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CONDITIONS AND CHARACTERISTICS OF WELL IRRIGATION UNDER PALAR BASIN, TAMIL NADU

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Abstract

This study demonstrates that properly designed sample surveys of wells and well owners provide an independent check on official data on the number of wells, the number in use, energisation and area irrigated. By studying villages in different segments of a basin selected on the basis of a typological classification (reflecting differences in the categories of wells and their density) and a more rigorous sampling within villages, one could get a far more detailed and accurate picture of the characteristics of well irrigation, its current use patterns and variations between different segments, categories of wells and classes of farmers within it. They also help reconstruct the spatial and temporal patterns of evolution in groundwater exploitation and its impact on the water table. That the amount of information, which can be obtained by such a survey, is far more and far richer than anything currently available, should be obvious from the results of our inquiry in the Palar basin. It highlights the rich and complex heterogeneity of conditions and experience even in a small basin. The findings call for the commonly held beliefs about these patterns – eg. The role of location, farm size and water markets – that are called into question. In doing so, they also help redefine the focus and methods of investigating the factors underlying the dynamics of groundwater exploitation, their implications for the future and ways to address the emerging problems.

This is not to suggest that the surveys and the information obtained from them are complete or flaw less. The selection of villages based on typologies are inadequate basis for deriving statistically reliable estimates for the basin and its segments. Information provided by respondents, especially regarding the past, are affected by recall lapses and even biases. It does not cover a crucial aspect namely the quantum of water extracted and applied. This information cannot be obtained by interviews but call for systematic measurements which are time consuming and expensive. In order to get a more accurate idea of groundwater dynamics, such surveys and measurements need to be repeated at periodic intervals taking care to ensure comparability of concepts, methods and estimates. Such an approach can work if research institutions can be persuaded to commit themselves to periodic surveys repeated over a reasonably long period and assured of financial support to implement the programme.

***** Report of a Research Project sponsored by the Planning Commission, Government of India. Field work for the survey was done by A.Rajagopal and S.Mariasusai. They also did the initial tabulations and prepared the first draft. The present version, however, is based on a complete retabulation and analysis of the primary data. Though A.Rajagopal did not participate in the revision and redrafting, his contribution to the study is gratefully acknowledged.

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CONDITIONS AND CHARACTERISTICS OF WELL IRRIGATION UNDER PALAR BASIN, TAMIL NADU

Introduction

This paper presents the findings of a survey of the characteristics of well irrigation in the Palar basin. The survey, undertaken as part of a project on irrigation sponsored by the Union Planning Commission, was aimed at (a) mapping the modes and spatial distribution of well irrigation in the basin on the basis of official records; (b) conducting a survey in a selected number of locations on the characteristics, costs and utilisation of wells; and (c) assessing the impact on agriculture.

The characteristics of well irrigation are influenced by a variety of environmental factors such as rainfall, topography, soil type, sediment formation, surface run-off, and groundwater recharge. The technology of water lifting and irrigated agriculture and the economic position of farmers influence the extent to which the resource is exploited and its impact on productivity. These contextual factors vary a great deal in a basin as large as that of Palar. It is therefore essential to divide the basin into segments (zones) based on homogeneity of relevant characteristics so that their influence on the extent of irrigation and its impact on agriculture is captured.

The first part provides a macro view of the physical features of the basin (such as topography, permeability of the soil, rainfall, surface run-off etc.) across different zones. It describes, on the basis of available secondary data,[1] the general agro-climatic environment, water resources potential, current utilisation of both surface and groundwater in the basin as a whole and in different segments. The second part presents the results of a first hand survey in 27 Villages selected from different segments of the basin to ascertain the actual position on the ground in terms of number of wells, number in use as the sole source of irrigation and as a supplement to tank water, the lifting devices used, the area irrigated and the extent to which water is purchased and sold. The survey estimates are compared with those of official records. An attempt is also made to reconstruct the time pattern of evolution of well irrigation and the behaviour of the groundwater table. For lack of time and resources, we could not undertake a detailed farm level survey of farms and plots irrigated by wells.

1. This part of the report is based on the UNDP study of Palar basin undertaken by the Institute for Water Studies, Tharamani, Chennai. We are grateful to them for permission to use the data (mostly technical) from their study.

Part - I
Irrigation in Palar basin: An Overview

Physical Features of the Basin

The Palar river basin is one of the major river basins in Tamilnadu accounting for about ten percent of the total area of the state. The river originates in Nandhi Durg in Karnataka, passes through south-western part of Andhra Pradesh and northern part of Tamilnadu before emptying into the Bay of Bengal. The total area of the basin is about 18,300 sq.km, out of which 3123 sq. km. (17.1%) lies in Karnataka, 4267 sq.km 23.3%) in Andhra Pradesh. A major portion (about 60 per cent) of the basin thus falls within Tamilnadu covering three districts viz. North Arcot Thiruvannamalai and Chengalpattu. However, the basin does not cover the entire stretch of all the districts. **Table 1** provides details about the taluks covered by the basin in each district.

Table 1 Names of the Taluks and Districts Covered by the Palar Basin

Sl.no	Name of the taluks	Districts
1	Vaniyambadi	North Arcot
2	Thirupathur (part)	North Arcot
3	Gudiyatham	North Arcot
4	Walajapet (western part)	North Arcot
5	Vellore	North Arcot
6	Arcot	North Arcot
7	Chengam	North Arcot
8	Polur	Thiruvannamalai
9	Arni	Thiruvannamalai
10	Cheyyar	Thiruvannamalai
11	Vandavasi	Thiruvannamalai
12	Thiruvannamalai(northrn part)	Thiruvannamalai
13	Kancheepuram	Chengalpattu
14	Uthiramerur	Chengalpattu
15	Chengalpattu	Chengalpattu
16	Maduranthagam	Chengalpattu
17	Sriperumpudur	Chengalpattu

Source: Water resources under Palar basin, study by Institute for Water Studies (IWS Report), 1991. Chennai.

Zonewise distribution of area under Palar basin is given in **Table 2**. The agro-climatic zones of the Palar basin is shown in Map 1. The total area of the basin is 10,880 sq.km. While more

than a fourth of area is located in the upper Palar Zone, the least area of about 8 per cent is situated in the Kamandala Naganadhi zone.

Table 2 Extent of Area Falling under Each Zone in Palar Basin

Sl.no.	Name of the zone	Area(sq.km)	%
1.	Upper Palar	3085	28.4
2.	Kamandala Naganadhi	824	7.6
3.	Upper Cheyyar	1964	18.0
4.	Lower Cheyyar	1151	10.6
5.	Lower Palar	1569	14.4
6.	Kiliyar Palar	2287	21.0
	Total	10,880	100.0

Source: Water resources under Palar basin, study by Institute for Water Studies (IWS Report), 1991. Chennai.

Map 1: Agro-climatic Zones in the Palar Basin

Upper Palar Zone lies in the upper reach of the basin and starts from the north western boundary of the river i.e. Kolar area of Karnataka state. It consists mostly of plains except for Ambur hills. The total area is about 3085 sq. km extending over Vaniyambadi, Gudiyatham, Walajabad taluks. The zone has low yield and high surface run-off ratio. It has also good drainage and as a result ground water recharge is less.

Kamandalanadhi Zone is drained by the tributaries of Palar viz Kamandala Aru and Naganadhi. This is the smallest among the zones with a total area of about 825 sq. km.

