XVIITH CONGRESS OF INTERNATIONAL COMMITTEE OF WORK STUDY

AND LABOUR MANAGEMENT IN AGRICULTURE

(C.I.O.S.T.A.)

MECHANIZATION OF SMALL FARMS IN DEVELOPING COUNTRIES

CH.MOURAD, H.W. VOS

AGRICULTURAL ENGINEERING DEPARTMENT - AGRICULTURAL UNIVERSITY

WAGENINGEN - NETHERLANDS

PESARO (ITALIA) - 18TH/22ND OF JUNE 1974

MECHANIZATION OF SMALL FARMS IN DEVELOPING COUNTRIES

Ch. Mourad, H.W. Vos, Agricultural Engineering Department,
Agricultural University,
Wageningen, the Netherlands

Small farms in developing countries may be mechanized in two different ways independantly from the degree of mechanization:

- Individually by means of appropriated light equipment (power tiller) (2,6),a system widespread in South Asia.
- Collectively through the use of conventional four-wheeled tractors with corresponding implements similar to the practice on large farms on the base of partner-ownership or by the introduction of custom work or hire-service which is more common in the other parts of the world.

The application of both systems is incorporated with implications and they have their advantages and inconveniences as it is shown in the following:

Power tiller	Four-wheeled tractor
- It fits small farms due to its limited capacity	- Higher capacity and suitable for heavy jobs
- Suitable for mountainous farming	- Not suitable for difficult accessible plots
- Easy to run and repair	- Needs high skill for repair and service
- Relatively expensive per unit area with the diversified and the disintegrated accessories	- Reasonable in price per unit area when adequate area is available and can be served
- Can be cumbersome and even dangerous	- Comfortable to drive, can be dangerous too
- Not suitable for nonfarm activities	- Suitable for multipurpose use including transport
- Each farmer needs training	- Only the operator needs to be trained
- Keeps farmers independant	- Makes farmers more dependant

In this paper, the use of the conventional four-wheeled tractor will be dealt with, where both arable and mixed farming systems are practiced. It is the intention of the authors that this will be best suited for newly cultivated lands such as in large irrigation projects in densely populated areas or for existing systems where landreform is enforced and redistribution of land has taken place.
Mechanization in general will be introduced for the purpose of(1):

- permitting crop intensification thus increasing production and employment
- eliminating labour peaks
- improving farming practices by introducing new tools and new techniques
- reduces work load in field practices such as soil preparation etc.
- makes animals free from work and be converted into other purposes such as dairy and meat production

Nevertheless mechanization must be:

- simple to organize and to operate
- reasonable in purchase and running costs
- versatile end multipurpose in use

Taking above mentioned objectives in consideration a certain scale and a time path for introducing of mechanization has been applied. Tillage practices, sowing and when possible combine harvesting of cereals is taken as ultimate step to start with to permit double- or multiple cropping, to flatten labour peaks and even eliminates hired seasonal labour. For the purpose of this study, the Euphrate Project in Syria has been taken as an example. Labour requirements for manual and mechanical operations have been compiled in tables 1 and 2 for most commercial crops existing and recommended to be grown in the area.

Linear Programming (LP) techniques (4) and the added value per crop according to local standard has resulted in the selection of the following cropping pattern:

30% cotton	30% maize (double crop)
20% sugarbeet (summer&winter)	10% alfalfa
10% wheat	10% soya beans
10% lentils	10% broad beans

The farm size of 5.3 hectares has been found the most profitable size of holding for a 2 man equivalent family on both farm- and national levels. The rate of employment obtained through the application of this program has been 61% net i.e. labour directly related to field work, while the cropping index is 130%. Family revenues outdo their former incomes, for the storage lake area by $\pm$ 25% and are nearly double to the average of the rural population in the country.

