45 to 0.66 for drip irrigation projects.

For a few irrigation projects, for which some more detailed information was available from DSI reports (although some characteristics had to be estimated), realistic estimations of irrigation efficiencies for gravity systems have been conducted, based on the procedure and information provided by BOS and NUGTEREN, 1982. The resulting project irrigation efficiencies (Ep) range only from 0.25 to 0.35. That's why it is suggested to reduce the given Ep-values of Table 5A.4 by 15% for the second alternative of the crop pattern model.

5A.6 Input Data Related to Irrigation for the Crop Pattern Model

Table 5A.4 summarizes all input data which are needed for the crop pattern model. The 17 irrigation projects of the GAP region (partly lumped together) have been grouped according to the 2 agroecological zones North and South, although some irrigation areas are located across this borderline.

The implementation date, mentioned in Table 5A.4, means the first year of irrigation. As the on-farm irrigation development will be delayed compared to the off-farm irrigation development (see MP) a staggered increase of the irrigation area for a project has to be considered: 1st year 50% irrigated, 2nd year 75%, 3rd year 90% and 4th year 100% (annual and monthly peak water supply have to be reduced by the same percentage).

The maximum net irrigable area (DSI information of Jan./Febr. 92) is a restriction for the model. On the other hand for model runs with future projections a fixed irrigable area has to be used for those projects which have not yet been constructed. It is suggested to run the model for the year 2010 and the most probable scenario (all projects are implemented) and to use these calculated irrigated areas as fixed data for other model runs.

The gross area factor is needed to calculate the gross irrigated area, which has to be subtracted from the available rainfed area.

The annual and monthly peak water supply data are not really supply values as DSI has submitted these data based on their own calculations of irrigation water requirements (old Blany-Criddle-method, specific cropping pattern and cropping intensity). As no real other supply data have been made available, they have been used, being the 2nd and 3rd restriction for the model.

To get an idea of the supply situation, in Table 5A.5 the available supply has been related to ETO, on an annual as well as on a peak monthly basis. It is obvious that the Batman-Silvan and Adiyaman-Göksu-Araban projects will experience the most severe water shortages whereas the Silopi project gets relatively the highest amount of water.

Table 5A.4: Summary of Input Data

Irrigation Project	Code	Status*	Implementation Date*	Max. net irrigation area** [ha]	Gross area factor**	Annual water supply** [$10^6 m^3$]	Monthly peak supply** [m^3/s]	Ep*** [%]
NORTH-GAP								
Siverek-Hilvan	N1	F/S	2006	139772	1.14547	1746	174	46
Adiyaman-Kahta	N2a	F/S	1997	67940	1.14548	669	68	50
Adiyaman-Göksu-Araban	N2b	U/C	2000	62504	1.14549	535	52	51
Dicle right + right pumped	N3	U/C	1994	110068	1.14547	1198	122	51
Garzan	N4a	M/P	2003	52380	1.14548	440	54	53
Batman right + left	N4b	U/C	1993	32950	1.14549	285	39	51
Batman-Silvan	N4c	M/P	2003	231300	1.11111	1386	168	45
SOUTH-GAP								
Urfa-Harran	S5	U/C	1993	126441	1.12175	1640	178	51
Mardin-Ceylan. (1st + 2nd stage)	S6	D/D	2000	296163	1.12991	3593	396	50
Bozova pumped	S7	F/S	1998	58968	1.18203	707	72	47
Suruç-Baziki	S8	F/S	2003	102402	1.16605	1322	122	49
Gaziantep****	S9	D/D	2001	71234	1.14547	651	78	51
Nusaybin-Cizre-Idil	S10	F/S	2003	77697	1.14548	761	83	54
Silopi	S11	F/S	2003	25749	1.24277	321	34	53

* DSJ information of Oct. 1991 (M/P = Master Plan, F/S = Feasibility Study, D/D = Detailed Design, U/C = Under Construction)
** DSI information of 24.1. and 10.2.1992
*** Working Paper 15 of MP, Ep should be reduced by 15% alternatively
**** excluding Hancagiz, being already in operation