Upper Cheyyar Zone covers Chengam and Palar taluks with a total area of 1964 sq. km. The north-western part of the zone is a hilly region made up of Javadhi hills. The south-eastern part is more or less plain area. Like Upper Palar, the zone also has less surface water yield but with extended flow. The zone is characterised by good drainage and low rate of ground water recharge.

Lower Cheyyar Zone extending over 1150 sq. km in Cheyyar taluk, is more or less plain country dotted with numerous tanks. The surface water yield is less due to higher bifurcation ratio. The zone is relatively poor in terms of drainage and hence has good recharge capacity.

Lower Palar Zone lies in the coastal region. The total area of the zone, about 1570 sq. km, falls in Chengalpattu district. The land is mostly plain, with a much smaller slope (west to east) compared to other zones. A relatively higher bifurcation ratio makes the surface water yield lower, but has good ground water recharge capacity.

Kiliyar Palar Zone The entire area of the zone is plain with good permeability of the soils. The total area is 2287 sq. km covering Maduranthagam and Vandavasi taluks. Like that of other zones, the yield of the zone is less. Due to less drainage facility, there is good potential for ground water recharge.

In terms of physical features, the above zones fall into two distinct groups: The upper part of the basin (consisting of Upper Palar, Kamandala Naganadhi and Upper cheyyar) is predominantly hilly region. Hence the streams are more numerous, the run-off is relatively higher, recharge of groundwater is rather low. Erosion is also likely to be higher. The lower reach (consisting of other zones) is mainly plain region: The slope is less; there are fewer

streams and the soil more permeable. All these make for low surface run-off and good potential of ground water recharge compared to the upper part.

Rainfall Pattern Across Zones

The average annual rainfall in different zones is in the range of 900 to 1200 mm **[Table 3]**. While Kiliyar-Palar zone has the highest rainfall (1155 mm), Upper palar has the lowest (870 mm). The south west monsoon is more important than the north east monsoon in Upper Palar, Upper Cheyyar and Lower Cheyyar zones; the north-east monsoon is more important in Kiliyar and Lower Palar Zones. In Kamandala Naganadhi, both seasons seem to be equally important.

Table 3 Mean Annual/Seasonal Rainfall Across Different Zones n Palar Basin (Average for the period 1943 to 1987)

Zone	S.W. Monsoon (mm)	N.E. Monsoon (mm)	Total (mm)
Upper Palar	421	326	871
	(48.3)	(37.4)	
Kamandala	460	459	1056
Naga Nadhi	(43.4)	(43.5)	
Upper Cheyyar	465	430	1041
	(44.7)	(41.3)	
Lower Cheyyar	499	446	1048
	(47.6)	(42.6)	
Lower Palar	481	515	1091
	(44.1)	(47.2)	
Kiliyarr	451	708	1155
	(39.0)	(61.3)	

Note: Figures in brackets represent percentage to the total.
Source: IWS report, 1991. Chennai.

Between south-west and north-east monsoons the former is more important in upper palar but the latter is important in Kamandala Nadhi zone. In the remaining four zones, the coefficient of variation indicates, the north-east monsoon is more important (**Table 4**). In the basin as a whole Kiliyar zone receives the maximum rainfall followed by lower palar. The minimum rainfall occurs in upper palar followed by upper cheyyar.

Table 4 Co-efficient of Variation in Rainfall Across Different Zones by Seasons and Annum for the Period 1943-87

Zone	Co-efficient of variation (%)		
	South west monsoon	North East monsoon	Annual rainfall
Upper Palar	29	36	21
Kamandala Nadhi	27	45	23
Upper Cheyyar	28	34	21
Lower Cheyyar	28	37	22
Lower Palar	28	45	24
Kiliyar	28	36	27

Source: Computed from rainfall data provided in UNDP study by IWS, 1991. Chennai.

Evapotranspiration (ET) and Water Deficit

Evapotranspiration - which is a function of temperature, humidity, wind velocity and hours of sun shine - is an important parameter which indicates the water requirement for crop growth in an area. Both in Chengalpattu and North Arcot districts rainfall is inadequate to meet crop water needs in 8 to 9 months of the year. Precipitation exceeds ET only during the NE monsoon period. It is only about eighth of ET in February-May and about 45-55 per cent in June-September [**Table 5**].

Table 5 Evapotranspiration and Rainfall in Chengalpattu and North Arcot Districts

Details	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Evapotranspiration(MM)	**Chengalpattu**												
	162	186	198	213	219	222	240	225	138	129	96	90	2118
Mean Rainfall (MM)													
	33	10	14	18	54	68	102	144	145	209	222	95	1113
Evapotranspiration(MM)	**North Arcot**												
	156	159	186	207	228	285	246	216	168	114	99	87	2151
Mean Rainfall (MM)													
	21	5	14	23	63	71	115	126	129	163	167	87	982

Source: IWS report, 1991. Chennai.

Irrigation and Agriculture in the Palar Basin

Tables 6 and 7 give the official statistics of cultivated and irrigated areas, sources of irrigation, number of wells and irrigation under wells, and the irrigation and cropping intensities across different zones in Palar Basin. The net sown area in the basin is around 370 thousand hectares

of which over half is irrigated. The irrigation ratio (proportion of net irrigated to net sown area) for the basin as a whole is 55 per cent - well above the state average. It is the least in Kamandala-Naganadhi zone (less than 40 percent) and highest (74 percent) in lower Palar. Irrigation is considerably more widespread in the lower half of the basin than in the upper reaches.

Table 6 Basic Data Relating to Irrigation and Agriculture of Different Zones in the Palar Basin (Area in Hectares)

Sl. No.	Zone	Gross Cropped Area	Net Sown Area	Gross Irrigated Area	Net Irrigated Area	NIA/ NSA %	Irrigated Area under				Conjunctive use of			No.of sole wells	NIA per sole well 11/15
							Canal	Tank well	Tube-well	Open-wells	NIA	GIA	No.of wells		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	UP	43,843	38,665	19,835	17,361	45	1,133	1,523	-----	13,960	--	--	---	21,920	.637
2.	KI	54,417	44,559	25,453	17,484	39	178	2,051	-----	14,455	3,050	3,225	NA	40,555	356
3.	UC	117,471	96,786	67,516	50,193	52	983	8,535	-----	40,375	6,856	9,665	NA	47,140	.856
4.	LC	58,541	51,019	33,255	26,173	51	171	7,578	-----	18,419	3,545	4,467	--	32,160	573
5.	LP	65,773	55,561	50,972	41,254	74	---	27,894	1,830	11,219	2,750	3,074	6,913	9,711	1.16
6.	KR	94,115	82,169	61,142	54,481	66	160	18,903	-----	35,418	10,695	11,755	3,399	59,656	594
Total		**434,160**	**368,759**	**258,173**	**206,946**	**56**	**2,625**	**66,484**	**1,830**	**133,846**	**26,896**	**32,186**	**10,312**	**211,142**	**.634**

Source: Taluk level 'G' returns data, from Departments of Statistics grouped according to zones. 1991-92.

There are an estimated 240,000 wells in the basin, of which 211,000 are used as the sole source of irrigation. Area irrigated entirely by ground water constitutes about 70% of net irrigated area. Except lower Palar, wells are the predominant source of irrigation accounting for 65 percent or more of net irrigated area; and close to 80 per cent in zones 1 and 2. In lower Palar, tank irrigation is dominant (accounting for 70 percent of net irrigated area), but even here more than a quarter of the area receives irrigation from wells. (Data on source wise gross irrigated area are not available).