Crops \ Months	J	F	M	A	M	J	J	A	S	O	N	D	Total
Cotton April 15			3 5	- 2	3 10	8 7	8 8	3 2	- 20	12 10			101
Cotton May 1			1 -	3 3	10 1	8 5	10 10	11 2	2 20	12 10			108
Sesame					6	3 -	2 5	2 6	2 10	4 6	10		56
Sorghum (grain)				7	2 -	2 5	2 1	2 -	12 2				35
Soyabeans					7 2	- 2	4 2	4 3	- 3				27
Sugarbeet summer		1 4	3 4	4 2	4 3	6 9	8 6	2 -	2 5	7 5	5		80
Sugarbeet winter		4 -	4 2	8 2	7 3	7 2	- 5	6 5	4 -	- 5	5 2		71
Alfalfa			2 -	4 1	4 -	4 -	4 -	2 2	2 2	2 5			34
Wheat			2 1	3 -	2 -	1 1	- -	- -	- -	- 2	2		14
Lentils			2 -	2 1	2 8	- -	2 -	- -	- -	- 2	2		21
Broadbeans			2 3	2 4	2 -	8 -	2 -	- -	- -	- 2	2		27
Maize (grain)						6 5	2 6	3 2	- 6	6 6	12		54
Maize forrage						6 -	2 1	2 2	2 2				17

Table 1: Manual labour requirements in mandays per half months for major crops recommended in the Euphrate Project.

Table 2.

Farming Operations and machines performances for the agricultural calendar in the Euphrate Project in Syria.

	FARM OPERATION	CULTIVATED CROPS	OPERATION CALENDAR START	OPERATION CALENDAR END	TOTAL DAYS D	HOLIDAY COEF. %	EFF. DAYS D	WORK-SHIFT	HOURS /DAY h	WORK-ABILITY %	EFF. HOURS h	IMPLEMENTS USED & THEIR PERFORMANCE SPECIFICATION & TYPE	WIDTH m	SPEED Km/h	TASK h/ha	CAP. ha	U. PRICE £S	NO. REQ'D	REMARKS
1	STALKING	COTTON	15.10	30.11	45	.80	36	1	9	.90	280	ROTARY S.	1.65	6	2.0	140	2.500-	1	
2		MAIZE	15.10	30.11	45		36				280	CUTTER	"	"	2.0	140			
3	PLOUGHING	COTTON	15.10	30.12	75	.80	60	1	9-8	.90	452	3 & 4	1.05	4	4.6	98	1500.-	1	Same plough for
4		"	1.3	15.4	45		36		8		288	BOTTOM	1.40	6	2.6	99			different purposes.
5		SOYA	15.30	30.12	75		60		9-8		452	PLOUGH	1.05	4	4.6	98			bottoms may be red.
6		"	16.3	15.5	60		48		8-9		366		1.40	6	2.6	140			when performing heavy
7		S.S. BEET	15.10	30.12	75		60		9-8		452		1.40	4	3.5	129			job.
8		W.S. BEET	15.10	30.11	45		36		9-8		280		"	"	3.5	80			
9		WINT. CROPS	15.10	30.11	45		36		9-8		280		"	"	3.5	80			
10		MAIZE	10.6	10.7	30		24		9		194		"	"	3.5	55			
11	HARROWING	COTTON	1.3	15.4	45	.80	36	1	8	.90	258	TANDEM	2.50	6	1.42	182	1500.-	1	
12		SOYA	15.3	15.5	60		48		8-9		366	DISC				258			
13		S.S. BEET	15.2	15.3	30		24		8		172	HARROW				121			
14		W.S. BEET	1.11	30.11	30		24		9-8		183					129			
15		W. CROPS	1.11	15.12	45		36		9-8		269					189			
16		MAIZE	15.6	15.7	30		24		9		194					137			
17	PLANTING	COTTON	15.4	30.4	15	.80	12	1	9	.90	97	6-UNITS	3.00	5	1.72	56	3000.-	1	
18		SOYA	1.5	30.5	30		24		9		194	PLANTER				113			
19		S.S. BEET	15.2	15.3	30		24		8		172	(ADJUSTABLE)				100			
20		W.S. BEET	1.11	30.11	30		24		9-8		183					106			
21		B. BEANS	1.11	15.12	45		36		9-8		269					156			
22		MAIZE	15.6	15.7	30		24		9		194					113			
23	DRILLING	W. CROPS	1.11	15.12	45	.80	36	1	9-8	.90	269	21-PIPES	4.00	6	1.4	192	3000.-	1	
24	RIDGING	W. CROPS	1.11	15.12	45	.80	36	1	9-8	.90	269		-	6	1.4	192	600.-	1	Local made type
25		MAIZE	15.6	15.7	30		24		9		194					139			
26	HAY MAKING	ALFALFA	1.4	15.4	15	.80	12	1	8	.90	86	CIRCULAR	2.00	8	1.46	59	3000.-	1	
27	(MOWING+	"	1.5	15.5	15		12		9		97	MOWER				66			
28	BALING)	"	1.6	15.6	15		12		9		97	H.P. PICK-UP	2.00	8	1.46	66	9000.-	1	
29		"	1.7	15.7	15		12		9		97	BALER				66			
30		"	15.8	30.8	15		12		9		97					66			
31		"	15.9	30.9	15		12		9		97					66			
32		"	15.10	30.10	15		12		9		97					66			
33	BALING	WH. STRAW	1.6	30.6	30	.80	24	1	9	.90	194	H.P. RUPBALER	4.00	8	1.0	194	9000.-	1	
34	C. HARVEST.	WHEAT	1.6	30.6	30	.80	24	1	9	.90	194	14' SELFPROP	3.90	3.6	1.6	122	40000.-	1+3	with sack platform
35		SOYA	15.9	30.9	15		12		9		97	COMBINE-				61			Working stationary when
36	THRESHING	W. CROPS	15.7	15.9	60	.80	48	1	9	.90	388	HARVESTER						1+6	threshing only