Table 5A.5: Relative Water Supply

		Annual Water Supply*		Monthly Peak Supply**	
Irrigation Project	Code	[l/s/ha]	[m^3/m^3ETo]	[l/s/ha]	[m^3/m^3 ETo]
NORTH-GAP					
Siverek-Hilvan	N1	0.59	0.85	1.24	1.13
Adiyaman-Kahta	N2a	0.47	0.72	1.00	0.97
Adiyaman-Göksu-Araban	N2b	0.40	0.63	0.83	0.81
Dicle right + right pumped	N3	0.51	0.84	1.11	1.05
Garzan	N4a	0.40	0.77	1.03	1.24
Batman right + left	N4b	0.41	0.79	1.18	1.42
Batman-Silvan	N4c	0.28	0.55	0.73	0.87
SOUTH-GAP					
Urfa-Harran	S5	0.61	0.89	1.41	1.27
Mardin-Ceylanpinar (1st+2nd stage)	S6	0.57	0.92	1.34	1.30
Bozova pumped	S7	0.57	0.82	1.22	1.10
Suruç-Baziki	S8	0.61	0.99	1.19	1.20
Gaziantep	S9	0.43	0.69	1.09	1.11
Nusaybin-Cizre-Idil	S10	0.46	0.81	1.07	1.32
Silopi	S11	0.59	1.01	1.32	1.50

Notes: * based on 245 days with irrigation (April to November)
** expected peak month: July

5A.7 Yield Factors Related to Irrigation Deficit

5A.7.1 Basic Concept

For application in operation of irrigation schemes, it is possible to analyse the effect of water supply on crop yields. The relationship between crop yield and water supply can be determined when crop water requirements and crop water deficits, on the one hand, and maximum and actual crop yield on the other hand can be quantified. Water deficits in crops, and the resulting water stress on the plant, have an effect on crop evapotranspiration and crop yield. Water stress in the plant can be quantified by the rate of actual evapotranspiration (ETa) in relation to the rate of (maximum) crop evapotranspiration (ETc). When crop water requirements are fully met from available water supply then ETa=ETc; if water supply is insufficient, ETa<ETc.

When the full crop water requirements are not met, water deficit in the plant can develop to a point where crop growth and yield are affected. The manner in which water deficits affects crop growth and yield varies with the crop species and crop growth period. Where economic conditions do not restrict production and in a constraint-free environment, actual yield (Ya) is equal to maximum yield (Ym) when full water requirements are met; if full water requirements are not met by available water supply, Ya<Ym.

In order to quantify the effect of water stress ist was necessary to derive the relationship between relative yield decrease and relative evapotranspiration deficit given by the empirical-derived yield response factor (ky), or

$$1 - Ya/Ym = ky * (1-ETa/ETc)$$

where:	Ya	=	actual harvested yield
	Ym	=	maximum harvested yield
	ky	=	yield response factor
	ETa	=	actual evapotranspiration
	ETc	=	(maximum) crop evapotranspiration (= crop water requirements)

Since this relationship is also affected by factors other than water, such as variety, fertilizer, salinity, pests and diseases, and agronomic practices, the relationship presented refers to high producing varieties, well-adapted to the growing environment, growing in large fields where optimum agronomic and irrigation practices, including adequate input supply, exept for water, are provided.

The ky values for most crops have been derived on the assumption that the relationship between relative yield (Ya/Ym) and relative evapotransiration (ETa/ETc) is linear and is valid for water deficits of up to about 50% or 1-ETa/ETc = 0.5.

For most crops there are 3 different types of yield response factors available, relating yield decrease (1-Ya/Ym) to relative evapotranspiration deficit (1-ETa/ETc):

Type A: if the water deficit occurs continuously and equally spread over the total growing period of the crop (so ETa and ETc of the total growing period have to be considered).

Type B: if the water deficit only occurs during an individual growth period of the crop (so ETa and ETc of this specific growth period only have to be considered).

Type C: if the water deficit during a particular growth period is expressed as a water deficit over the total growing period (so ETa and ETc of the total growing period have to be considered).

To maximize the total production under a limited water supply for an existing irrigation system the crop pattern model has to select an appropriate cropping pattern of crops considering the crop response factors of the different crops.