Tanks are the main source of surface irrigation everywhere and area under canal irrigation is very limited. Surface irrigation accounts for about one sixth of irrigated area in the upper reaches (zones 1 to 3). It plays a much greater role in the lower reaches, especially in Lower Palar where it accounts for about 70 per cent of irrigation. Conjunctive use of ground water in surface irrigated areas is widespread and covers the major part of surface command in all zones except Lower and Upper Palar.

Well density is around 1.5 per ha, varying from 0.74 in Lower Palar to 2.82 per ha in Kamandalanadhi zone. There is no clear pattern in the variation across zones. On the average, a well irrigates 0.75 ha again with large zonal variations: 0.36 in zone (2) and 1.34 in Lower Palar. There is a strong inverse relation between well density and area irrigated per well: higher the density lower the yield per well.

Cropping Intensity and Cropping Pattern in the Palar Basin

The overall cropping intensity (GCA/NSA) is around 1.13 in zone 1 and the highest (1.22) in zone 2 **[Table 7]**. Leaving zone 1 we can see a clear tendency for cropping intensity to fall from head to the tail reaches. Irrigated crop intensities (GIA/NIA) follow a similar pattern but the zonal variations are much greater.

Table 7 Some Indicators of Irrigation and Agriculture Across Different Zones

Sl.no.	Zones	GCA/NSA	GIA/NIA	Percentage of NIA			NIA per sole well (Ha)
				Ground-water	NIA Sole Well	Sole well/ hectare	
1	Upper Palar	1.13	1.14	80.41	0.64	1.57	.637
2	Kamandalanadhi	1.22	1.46	82.68	0.36	2.81	.356
3	Upper Cheyyar	1.21	1.35	80.44	0.86	1.17	.856
4	Lower Cheyyar	1.15	1.27	70.37	0.57	1.75	.573
5	Lower Palar	1.18	1.24	27.23	1.34	0.74	1.16
6	Kiliyar	1.15	1.12	65.01	0.59	1.68	.594

Source: Based on Taluk level G.return data of Department of Statistics, Government of Tamilnadu. 1991-92.

We do not have data on crop pattern for the basin as a whole. But a comparison of the data for North Arcot and Chengalpattu districts gives some idea of the differences between upper and lower parts of the basin. Commercial crops like sugarcane and groundnut are important in North Arcot district accounting for 30 to 40 per cent of GIA in a majority of taluks and paddy accounts for a smaller proportion of irrigated crop area. In Chengalpattu, however, paddy is dominant accounting for 70 to 90 per cent of irrigated crop area. Commercial crops are far less significant. Ragi and coconut are other important irrigated crops in some taluks of North Arcot district. Thus the irrigated cropping pattern is quite diversified in western part of the basin (i.e., North Arcot) whereas mono (paddy) culture is dominant in eastern part (Chengalpattu).

Ground Water Potential and its Utilisation

Table 8 provides data on the estimated groundwater potential and its utilisation across different zones in Palar basin. The extent of utilisation is more than 85 percent of estimated potential in all the zones. Taking the basin as a whole, the utilisation is up to 92 percent of its potential. Groundwater is more intensively exploited in the basin compared to state as a whole where it is only 60 per cent of recharge. Hence the basin region is classified as 'black' zone (signifying over exploitation) by the State Ground Water department.

Table 8 Ground Water Potential and its Utilisation in Different Zones under Palar Basin

Sl. No.	Name of the zone	Avg.Annual Recharge ($M m^3$)	Avg.Annual Discharge ($M m^3$)	Percentage of Utilisation
1	Upper Palar Zone	666	587	88.13
2	Kamandalanadhi zone	149	127	85.24
3	Upper Cheyyar zone	484	429	88.64
4	Lower Cheyyar zone	366	335	91.53
5	Lower Palar zone	912	888	97.37
6	Kiliyar-Palar zone	839	782	93.21
	Total	3416	3148	92.15

Source: UNDP Study of IWS, 1991. Chennai.

As early as 1969, the government issued orders for regulation of ground water in the region. Digging of wells was prohibited within a distance of two furlongs from the river and streams. However, the order was amended in 1989 allowing wells to be dug even within 200 metres from the river and streams. Thus dilution of the 1969 order might have contributed for over exploitation of groundwater in some areas. It is noticed that in some pockets, the ground water utilisation is nearing 100 per cent.

Characteristics of Groundwater and Well Irrigation in the Palar Basin

Water table occurs generally at about 8 to 13 metres below the ground level. The water table in Nanjai lands occurs at a level (depth) lower than Punjai lands. In other words, the Depth of wells in the Punjai lands (non-ayacut) is slightly more than Nanjai (ayacut) wells in most parts

of the basin **[Table 9]**. However, during summer, both nanjai and punjai wells are having same level of water table in most parts of the basin except zones 1 and 2. In Upper Palar and Kamandalanadhi zones, punjai wells have lower water table than nanjai wells. This may be due to lack of recharge from surface sources like tanks which are not well developed in this zone due to topography.

Table 9 Details of Ground Water Table, its Utilisation and Recharge Across Sub-basin of Palar Basin (in Metres)

Sub Basin	Depth of Wells				Water Table (Summer)			
	AY	NA	EL	All	AY	NA	EL	ALL
Upper Palar	11.5	12.0	13.0	12.5	9.0	11.0	11.0	10.0
Kamandalanadhi	13.0	13.0	13.0	14.0	6.0	11.0	10.0	13.0
Upper Cheyyar	11.0	11.0	10.0	11.0	8.0	8.0	9.0	9.0
Lower Cheyyar	11.0	12.0	11.0	--	9.0	9.0	9.0	---
Lower Palar	8.0	11.0	12.0	13.0	6.0	6.0	12.0	11.0
Kiliyar	8.0	8.5	9.5	--	5.5	5.5	8.0	---

Note: AY - Ayacut (Nanjai) NA - Non ayacut (Punjai) EL- Elevated
Source: UNDP study of IWS, 1991. Chennai.

Draw down water table (after specified hours of pumping) in summer ranges between 1 to 3 metres; there is not much difference between nanjai and punjai wells across all zones. It takes about 15 to 20 hours for recuperation of water table in summer and more time is taken by punjai wells than wells in Nanjai in all zones.

Well irrigation is relatively more pronounced in the upper part of the basin - that is Upper Palar, Kamandalanadhi and Upper Cheyyar zones when compared to lower parts like Lower Palar and Lower Cheyyar **[Table 10]**. It is also seen that density of wells (wells/acre) is significantly more in nanjai lands than punjai lands across all parts of the basin. The same is true when we look at the more disaggregated (village) level data: The proportion of villages which have no wells on punjai lands is much higher (except in lower Palar) than those with, no wells on nanjai lands; the proportion of villages reporting low well densities on punjai lands is higher in all zones.