ILR Taaktijden, St. Abst, Syria, NEDECO, Gibb.

The medium size four-wheeled tractor (55 kW) with appropriate implements has been adopted to do mechanized work because of the intention of local manufacturing of these utilities. This choice does not seem unjustified where findings elsewhere (9) support this opinion (1970 price basis).

Mathematical models have been compiled for the determination of the maximum annual capacity that may be attained by such a tractor. The following major constraints have been taken into consideration:

- field operation sequences to be performed machinally based on the above mentioned cropping pattern,
- timeliness due to climatic and agronomic conditions;
- one work-shift of 9 hours/day in the summertime and 8 hours/day in the wintertime;
- machine productivity per effective working hour.

LP results as projected in fig. 1 show that 65 ha are easily served by one single tractor, whereas only the Autumn period is fully occupied. Nevertheless this limited occupation means 900 full tractors hours per year used effectively. This is far above the level obtained in most developed countries with higher level of mechanization where the average use is about 750 h/year.

Being the fact that mechanization is the most capital intensive production factor on the farm level, a better and more intensive utilization is required. Therefore a certain overtime allowance is permitted on the condition that only one critical period may be trespassed and be limited to 30% at one time.

Accordingly 84 ha per tractor per year has been found the optimal capacity totalling 1158 effective hours per year with only 128 excess hours as overtimes to be carried on in the fall period. Whereas the summer period has been brought to the critical limit as shown with the dotted lines again on fig. 1. Accordingly the effective employment rate for tractor operators per year has been brought to 52%.
This solution is a correct and an attractive one for both tractor and operator, but not for the farm implements. A tractor runs usually one machine at one time. Under this condition no single implement becomes fully utilized. Therefore individual tractor exploitation leads to irrational machine utilization. Any plan, that contemplates the full exploitation of farm machines, implies the allocation of one tractor to every farm implement put in service to carry this during the available time span of the appropriate operation. As the performance and the capacity of each machine is different there will be a need for grouping more tractors together to form an optimal combination under one management. This means at the same time a larger field operation unit and a reduction in overhead charges.

The determination of the size of such an O.U. is a conflicting point between planners with different backgrounds and policies.