A5.7.2 Application of Yield Response Factors

Such large irrigation projects, as these DSI projects in the GAp region, should not be planned and designed with a water deficit during an average year. As they will be operated by DSI personal but the water is finally used by thousands of independent farmers there would come up tremendous conflicts in case of water shortages. Farmers of the upstream reaches of the irrigation canals will try to steal water and/or bribe operating personal and downstream farmers will get less or even no water. And during periods of sufficient water supply upstream farmers will try to take more water than needed (expecting a shortage later on) creating also a water deficit for downstream farmers and a decrease of the project efficiency. Seeding dates of downstream farmers will be delayed or they will abandon to grow high yield varieties and/or to provide other expensive inputs becaue of the high risk. So there will not be any more an effective operation of such an irrigation project and high investment expenditures for downstream canal reaches are lost. And what may be even worse, these poor experiences of downstream farmers will be reported to farmers of newly constructed irrigation projects and a similar behaviour will develop from the very beginning, even if these new projects are designed with a full water supply.

So it is strongly recommended to plan and design all irrigation projects in the GAP region for a full water supply, which is also international standard. Only for already existing irrigation projects a cropping pattern based on limited water supply may be acceptable. In this case the following stepwise procedure is suggested:

- First run of crop pattern model without taking into account yield response factors (ky). The result would be an optimum cropping pattern from a farmer's point of view (upstream and downstream farmers), perhaps for an area which is smaller than the technically irrigable area. The acreage which can be irrigated with full supply should be calculated. That time period where water requirements are as high as supply must be identified (peak period).
- Run crop pattern model, taking into account ky. The resulting cropping pattern is an optimum one with respect to total production but not from at least upstream farmer's point of view. Maximum irrigable area with limited water supply has to be identified.
- Decision makers (GAP administration) have to decide which of these 2 cropping patterns with the respective irrigated area should be used for later model runs in the future.

In the case of limited water supply the appropriate type of yield response factors has to be selected. The factors of type A cannot be applied for the irrigation projects in the GAP region as for most crops there cannot be expected a water deficit continuously and equally spread over the total growing period, because of winter rain and/or pronounced peak irrigation requirements. The factors of type B and C are applicable. But for a simplified approach those of type B are recommended. This simplified approach assumes only a water deficit during the peak period of June to August for all irrigation projects. For all field crops (including alternative seeding dates) it has been examined which of the individual growth periods fall into the peak period and the respectivy ky factors have been selected using the data and figures of FAO, 1979. These selected ky factors of type B have been used to calculate the yield factors related to irrigation deficit (Irr 80 means 20% deficit and Irr 60 means 40% deficit) and are presented in the Tables 5A.6a and 5A.6b.

Table 5A.6a: Yield Factors Related to Irrigation Deficit (only during June to August), North