Table 10 Frequency Distribution of Villages According to Well Density in Nanjai and Punjai Lands

Zone	No. of Villages Reporting No Wells	Frequency Distribution of Villages having well per acre 0.01 0.05	0.06 0.10	0.11 0.15	0.16 0.20	0.21 0.25	+0.25	Total	Overall Density
				NANJAI WELLS					
Upper Palar	23	1	3	6	12	13	66	124	33
Kamandalanadhi	27	3	2	11	8	14	89	154	30
Upper Cheyyar	42	1	3	13	11	22	154	180	32
Lower Cheyyar	13	12	15	10	12	19	76	157	.19
Lower Palar	95	74	52	44	20	21	38	344	12
Killiyar	29	32	39	20	33	25	57	235	NA
				PUNJAI WELLS					
Upper Palar	6	11	20	36	27	11	15	126	13
Kamandalanadhi	5	4	21	35	23	31	35	154	17
Upper Cheyyar	14	18	27	59	54	36	34	242	13
Lower Cheyyar	9	21	37	40	26	12	12	157	.11
Lower Palar	117	100	60	43	11	6	6	344	.07
Kiliyar	NA								

Source: Computed from the data available in the UNDP study of Water Resources of Palar Basin, IWS, 1991. Chennai. NA - Not Available.

Table 11 provides data on water lifting devices used for well irrigation. It is quite surprising that Kavalai (mhote) is still reported to be used to a significant extent as a mode of lifting of water in all zones! In fact, it is the dominant mode of lifting in Cheyyar part of the basin (viz Upper and Lower Cheyyar zones). Electric motor is the next important source of lifting in a number of zones and a dominant mode of energisation of wells in Lower Palar zone. It is to be noted that, according to this data set, diesel engines are rarely used in the basin.

Table 11 Mode of Energy Use for Ground Water Extraction

Zone	Mode of Energy used (Number of Wells)						
	Electric	**% to Total**	Diesel	**% to Total**	Kavalai	**% to Total**	Total
Upper Palar	8249	**49.4**	238	**1.4**	8226	**49.2**	16715
Kamandalanadhi	11528	**48.2**	189	**0.8**	12205	**51.0**	23922
Upper Cheyyar	12839	**36.9**	1224	**3.5**	20792	**59.6**	34855
Lower Cheyyar	12345	**38.8**	1244	**3.9**	18229	**57.3**	31818
Lower Palar	6303	**63.6**	412	**4.2**	3186	**32.2**	9901
Kiliyar palar	6773	**45.7**	1261	**8.5**	6780	**45.8**	14814
Total	**58037**	**44.0**	**4568**	**3.5**	**69418**	**52.5**	**132025**

Source: IWS Report, 1991. Chennai.

Part II

RESULTS OF FIELD SURVEY

Selection of Villages for the Field Survey

There are 1241 villages in the basin. Constraints of resources and time limited the number of villages that could be covered to 27. As characteristics of well irrigation are influenced by the existing agro-climatic conditions, we selected villages from all the six zones of the basin, the number in each being roughly proportionate to the number of villages in each zone. **Table 12** gives details about total number of villages and number of them selected for the survey from each zone in the basin.

Table 12 Details About Total Number of Villages and Number of them Selected for the Survey

Zone	Total number of villages	Number of villages selected for the survey
Upper Palar	126	3
Kamandala Naga Nadhi	143	4
Upper Cheyyar	225	6
Lower Cheyyar	157	3
Lower Palar	344	5
Kiliyar	246	6
Total	1241	27

Source: Survey, 1993.

The characteristics of wells also vary between nanjai and punjai lands. Villages were, therefore, first divided into three categories on the basis of well density (High, Medium and Low) both in Nanjai and Punjai lands. This gives 9 groups on the basis of the relative densities in both categories of land.

Villages with high well density in both nanjai and punjai lands are classified as HH. Those with high nanjai well density and low punjai well density are demarcated as HL and so on. Based on these classifications, villages were purposively selected so as to capture the predominant categories in each zone. The details of villages thus selected in each zone are given in **Table 13**.

Table 13 Details of Villages Selected for the Survey

Zone	Taluk	Village	Well Density
Upper Palar	Vaniyambadi	Aithampattu	HH
	Vaniyambadi	Somalapuram	HM
	Vaniyambadi	Vellakuttai	MH
Kamandala Nadhi	Vellore	Perumugai	HH
	Gudiyatham	Pasumathur	HM
	Vellore	Athiyur	MH
	Gudiyatham	Goodanagaram	HM
Lower Cheyyar	Chengam	Chengam	HH
	Chengam	Kayampattu	HH
	Chengam	Thukkapettai	MM
	Vandavasi	Namatode	MM
	Chengam	Arasanganni	OL
	Thiruvannamalai	Kattuputhur	OM
Upper Cheyyar	Vandavasi	Aiylam	HH
	Cheyyar	Marianallur	OH
	Arcot	Vilari	HL
Lower Palar	Kancheepuram	Uthukkadu	ML
	Kancheepuram	Vallabakkam	MM
	Kancheepuram	Kunnavakkam	LL
	Kancheepuram	Brammadesam	LM
	Kancheepuram	Agaram	LO
Kiliyar	Vandavasi	Vengunam	HH
	Chengalpattu	Murukkeri	HM
	Chengalpattu	Thottanaval	ML
	Chengalpattu	Echoor	HH
	Chengalpattu	Melakuppam	ML
	Chengalpattu	Karanai	HL

Note: H=High Density. M=Medium Density. L=Low Density. O=NIL.
Source: Survey, 1993.

Selection of Samples

Within each selected village, all the survey numbers of punjai and nanjai lands with and without wells as reported in the Adangal were listed. From each of these 4 categories (namely nanjai with well; punjai with well and nanjai and punjai without well) 20 survey numbers were selected. Thus in each selected village, 40 survey numbers with wells and 40 without wells have been selected. If the total number of plots listed in a category falls short of 20, all survey numbers in those categories have been taken up for the survey. **Table 14** gives the details about the

Table 14 Total Number of Survey Numbers in Each Village and the Number of Them Selected for the Survey

Sl. No.	Name of Village	Total Survey Numbers				No. of Survey Nos. Selected for the survey			
		Nanjai		Punjai		Nanjai		Punjai	
		W	NW	W	NW	W	NW	W	NW
1.	Aythampattu	31	76	22	33	20	20	20	20
2.	Somalapuram	43	74	12	19	20	20	12	19
3.	Vellakuttai	22	15	237	123	20	15	20	20
4.	Athiyur	7	5	216	122	7	5	20	20
5.	Goodanagaram	144	200	97	80	20	20	20	20
6.	Pasumathur	108	306	130	153	20	20	20	20
7.	Perumugai	13	44	46	13	13	20	20	13
8.	Arasanganni	Nil	Nil	17	8	Nil	Nil	17	8
9.	Chengam	52	33	128	23	20	20	20	20
10.	Kattuputhur	Nil	Nil	46	13	Nil	Nil	20	13
11.	Kayampattu	42	25	106	31	20	20	20	20
12.	Namatodu	95	96	101	63	20	20	20	20
13.	Thukkapettai	32	29	59	43	20	20	20	20
14.	Ayilam	8	16	176	367	8	16	20	20
15.	Marianallur	Nil	102	20	118	Nil	20	20	20
16.	Vilari	29	69	37	68	20	20	20	20
17.	Agaram	1	425	Nil	9	1	20	Nil	9
18.	Brammadesam	47	470	46	164	20	20	20	20
19.	Kunnavakkam	4	349	9	74	4	20	9	20
20.	Uttukkadu	48	189	14	94	20	20	14	20
21.	Vallabakkam	29	270	4	11	20	20	4	11
22.	Echoor	32	95	20	34	20	20	20	20
23.	Karanai	9	78	29	71	9	20	20	20
24.	Melakuppam	3	11	8	16	3	11	8	16
25.	Murukkeri	10	29	8	23	10	20	8	20
26.	Tottanaval	9	97	4	49	9	20	4	20
27.	Vengunam	69	110	75	127	20	20	20	20
		887	3213	1673	1949	364	467	436	489

Source: Derived from Annexure 1.

villages, total number of survey numbers of nanjai and punjai lands, their distribution into those with well and those without wells and the number of survey numbers selected from each category. Zone wise distributions are given in **Table 15**.