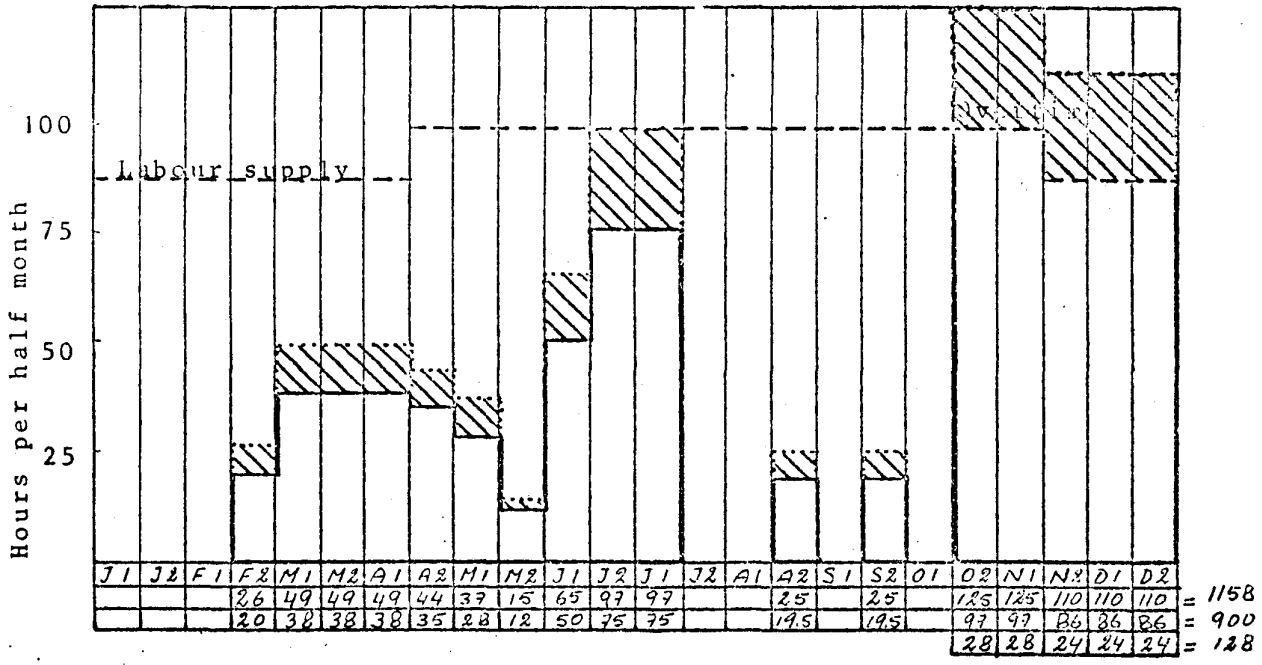

Fig.1 Profile of effective tractor hours per year for 5.3 ha holding for 65ha and 84ha capacity with overtime.