Crop	Seeding Date		Irr80	Irr60	Crop	Seeding Date		Irr80	Irr60
Alfalfa			0,82	0,70	Onion-spring	15.3.	☆	0,87	0,74
Barley	7.11.	☆	0,94	0,88	Onion-winter	24.8.		0,95	0,90
"	23.10.		1,00	1,00	"	9.9.	☆	0,93	0,86
Bean, dry	5.4.	☆	0,84	0,68	"	24.9.		0,90	0,80
Cabbage	1.8.		0,84	0,68	Pepper	5.5.	☆	0,81	0,62
"	15.8.	☆	0,89	0,78	"	20.5.		0,80	0,60
"	1.9.		1,00	1,00	Potato	28.3.		0,90	0,80
Carrot-spring	17.3.	☆	0,84	0,68	"	5.5.	☆	0,80	0,60
Carrot-winter	9.9.	☆	1,00	1,00	"	20.5.		0,78	0,56
Cauliflower	15.7.	☆	0,96	0,92	Potato, early	28.3.	☆	0,96	0,92
Chickpea	1.11.		0,98	0,96	Rice	20.5.	☆	0,50	0,00
"	15.11.	☆	0,96	0,92	Sorghum-grain	1.4.		0,82	0,64
"	30.11.		0,95	0,90	"	16.4.		0,82	0,64
Corn-grain	1.4.		0,58	0,16	"	1.5.		0,82	0,64
"	16.4.		0,62	0,24	"	16.5.		0,82	0,64
"	1.5.		0,68	0,36	"	1.6.		0,87	0,74
"	16.5.		0,74	0,48	"	16.6.		0,93	0,86
"	1.6.		0,80	0,60	"	1.7.	☆	0,95	0,90
"	16.6.		0,86	0,72	Sorghum-sillage	1.4.		0,82	0,64
"	1.7.	☆	0,92	0,84	"	16.4.		0,82	0,64
Corn-sillage	1.4.		0,58	0,16	"	1.5.		0,82	0,64
"	16.4.		0,62	0,24	"	16.5.		0,82	0,64
"	1.5.		0,68	0,36	"	1.6.		0,87	0,74
"	16.5.		0,74	0,48	"	16.6.		0,93	0,86
"	1.6.		0,80	0,60	"	1.7.	☆	0,95	0,90
"	16.6.		0,86	0,72	"	16.7.		0,96	0,92
"	1.7.	☆	0,92	0,84	Soybean	1.4.		0,83	0,66
"	16.7.		0,93	0,86	"	16.4.		0,82	0,64
Cotton	25.4.	☆	0,88	0,76	"	1.5.		0,81	0,62
Cucumber	5.5.	☆	0,80	0,60	"	15.5.		0,80	0,60
"	20.5.		0,80	0,60	"	1.6.		0,80	0,60
Eggplant	1.4.	☆	0,80	0,60	"	16.6.		0,83	0,66
"	15.4.		0,80	0,60	"	1.7.	☆	0,86	0,72
Groundnut	1.4.	☆	0,82	0,64	Spinach-spring	17.3.	☆	1,00	1,00
"	15.4.		0,81	0,62	Spinach-winter	5.9.		1,00	1,00
"	1.5.		0,80	0,60	"	20.9.	☆	1,00	1,00
"	16.5.		0,80	0,60	"	5.10.		1,00	1,00
"	1.6.		0,84	0,68	Squash	5.5.	☆	0,80	0,60
"	16.6.		0,88	0,76	Sugarbeet	1.4.	☆	0,88	0,74
"	1.7.		0,92	0,84	"	16.4.		0,88	0,74
Leek	15.7.	☆	0,96	0,92	Sunflower	1.4.	☆	0,80	0,60
Lentil	3.11.	☆	0,94	0,88	"	16.4.		0,80	0,60
Lettuce	1.10.		1,00	1,00	Tomato	1.4.	☆	0,78	0,56
"	15.10.	☆	1,00	1,00	"	16.4.		0,79	0,58
"	1.11.		1,00	1,00	Watermelon	1.5.	☆	0,80	0,60
Melon	3.5.	☆	0,80	0,60	"	15.5.		0,79	0,58
Okra	5.5.	☆	0,88	0,76	Wheat	23.10.		0,96	0,92
					"	7.11.	☆	0,93	0,86

Note: Irr80 and Irr 60 only to be applied for Dicle right bank, Dicle right bank pumped, and Batman right and left bank

☆ = main seeding date

Table 5A.6b: Yield Factors Related to Irrigation Deficit (only during June to August), South

Crop	Seeding Date		Irr80	Irr60
Alfalfa			0,82	0,70
Barley	10.11.	☆	1,00	1,00
"	26.10.		1,00	1,00
Cabbage	8.8.		0,87	0,74
"	23.8.	☆	0,95	0,90
"	8.9.		1,00	1,00
Carrot-spring	7.3.	☆	0,90	0,80
Carrot-winter	19.9.	☆	1,00	1,00
Cauliflower	25.7.	☆	0,97	0,94
Chickpea	5.11.		0,99	0,98
"	20.11.	☆	0,98	0,96
"	5.12.		0,96	0,92
Corn-grain	15.3.		0,60	0,20
"	1.4.		0,59	0,18
"	16.4.		0,63	0,36
"	1.5.		0,69	0,38
"	16.5.		0,74	0,48
"	1.6.		0,79	0,58
"	16.6.		0,85	0,70
"	1.7.	☆	0,92	0,84
"	16.7.		0,94	0,88
Corn-sillage	15.3.		0,60	0,20
"	1.4.		0,59	0,18
"	16.4.		0,63	0,26
"	1.5.		0,69	0,38
"	16.5.		0,74	0,48
"	1.6.		0,79	0,58
"	16.6.		0,85	0,70
"	1.7.	☆	0,92	0,84
"	16.7.		0,94	0,88
"	1.8.		0,97	0,94
Cotton	10.4.	☆	0,88	0,76
"	22.4.		0,88	0,76
"	6.5.		0,88	0,76
Cucumber	16.4.	☆	0,84	0,68
"	1.5.		0,82	0,64
"	16.5.		0,80	0,60
Eggplant	15.3.		0,80	0,60
"	1.4.		0,80	0,60
"	16.4.		0,80	0,60
Groundnut	15.3.		0,85	0,70
"	1.4.		0,83	0,66
"	16.4.		0,82	0,64
"	1.5.		0,81	0,62
"	16.5.		0,81	0,62
"	1.6.		0,85	0,70
"	20.6.	☆	0,96	0,93
Leek	25.7.	☆		
Lentil	15.11.	☆	1,00	1,00
Lettuce	15.10.		1,00	1,00
"	1.11.	☆	1,00	1,00
"	15.11.		1,00	1,00
Melon	13.4.	☆	0,84	0,69
Okra	15.4.	☆	0,88	0,76