Table 15 Total Number of Survey Numbers in Each Zone and Numbers Selected

Zone	Total Survey Numbers				Survey Numbers Selected for Survey			
	Nanjai		Punjai		Nanjai		Punjai	
	Well	Nowell	Well	Nowell	Well	Nowell	Well	Nowell
Upper Palar	96	165	277	175	60	55	52	59
Kamandalanadhi	272	555	489	368	60	65	80	73
Upper Cheyyar	221	183	457	181	80	80	117	101
Lower Cheyyar	37	187	233	553	28	56	60	60
Lower Palar	129	1703	73	352	65	100	47	80
Kiliyar	132	420	144	320	71	111	80	116
Total	887	3213	1673	1949	364	467	436	489

Source: Derived from Table 14.

Current characteristics of wells

Number of Wells: Spot verification of the current position in the sampled plots bought out significant differences from the particulars recorded in the village revenue records (Adangal): On the sampled nanjai well plots the actual number tallied with the Adangal figures in 11 villages; and was lower in 11 villages. In nanjai non-well plots wells were found to exist in 6 villages. Most of them in the lower reach segments (Lower Palar and Kiliyar).

Much the same is the case with punjai plots: in 16 villages the number of wells found on the sample plots was less than the Adangal figures, but the margins are substantially greater than in the nanjai plots. A substantial number of wells were also found on non-well sample plots in the tail end zone of the basin (Table 16).

Table 16: Number of Wells in Sampled Plots as per Adangal and Survey

Zone	Nanjai				Punjai			
	Well plots		Non-well plots		Well plots		Non-well plots	
	Adangal	Survey	Adangal	Survey	Adangal	Survey	Adangal	Survey
UP	74	58	0	0	79	68	0	0
KI	81	75	0	2	142	109	0	0
UC	125	115	0	0	225	203	0	0
LC	30	24	0	0	79	63	0	0
LP	70	68	0	4	50	47	0	1
KR	93	77	0	20	133	118	0	19
ALL	473	417	0	26	708	608	0	20

Source: Derived from Annexure 1.

The proportion of plots with wells is much higher than that of punjai plots in all zones except the tail end zone (Table 17). On the other hand, the number of wells per plot with wells is, with one exception, higher in punjai than in nanjai lands. This difference may be partly due to the fact that nanjai plots are generally much smaller than punjai plots. Since we did not collect information on the area of sampled plots, it was not possible to estimate the well density per unit area.

TABLE 17 Number of Plots with Wells and Wells per Plot Estimated From the Survey

Zone	Nanjai			Punjai		
	Total Plots	Plots with wells	Estimated No.of Wells	Total Plots	Plots with wells	Estimated No.of Wells
UP	261	96(37)	94	452	277 (61)	382
KI	827	272(33)	345	857	489 (57)	670
UC	404	221(55)	325	638	457 (72)	804
LC	224	37(17)	31	786	233 (30)	300
LP	1832	129(07)	135	425	73 (17)	70
KR	552	132(24)	134	464	144 (31)	180
Total	**4100**	**887(22)**	**1065**	**3622**	**1673 (46)**	**2406**

Note: Estimated number of wells exclude wells under no well plots.
Figures in brackets indicate percentage to total plots.
Source: Derived from Annexure 1.

Wells in Use: The survey also found about 5-6 percent of existing both nanjai and punjai wells in the sample have not been in use for 3 or more years (Table 18).In half the villages, however, all the nanjai wells were in use; while in the other half the proportion in disuse ranged from 10 to 30 per cent. Punjai wells out-of-use were noted in half the villages, the incidence ranging from 3 to 30 percent. The Adangal does not distinguish between wells in use and wells not in use.

Table 18 Wells in Use and Not in Use

Zone	Nanjai			Punjai		
	Total	In Use	%	Total	In Use	%
UP	58	56	96.5	68	66	97.1
KI	77	73	95.0	109	104	95.4
UC	115	107	93.0	203	188	92.6
LC	24	23	96.0	63	52	82.5
LP	72	67	93.0	48	46	95.8
KR	97	90	92.8	137	129	94.2
Total	**443**	**416**	**93.9**	**628**	**585**	**93.2**

Source: Derived from Annexure 2.

Depth of Water Table: The principal characteristics of wells in use in sample villages are shown in Annexure 3. The average depth of the water table in nanjai wells varies from less than 20 feet below ground level to over 50 feet. Water is within 25 feet from ground level in 6 villages and more than 40 feet in 8. Wells are generally much deeper in the upper most reaches than in tail segments villages – average depth exceeding 40 ft all 3 villages in Upper Palar and in 2 out of 4 in Kamandala Nadhi. In Kiliyar segment, at the tail end of the basin, it is less than 30 feet in all villages. Punjai wells are shallower than nanjai wells in 11 villages, deeper in 11 and in one case about as deep. Punjai wells in the upper segment of the basin tend to be deeper than in others and to decline towards the lower reaches. The mean depth of punjai wells ranges from 25 feet to 53 feet; the range in nanjai wells is 21 feet to 51 feet. Over half the villages report mean depth of 25 to 35 in punjai wells compared to less than 40 percent in nanjai wells.

Zone wise frequency distribution of wells by current depth and estimated mean depth are given in **Table 19**. Mean depth is highest in Upper Palar followed by Kamandalanadhi and Upper Cheyyar. It increases sharply in Lower Cheyyar to nearly the same level as in Upper Palar and falls thereafter. The mean depth in the two tail end segments is the lowest among all zones. A similar pattern is also noticeable in punjai wells but it is much less pronounced.

Table 19 Distribution of Wells in Use by Current Depth (in feet)

Zone	<20	21-40	41-60	61-100	>100	Total	Mean Depth	<20	21-40	41-60	61-100	>100	Total	Mean Depth
	Nanjai wells							**Punjai wells**						
UP	0	18	33	4	1	56	47.8	1	20	37	8	0	66	48.7
KI	14	27	27	5	0	73	37.6	13	44	35	12	0	104	40.5
UC	9	80	18	0	0	107	32.1	24	107	53	4	0	188	34.1
LC	0	6	17	0	0	23	48.0	4	26	20	2	0	52	42.9
LP	23	31	8	5	0	67	28.2	7	29	5	4	1	46	36.0
KR	24	66	0	0	0	90	22.9	24	103	2	0	0	129	24.9
Total	70	228	103	14	1	416	33.5	73	329	152	30	1	585	35.8

Source: Derived from Annexures 3 and 3A

Depth depends on a variety of factors including volume and seasonal distribution of local rainfall, subsurface geology, economic viability and, in the case of nanjai wells, the supply in the tanks that recharge them. The fact that there is a perceptible positive correlation between mean depth of the two categories of wells points to the importance of geo-physical factors. Since depth shows a tendency to fall from head to tail segments, conditions for both categories of wells seem more favourable in the tail segments.