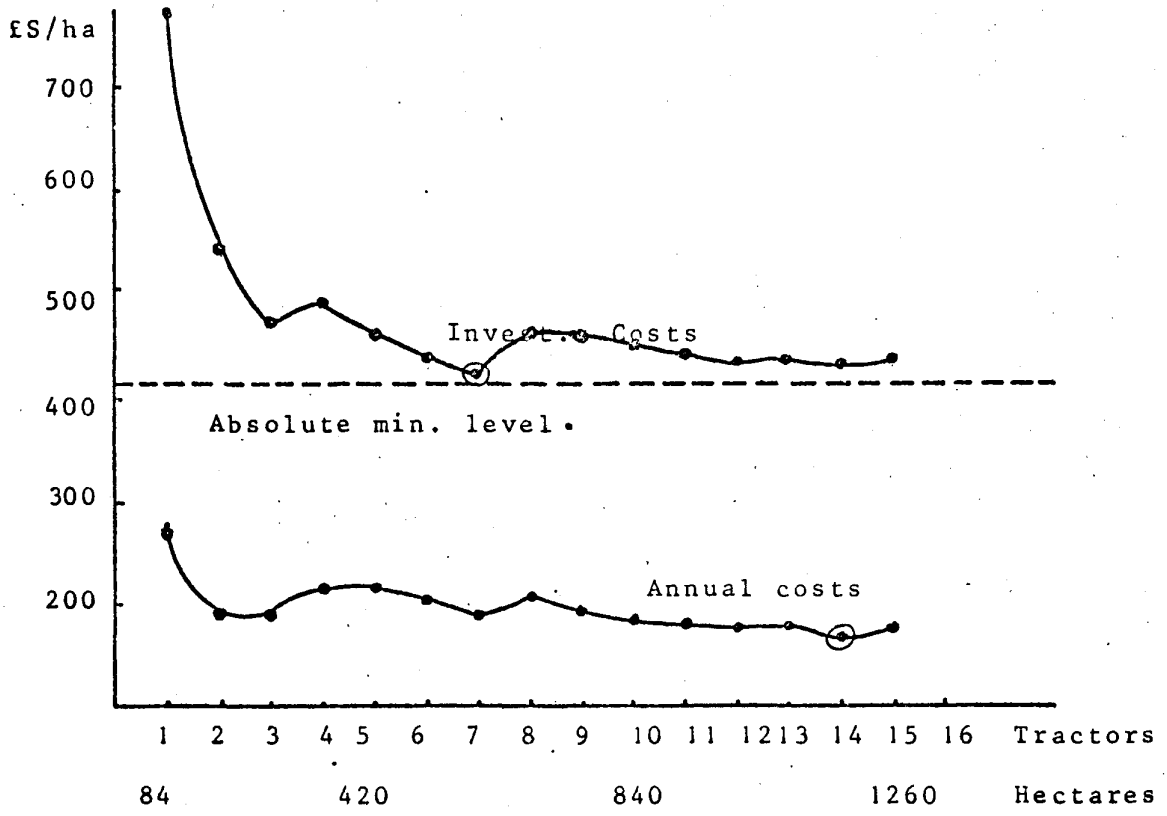

Fig.2 Trend of investment and running costs per ha for tractor combinations (Operation Units) in the Euphrates project.

Even in the countries with centralized planning, where this is general application, the discrepancy is great. The size of such units is varying between a few hundreds to several thousands of hectars (3).

In this issue, rational utilization and cost factors of mechanization have been used basically for the optimization of the size of the concerned O.U. Continuous Programming with rounding the results to get whole farm inplements, has been applied instead of parameter or integer programming, due to practical and economical reasons. The results have given an optimal combination with ultimate machine use and minimal investment costs for mechanization in a unit area.

Fig. 2 which is drawn from table 3 demonstrates this trend. The combination of 7 tractors fulfills this purpose perfectly. Adding running costs and personnel charges to the investment, a larger combination is gaining position; 14 tractors seem to be a more profitable size which correspond with 1246 ha arable land net, including 70 ha for private use. This should be considered as one integral Operation Unit, housing 235 farmer's families and having its own management and farm workshop for primary repairs, daily maintenance and service. Projecting these findings in the Balikh area and including non-arable land within the borders of the irrigation scheme (10), the gross area of the projected O.U. amounts to 4500 ha which means an operation radius of 4 km, thus 20-30 minutes at driving speeds of 12 - 8 km/h respectively. Capital repairs and spare-parts supply are kept for special workshops functioning at higher organizational levels.

Combine harvesting according to these findings may and is arranged for each O.U. separately as the market may supply the appropriate machine for field and stationary work.
A self propelled 14 footer has been very suitable for the job.

Table 3.

Development of mechanization costs for Operational Units of different sizes in the Euphrate Project in Syria (holdings of 5.3 ha)