Crop	Seeding Date		Irr80	Irr60
Onion-spring	6.3.	☆	0,92	0,84
Onion-winter	4.9.		0,99	0,98
"	19.9.	☆	0,97	0,95
"	4.10.		0,94	0,88
Pepper	20.4.	☆	0,81	0,62
"	5.5.		0,80	0,60
Potato	20.3.		0,91	0,82
"	15.4.	☆	0,83	0,66
"	1.5.		0,80	0,60
"	16.5.		0,78	0,56
Potato, early	15.5.	☆	1,00	1,00
Rice	1.5.	☆	0,50	0,00
Sorghum-grain	15.3.		0,85	0,70
"	1.4.		0,83	0,66
"	16.4.		0,82	0,64
"	1.5.		0,82	0,64
"	16.5.		0,82	0,64
"	1.6.		0,87	0,74
"	16.6.		0,93	0,86
	1.7.	☆	0,95	0,90
	16.7.		0,96	0,92
Sorghum-sillage	15.3.		0,85	0,70
"	1.4.		0,83	0,66
"	16.4.		0,82	0,64
"	1.5.		0,82	0,64
"	16.5.		0,82	0,64
"	1.6.		0,87	0,74
"	16.6.		0,93	0,86
"	1.7.	☆	0,95	0,90
"	16.7.		0,96	0,92
"	1.8.		0,97	0,94
Soybean	15.3.		0,85	0,70
"	1.4.		0,84	0,68
"	16.4.		0,83	0,66
"	1.5.		0,81	0,62
"	16.5.		0,80	0,60
"	1.6.		0,80	0,60
"	16.6.		0,83	0,66
"	1.7.	☆	0,86	0,72
Spinach-spring	7.3.	☆	1,00	1,00
Spinach-winter	18.9.		1,00	1,00
"	3.10.	☆	1,00	1,00
"	18.10.		1,00	1,00
Squash	15.4.	☆	0,82	0,64
Sugarbeet	15.3.	☆	0,91	0,82
"	1.4.		0,88	0,74
"	16.4.		0,88	0,74
Sunflower	15.3.	☆	0,81	0,63
"	1.4.		0,80	0,60
"	16.4.		0,80	0,60
Tomato	15.3.	☆	0,80	0,61
"	1.4.		0,79	0,58
"	16.4.		0,79	0,58
Watermelon	18.4.	☆	0,86	0,72
"	3.5.		0,82	0,64
Wheat	26.10.		1,00	1,00
"	10.11.	☆	0,96	0,92

Note: only to be applied for Urfa-Harran Project ☆ = main seeding date

A5.8 Water Charges

The average water charges used in the model have been based on the DSI data presented on Table 5A.7.

Table 5A.7: Water Charges (1988 prices)

	Yearly Labor Cost (I) (TL/da)	Yearly Inv. Cost (II) (TL/da)	Water Charge (I+II) (TL/da)
Cereals	2084	460	2544
Pulses	3380	460	3840
Melon	3184	460	3640
Sugar	4880	460	5340
Cotton	4880	460	5340
Tobacco	4300	460	4760
Anis	4300	460	4760
Groundnuts	4300	460	4760
Sunflower	2388	460	2818
Poppy	3016	460	3476
Flower	4532	460	4992
Linseed	2388	460	2848
Sesame	2388	460	2848
Corn	2304	460	2764
Rice	12368	460	12828
Seedling	1821	460	2284
Fig	3452	460	3912
Grape	3016	460	3476
Olive	2308	460	2768
Fruit	7128	460	7588
Strawberry	6456	460	6916
Citrus	9764	460	10224
Banana	19192	460	19652
Vegetable	6716	460	7176
Potato	4532	460	4992
Onion/Garlic	3548	460	4008
Fodder	2592	460	3052
Poplar	2908	460	3368

ANNEX 5B

TURGAP

SIMULATION RESULTS