Energisation: Currently the large majority of wells in use have energized lifts (**Table 20**). Upwards of 75 per cent of nanjai wells are energized in 15 out of 24 villages; the corresponding figure for punjai wells being 18 out of 26. Over 90 percent of the nanjai wells in Upper Palar are energized and all of them use electric pumps; the proportion of energized wells, the degree of electrification and the average HP per pump in the next two zones are lower in the next two segments touching the lowest level in all three reaches in Upper Cheyyar. In the lower half of the basin, all wells in Lower Cheyyar are energized with electricity and use pumps of relatively high horse power. All these indices are lower in the next two segments at the tail end of the basin. The pattern of variation is broadly similar in the case of punjai wells.

Table 20 Current Position of Energisation and Source of Energy by Zones

Zone	Nanjai			Punjai		
	Percent of wells energised	Electric pump as % of energized wells	**Mean** HP/ Well	Percent of wells energised	Electric pump as % of energized wells	**Mean** HP/ Well
UP	94.6	100.0	4.5	92.4	95.0	4.5
KI	80.8	96.7	3.5	80.8	97.6	3.2
UC	72.9	85.8	3.2	79.8	85.3	3.6
LC	100.0	100.0	4.8	96.2	92.0	4.7
LP	85.1	84.2	4.1	82.6	78.9	4.4
KR	86.7	91.0	3.7	89.9	78.4	3.8
Basin	83.7	91.6	3.8	85.4	87.5	3.8

Source: Derived from Annexures 3 and 4.

Inter-village and zonal differences in level and pattern of energisation are a function of several factors: costs (which depend on sub-surface conditions, depth and water yields), availability of electricity, and the benefits in terms of increased production (in turn a function of the quantum and reliability of well water supply and, in the case of nanjai plots, the condition of tank water supply). We have not been able to examine these aspects. All that we can say is that, judging by the proportion of plots with wells and the number of wells per plot, the upper half segments seem considerably better endowed with groundwater than the lower half. The positive correlation between depth and the degree of energisation of the two categories of wells seems to suggest that geophysical factors affect the potential for both in a similar fashion.

Area Irrigated per Well: During the reference year the net irrigated area per nanjai well (taken as the area irrigated during the first season, which in most, but not all, cases is the largest area served in any season) ranged from 0.9 acres to 4.4 acres. It was between 1 and 2 acres in 40 per cent of the villages and 2 to 3 acres in half of them. Wells serving more than 2 acres on the average seem to be more frequent in the two tail reach segments **(Table 21).**

Punjai wells on the average serve between 0.5 acre and 4 acres. In more than half the villages

net area irrigated per well lies between 1 and 2 acres; those reporting 2-3 acres per well constitute only one fourth of the total. Average irrigated area per nanjai well in zones of the upper half of the basin is the same or higher than that of punjai wells. In the lower half segments, the average area served by punjai wells is lower compared to nanjai wells both at the zonal level and in a majority of villages. One must however bear in mind that nanjai wells are used in conjunction with tank water and therefore can be expected to serve a larger area than punjai wells as the latter are the only source of irrigation for their command.

Table 21 Characteristics of Wells in Selected Villages

Zone	Village	Nanjai					Punjai				
		Mean Depth	% of wells in use	% of wells in use energized	Area served per well (acres)		Mean Depth	% of wells in use	% of wells in use energized	Area served per well	
					Net	Gross				Net	Gross
UP	Aythampattu	53.3	100	94	3.0	3.3	53.3	100	100	3.4	3.7
	Somalapuram	38.7	90	100	2.7	2.7	40.7	86	92	4.3	4.3
	Vellakkuttai	51.6	100	89	1.3	1.3	47.8	100	86	1.6	1.7
UP	Total	47.8	97	95	2.3	2.4	48.7	97	92	2.8	2.9
KI	Athiyur	48.7	78	100	3.5	3.6	45.0	100	97	2.5	3.2
	Goodanagar	38.7	100	83	1.8	1.8	38.7	100	73	1.2	1.4
	Pasumathur	41.2	91	90	2.2	2.2	58.9	83	92	1.4	1.2
	Perumugai	21.6	100	56	0.9	1.3	28.6	100	62	1.5	1.6
KI	Total	37.6	95	81	1.9	1.9	40.5	95	81	1.7	1.9
UC	Arasanganni	—	—	—	0.0	0.0	29.6	76	77	0.0	0.0
	Chengam	37.1	100	75	2.0	2.3	34.7	100	79	1.9	2.1
	Kattuputhur	—	—	0	0.0	0.0	44.7	100	98	0.0	0.0
	Kayampattu	44.8	100	64	2.2	2.5	27.6	100	44	1.7	1.7
	Namatodu	29.0	81	77	1.1	1.1	28.2	85	79	0.8	0.9
	Thukkapettai	29.3	93	75	1.7	2.2	31.3	84	92	2.5	3.5
UC	Total	32.1	93	73	1.7	2.0	34.1	93	80	1.8	2.4
LC	Ayilam	30.0	89	100	2.7	3.5	38.5	69	90	2.5	2.8
	Mariyanallur	——	—	——	0.0	0.0	30.2	90	100	0.0	0.0
	Vilari	46.7	100	100	2.5	2.5	37.7	100	100	4.1	4.3
LC	Total	48.0	96	100	2.6	2.8	42.9	83	96	2.8	3.3
LP	Agaram	30.0	100	100	2.0	2.0	—	—	—	0.0	0.0
	Brammadesam	50.5	95	100	2.3	2.7	34.2	100	94	1.7	2.1
	Kunnavakkam	0.30	100	75	1.5	3.8	28.3	100	67	1.7	3.2
	Uthukkadu	0.21	91	80	2.5	3.2	26.0	94	73	1.3	1.6
	Vallapakkam	22.4	92	78	1.0	1.4	25.0	60	100	1.8	2.7
LP	Total	28.2	93	85	1.9	2.4	36.0	94	83	1.6	2.2
KR	Echoor	28.3	100	86	2.4	3.9	26.1	98	86	2.2	3.4
	Karanai	21.8	73	91	2.1	2.6	27.3	89	96	1.6	1.7
	Melakuppam	25.7	100	57	3.2	7.1	26.0	96	96	2.5	3.4
	Murukkeri	23.8	89	76	2.4	3.2	25.0	75	67	1.5	1.9
	Tottanaval	26.6	94	100	2.8	3.8	25.0	100	83	2.2	2.4
	Vengunam	27.5	100	94	2.0	2.0	29.2	100	100	0.5	2.3
KR	Total	22.9	93	87	2.4	3.6	24.9	94	90	1.8	2.7
	Grand Total	**33.5**	**94**	**84**	**2.0**	**2.5**	**35.8**	**93**	**85**	**2.0**	**2.5**

Source: Derived from Annexures 3, 4 and 5.

Across villages, there is a weak association between average depth and area irrigated in the case of punjai wells. In the case of nanjai wells a similar association is noticeable in the 4 upper reach segments. Conditions in the lowest two reaches are different: though wells are shallower, area irrigated per well is relatively high. Significantly, there seems to be a positive, though weak, association between the extent of area served by the two categories of wells across villages. This suggests that climate, geology, and location have similar effects on groundwater conditions.