1	HECTARES	UNIT PRICE £S	84		168		252		336		420		504		588		672		756		840		924		1008	1092	1176	1260
2	EFF. TRACTOR HOURS		1160		2320		3480		4640		5800		6960		8120		9280		10440		11600		12760		13920	15080	16240	17400
3	TOTAL MACHINE HOURS		1500		3000		4500		6000		7500		9000		10500		12000		13500		15000		16500		18000	19500	21000	22500
4	STALK CUTTERS	2500	.28	1	.56	1	.84	1	1.12	2	1.40	2	1.68	2	1.96	2	2.24	3	2.52	3	2.80	3	3.08	4	3.36	4	3.64	4	3.92	4	4.20	5
5	PLOUGHS	1500	.99	1		2		3		4		5		6		7		8		9	9.96	10		11		12		13		14		15
6	HARROWS	1500	.19	1	.37	1	.56	1	.74	1	.93	1	1.12	2	1.30	2	1.49	2	1.67	2	1.86	2	2.05	2	2.23	3	2.42	3	2.60	3	2.79	3
7	PLANTERS	3000	.29	1	.58	1	.87	1	1.16	2	1.45	2	1.75	2	2.04	2	2.33	3	2.62	3	2.90	3	3.20	4	3.49	4	3.78	4	4.07	4	4.36	5
8	DRILLS	3000	.08	1	.16	1	.24	1	.32	1	.40	1	.48	1	.56	1	.64	1	.72	1	0.80	1	.88	1	.96	1	1.04	1	1.12	2	1.20	2
9	MOWERS	3000	.13	1	.25	1	.38	1	.51	1	.63	1	.76	1	.89	1	1.02	1	1.14	2	1.27	2	1.40	2	1.52	2	1.65	2	1.78	2	1.90	2
10	H. P. BALERS	9000	.13	1	.25	1	.38	1	.51	1	.63	1	.76	1	.89	1	1.02	1	1.14	2	1.27	2	1.40	2	1.52	2	1.65	2	1.78	2	1.90	2
11	RIDGERS	600	.28	1	.57	1	.85	1	1.14	2	1.42	2	1.70	2	1.99	2	2.27	3	2.56	3	2.84	3	3.12	4	3.41	4	3.69	4	3.98	4	4.26	5
12	TRAILERS	3000		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15
13	TRACTORS+20%Spare	1500		1		2		3		1+4		1+5		1+6		1+7		2+8		2+9		2+10		2+11		2+12		3+13		3+14		3+15
14	PICK-UPS	1500		1		1		1		1		1		1		1		2		2		2		2		2		2		2		3
15	COMBINES	40/ha		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1
16	WORKSHOP	50/ha		1		1		1		1		1		1		1		1		1		1		1		1		1		1		1
17	SUBTOTAL	£S	64660		91720		118780		166940		194000		222560		249620		312780		351840		378900		412060		440620	482660	512740	560900				
18	INVESTMENT COSTS	£S/ha	769.8		646.0		471.3		496.8		461.9		441.6		424.5		465.5		465.4		451.1		446.0		437.1	442.0	436.0	445.2				
19	ANNUAL COSTS 20%	£S	12932		18344		23756		33388		38800		44512		49924		62556		70368		79780		82412		88124	96536	102548	112180				
20	COSTS/EFF. HOUR	£S/h	11.15		7.91		6.83		7.20		6.69		6.40		6.15		6.74		6.74		6.88		6.46		6.33	6.40	6.31	6.45				
21	COSTS/HECTARE	£S/ha	154.0		109.2		94.30		99.4		92.4		88.3		84.9		93.1		93.1		95.0		89.2		87.4	88.4	87.2	89.0				
22																																
23	HEAD	12000	—		—		—		1		1		1		1		1		1		1		1		1	1	1	1				
24	FOREMAN	6000	1		1		1		—		1		1		1		2		2		2		2		2	2	2	3				
25	DRIVERS+20% Spare	3600	1		2		1+3		1+4		1+5		1+6		1+7		2+8		2+9		2+10		2+11		2+12	3+13	3+14	3+15				
26	CLERK	4200	—		—		—		—		1		1		1		1		1		1		1		1	1	1	1				
27	MECHANIC	6000 7200	—		—		1		1		1		1		1		1		1		1		1*		1*	1*	1*	1*				
28	ASSISTANT	3000	—		—		—		—		—		1		1		1		1		1		1		1	1	1	1				
29	KEEPER	2400	—		—		1		1		1		1		1		1		1		1		1		1	1	1	1				
30	SUBTOTAL	£S	9600		13200		22800		38400		52800		58800		62400		75600		79200		82800		87600		91200	98400	102000	111600				
31	COSTS/HECTARE	£S/ha	114.28		78.57		90.48		114.28		124.28		116.67		106.12		112.5		104.76		98.57		94.81		90.48	90.11	86.73	88.57				
32	COSTS/EFF. HOUR	£S/h	8.28		5.64		6.55		8.28		9.00		8.45		7.68		8.15		7.59		7.14		6.87		6.55	6.53	6.28	6.41				
33	TOTAL COST/ha	£S/ha	268.28		187.77		184.78		213.68		216.68		204.97		191.02		205.6		197.86		193.57		184.01		177.88	178.51	173.93	177.57				
34	TOTAL COST/Eff.h	£S/h	19.43		13.60		13.38		15.48		15.69		14.85		13.83		14.89		14.33		14.02		13.33		12.88	12.93	12.59	12.86				
35	TOTAL COST/mach.h	£S/h	15.02		10.51		10.35		11.97		12.13		11.48		10.70		11.51		11.08		10.64		10.31		9.96	10.09	9.74	9.94				

ASAE, Agricultural Yearbook, St. Abst, Syria.

REFERENCES

1. Abercrombi, K.C.	Agric.Mechanization and Employment in Latin America; 1972, I.L.Rev. 106, 1, pp. 11-45.
2. Esmay, M.L. and L.W. Faidley,	Agric. Mechanization and Labour Utilization in Asia 1973; AMA Vol. III n. 2, pp. 15-22.
3. Friedheim, P.	Entwicklungstendenzen in der Agrarpolitik der Osteuropäischen Staaten 1972; Bauernverband, Berlin.
4. Heady, E.D. and Candler, W.	Linear Programming Method, 1958; Iowa State College Press.
5. Lint, de M.M. et al	ILR Taaktijden voor de Landbouw,'72-73 ILR Wageningen- The Netherlands
6. Moens, A.	Landbouwmechanisatie in Ontwikkelingslanden; 1974, Landb.Tijdschrift 86-1.
7. NN	An Agro-Econ. and Socio-Econ.Evaluation of the Euphrates Project 1964; IV. Vol. NEDECO The Hague, Holland.
8. NN	ASAE Agric.Eng. Yearbooks 1955,1963,1967.
9. NN	Aspects econ, du choix et de l'utilisation des materiels agricoles, 1970; Etudes du CNEEMA nr. 350.
10. NN	Irrigation and Drainage Project in the Euphrates Basin. Gibb & Partners, IV vol. nov. 1967
11. NN	Statistical Abstract of Syria,1971; C.B.S. Government Press, Damascus, Syria.

MECHANIZATION OF SMALL FARMS IN DEVELOPING COUNTRIES

Ch. Mourad, H.W. Vos, Agricultural Engineering Department,
Agricultural University,
Wageningen, the Netherlands

Summary

The two means to mechanize small holdings, the power tiller and the medium size four-wheeled tractor for collective use are discussed. For the latter a mechanization model is computed for the Euphrates Project in Syria, based on an optimal cropping pattern. This also showed that a 5.3 ha holding produces reasonable incomes for a farmer's family with 2 man equivalent with a rather high rate of employment amounting 61% net. No hired labour is involved while peak periods are adjusted to family labour supply. The optimal area to be served by one tractor is 84 ha.

The annual effective tractor hours totalled 1158 which is about 52% of one work-shift supply. Only in the fall period room was given for overtime work.

The model has been extended to maximize the use of farm implements too through combining more tractors with fewer machines and limited additional manpower for managerial and maintenance purposes. 1246 ha cropped area with 14 tractors has been found as an optimal size for an Operational Unit that may house 235 farmer's famlilies. The operation radius depending on the waste land enclosed within the boundaries of the O.U. in the Euphrates Project area is about 4 km or 25 minutes drive.

MÉCHANISATION DES PETITES EXPLOITATIONS DANS LES PAYS EN VOIE DE DÉVELOPPEMENT

Ch. Mourad, H.W. Vos, Université d'agriculture,
Wageningen, Les Pays Bas.

Résumé

L'utilisation du motoculteur et du tracteur de la puissance moyenne est discuté. On a préparé un modèle de programmation linéaire pour l'emploi du tracteur basé sur un assolement optimal pour la région de l'Euphrate en Syrie. Ce dernier nous à montré qu'une exploitation de 5,3 ha avec polyculture peut garantir des revenues assez raisonables pour une famille de 2 main d'oeuvres avec un emploi annuel montant jusqu'à 61% sans l'utilisation de travail étranger. La durée annuelle maximale d'utilisation effective du tracteur se monte à 1158 heures en une seule équipe avec quelques heures supplémentaires en automne. Pour maximiser l'utilisation des materiels agricoles un autre modèle a été construit qui nous mène vers la combination des plusieurs tracteurs avec moindre machines agricoles en même temps a réduit les frais de l'entretien et de la manutention. 1246 ha de la surface agricole utile servie par 14 tracteurs parait d'être optimale pour une Unité Operationnelle fonctionnante comme une exploitation collective et emploit 235 familles paysannes. Le rayon d'action de cette unité dépend des terrains inutiles trouvées à place. Pour l'Euphrate c'est du 4 km, c'est à dire 25 minutes à conduire.