Gross irrigated area per nanjai well, (without taking into account differences in crop duration or water intensity), is the same or 10-15 per cent more than net irrigated area in villages of the 3 upper reach segments. This index is considerably higher in the lower reaches being the highest in the tail end segment (Kiliyar)(Table 21).

Gross irrigated area per punjai well is lower than per nanjai well in a large majority of villages. While variations across zones follow a broadly a pattern similar to that observed in nanjai wells, the ratio of gross to net irrigated area is both higher and shows a much steeper rise from upper to lower reaches than in the case of nanjai wells (Table 22).

Table 22 Crop Pattern on Nanjai and Punjai Wells by Zone

Zone	Percentage of gross irrigated area (adjusted) by categories of wells							
	Nanjai				Punjai			
	Paddy	Annual crops[1]	Trees[2]	Other Seasonal	Paddy	Annual crops[1]	Trees[2]	Other seasonal
UP	12.9	36.8	29.0	21.3	1.7	37.3	35.9	25.0
KI	36.9	21.2	33.8	8.1	7.9	9.6	28.9	53.6
UC	73.1	10.3	3.0	13.5	37.7	4.2	4.6	54.5
LC	56.5	28.8	—	14.6	25.6	16.5	9.5	48.5
LP	75.2	4.4	3.7	16.7	52.7	7.0	—	83.6
KR	91.2	5.6	2.2	1.0	35.3	5.1	4.0	55.6
Total	**65.0**	**14.1**	**10.3**	**10.6**	**27.6**	**11.2**	**12.2**	**49.1**

Note: 1=Sugarcane and Banana. 2.Coconut and other trees
Source: Reconstructed from Annexure 6.

Crop Patterns: That the cropping pattern varies greatly between nanjai and punjai wells across all zones that are evident from Table 22. Several features are noteworthy. In the case of nanjai wells, the proportion of gross irrigated area (as conventionally measured) growing paddy and other seasonal crops in the Upper Palar zone is relatively low, nearly two thirds of the area is used to raise sugarcane, banana, coconut and trees. This pattern changes progressively and in a

striking manner towards the lower reaches of the basin (except for Lower Cheyyar): the proportion devoted to annuals and permanent trees falls sharply to negligible levels in the tail end, even as that of paddy increases to nearly 90 per cent in the tail segment. As between annual crops and permanent trees, the latter are very prominent in the two uppermost zones and are negligible in others.

The proportion of area irrigated by Nanjai wells devoted to other seasonal crops is highest (21 per cent) in Upper Palar and the least in Kiliyar. In between the proportion increases from less than 6 percent in Kamandalanadhi to nearly 20 percent in lower Palar. In the case of punjai wells Upper Palar reports nearly 70 percent of area under long duration crops divided roughly equally between annuals and tree crops; the proportion is also high in Kamandalanadhi (over 40 percent) and in Lower Cheyyar (28 percent). In all others this group of crops accounts for less than 10 percent of the crop area.

Paddy figures less prominently in punjai well crop pattern than under nanjai wells in all zones, but as in nanjai increases towards lower reaches of the basin. Seasonal crops other than paddy are far more prominent accounting for 28 per cent to over 50 per cent of gross irrigated area. But there is no clear or consistent pattern in this respect across zones. Progression across zones is not as pronounced or consistent as in Nanjai lands.

Variations in Cropping Intensity: These differences evidently reflect adaptations to variations in the quantum and reliability of water supplies from surface sources and wells in nanjai lands and from wells in the case of punjai land. Nanjai lands are likely to have access to more water and can therefore grow more of paddy (water intensive crop) and perennials that need more water through the year. Lands dependent wholly on wells evidently do not have adequate water to sustain water intensive paddy or perennials on the same scale as nanjai wells.

The above, conventional measure of gross irrigated area does not allow for differences in the duration between planting and harvesting of different crops and their water requirements. Annual crops (like sugarcane and banana) and trees occupy the land for most or all of the year and need more water than seasonal crops. Trees, being deep rooted do not need as much irrigation as the annual cops. All cereals, pulses, cotton and oil seeds and vegetables are seasonal crops. But they differ in terms of water requirements: paddy is much more water intensive than others; and crops grown during the dry season need more irrigation than in the rainy season.

A proper measure of cropping intensity must therefore allow for differences in the duration and water requirements of different crops. When the index of intensity adjusted for duration perennials (taking 1 acre of perennial = 3 seasonal acres), as can be seen from **Table 23**, the picture changes dramatically: Adjusted cropping intensity is everywhere much higher than the conventional measure. The pattern of variation in "cropping intensity" across zones is also different: In fact there is an inverse relation between the conventional and adjusted index. Which means that areas with high intensity by the conventional measure tend to have low intensity when adjusted on the basis of season acres.

Table 23 Cropping Intensity Adjusted and Unadjusted on Well Irrigated Areas by Zones

Zone	NANJAI GIA/NIA			PUNJAI GIA/NIA		
	GIA adjusted	CI adjusted	Un-adjusted	GIA adjusted	CI-adjusted	Un-adjusted
UP	134.3	105	247	194.5	105	259
KI	142.2	105	220	198.6	112	213
UC	215.0	115	146	446.8	131	156
LC	64.9	110	172	172.5	120	185
LP	162.4	131	155	99.9	136	161
KR	311.2	144	167	350.3	148	173
Basin	1030.0	121	181	1462.6	126	188

Source: Derived from Annexure 7.

Factors Underlying Variations: Variations in cropping intensity by either definition are the result of three interacting factors: (1) moisture deficit – or irrigation requirement; (2) crop patterns; and (3) water availability in irrigation sources during the three seasons.

Required Moisture deficit - computed as the difference between evapo-transpiration and rainfall – gives a rough measure of irrigation requirements for crops **(Table 24)**. In the Palar basin in Season I, which has both rainfall and tank storage are relatively low, irrigation requirements are high. In season II, though the evaporation is less, the monsoon is active, and total rainfall exceeds evaporation, crops (especially paddy) often need irrigation to tide over long dry spells. The requirement in the 3rd season, when there is little rainfall and evaporation (about twice that in season I) is the highest.

Table 24 Moisture Deficits (in mm)* for Crops in Different Seasons in the Palar Basin

Name of District	Season I (June-Sep)	Season II (Oct-Jan)	Season III (Feb-May)
North Arcot	475	- 19	675
Chengalpet	366	- 82	721

Note: *potential evaporation less rainfall computed from Table (5).

There is a substantial difference in this respect between upper and lower portions of the basin reflecting differences in levels of precipitation and evaporation across seasons. Compared to the lower half of the basin, the deficit in the upper half is higher by about 30 per cent in the 1st season but marginally (6 percent) lower in the third season.

The area that can be irrigated in different seasons obviously depends on water availability. In nanjai lands, groundwater being a supplementary source, the availability of water in wells is less crucial for irrigated cropping than in punjai lands. However, in both categories there are significant seasonal variations in availability and this is reflected in the nature and extent of irrigation in different seasons.

It is noteworthy that in all zones and in both categories of wells the area under crops is highest in the first season. During this season rainfall is moderate, as is the moisture deficit; tank storage is low and therefore dependence on wells for irrigation is high. In season II, when rainfall exceeds evapo-transpiration, the need for well irrigation for seasonal crops is limited in nanjai lands. Water intensive crops on both categories of land need irrigation in this season. Consequently their extent, especially on punjai lands, will be constrained by groundwater supply. Cropping in season III, when there is little rain and evaporation is high, the extent and nature of crops depends crucially on water availability in tanks and wells.

The effect of these factors is reflected in the progressive reduction of area irrigated from season I to Season III in all zones and both categories of wells. This tendency is however not uniform between the two categories of wells or between regions. In nanjai wells, it is more pronounced in Upper Cheyyar, Upper Palar and Kiliyar than in others. A similar pattern is observed among punjai wells as well. Notably however, in the tail reach zone, this tendency is less pronounced under punjai wells than under nanjai wells **(Table 25)**.

Table 25 Area Irrigated in Different Seasons by Zones (acres)

Zone	Nanjai			Punjai		
	Area Irrigated in			Area Irrigated in		
	Season I	Season II	Season III	Season I	Season II	Season III
UP	127.3	94.4	92.4	185.5	148.0	146.0
KI	135.8	84.7	78.2	176.6	101.0	98.2
UC	186.6	52.6	33.1	341.9	129.8	60.6
LC	58.9	23.8	18.8	123.0	95.8	47.9
LP	124.4	53.0	15.0	73.4	35.5	9.0
KR	216.7	102.0	43.5	237.3	134.2	38.9

Source: Derived from Annexure 8.

Crop patterns, especially the area under water intensive crops, make a significant difference to irrigation requirements. There are marked differences in this respect too across zones and the two well categories **(Table 26)**. The composition of irrigated crops also varies across zones and season: Under nanjai wells paddy accounts for a higher proportion of irrigated area in season I than in other seasons; on the other hand the proportion of area under perennials increases progressively from season I to season III. Except in tail end zone (Kiliyar), practically the entire crop area irrigated by wells in the third season is under perennial crops.

Table 26 Percentage Distribution of Area Irrigated under Different Crops and Seasons

Zone	Nanjai												Punjai											
	Season I				Season II				Season III				Season I				Season II				Season III			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
UP	13	40	31	17	1	53	41	4	0	55	42	3	2	39	38	21	0	49	47	4	0	50	48	2
KI	36	22	35	6	4	36	57	4	0	38	62	0	8	15	32	44	1	27	57	15	0	28	58	14
UC	74	12	3	10	32	42	12	13	4	67	20	0	37	6	6	51	25	16	16	43	10	35	34	21
LC	59	30	0	11	8	79	0	13	0	100	0	9	29	25	13	32	5	32	17	46	6	60	34	0
LP	83	6	5	6	32	17	11	37	0	60	40	0	60	8	0	32	20	21	0	59	17	83	0	0
KR	89	9	2	0	71	18	8	3	41	40	18	0	47	8	6	39	6	13	10	70	9	46	36	9

Note: 1. Paddy
2 Annual crops sugarcane and banana
3. coconut and trees
4. other seasonal crops.

Source: Derived from Annexure 8.

This pattern shows how cropping is adjusted to water availability. Under nanjai wells, the high proportion devoted to perennials, especially water intensive sugarcane and banana, in the upper most segments and in Lower Cheyyar suggest relative abundance of water in all seasons. In the second season, perhaps because of better tank supply during the monsoon, these segments cut back on the seasonal crop area and use water for irrigating sugarcane and banana.

In other zones, supply from wells, together with tanks, is evidently adequate for extensive paddy cultivation in the first season but not for annual or perennial crops. In the second season available water is used on a smaller area mostly for growing seasonal crops. In the third season, available water is used entirely for perennials. The fact that the tail end zone can grow paddy on half the area suggests an exceptionally favourable supply of water from tanks or wells or both.

In punjai lands, for which wells are the sole source of irrigation, the differences are even more marked. In the two upper most zones, paddy cultivation in punjai wells is very limited in all seasons. Compared to nanjai, the proportion of area devoted to other seasonal crops is much higher in all seasons. But their share in total irrigated area declines sharply from season I to season III. Annual crops and trees account for the major portion of irrigated area. Permanent tree crops (coconut and trees) being irrigation intensive are more prominent than in nanjai.

In other zones paddy and other seasonal crops account for the major part of irrigated area in all seasons with the relative importance shifting to the latter over successive seasons. In season III the bulk of the shrinking irrigated area is under annual and tree crops.

The fact that the reduction in crop area under punjai wells during the second season in most zones is much less than in nanjai wells, and that in several cases the proportion of area under less water intensive seasonal crops increase, suggests that the water available after meeting the requirement of perennials cannot sustain extensive paddy cultivation in the second season. In the third season the decrease in total crop area compared to second is much less pronounced in the two head reach zones and Lower Cheyyar and Kiliyar. This could point to better groundwater conditions in these zones. In others the conditions are clearly less favourable and is reflected in the steep reduction in seasonal crop area.

The average number of watering and the number of hours for which well water is applied bear this out **(Table 27)**. Except in Kiliyar, nanjai wells report the largest number of hours of watering

per acre in season 1 in all zones; they fall sharply in season II (to negligible levels in the upper reach) but revive in the III season. Levels however are lower than in Season I, the difference being more marked in the middle and lower reaches (except KR). There are also significant differences in this respect between crops.

Table 27 Average No. of Hours of Watering per Unit Acre by Season and Major Crops

Zone		Nanjai					Punjai				
	Season	Paddy	Sugarcane	Banana	Coconut & Trees	All Crops	Paddy	Sugarcane	Banana	Coconut & Trees	All Crops
UP	I	217	129	0	73	112	650	94	0	111	87
	II	400	0	0	0	5	0	0	0	0	0
	III	0	129	0	90	118	0	207	312	108	183
	Gross	227	86	0	54	82	650	100	104	73	89
KI	I	197	79	200	25	105	191	94	57	39	55
	II	205	0	0	0	14	296	0	0	0	6
	III	0	69	90	151	121	0	46	122	90	106
	Gross	198	49	97	59	83	202	47	60	43	55
UC	I	150	109	0	0	128	330	61	0	0	148
	II	265	0	0	0	93	250	0	0	0	100
	III	550	80	0	51	92	268	137	192	60	126
	Gross	167	63	0	17	117	308	66	64	20	133
LC	I	296	28	180	0	200	318	37	214	67	127
	II	194	94	0	0	101	147	71	0	0	45
	III	0	94	0	0	66	255	71	0	11	49
	Gross	274	72	60	0	152	278	60	71	26	83
LP	I	140	194	0	0	137	206	40	0	0	141
	II	76	0	0	0	53	82	0	0	0	98
	III	0	0	0	0	0	180	136	0	0	151
	Gross	122	65	0	0	103	166	59	0	0	129
KR	I	89	3	0	0	80	220	21	0	0	117
	II	156	0	0	0	120	75	0	0	0	44
	III	237	128	0	0	178	195	125	0	0	135
	Gross	118	42	0	0	103	174	49	0	0	95
Basin	I	142	93	191	42	116	273	65	39	71	114
	II	155	9	0	0	58	142	15	0	0	42
	III	227	100	47	120	115	232	146	196	87	134
	Gross	148	67	79	54	100	236	75	78	53	97

Source: Derived from Annexure 9.

The pattern is different in punjai wells. In the two upper most zones during season 1 watering is done for more hours or equal to that of nanjai wells, with no watering in season II, and a considerably larger water application in season III. In other zones, again except KR and LP, the pattern is similar to that of nanjai wells with duration of watering declining with season. The watering hours in season II in all these zones are less than in nanjai but equal to or more than nanjai in the three upper reach zones.

Nanjai paddy receives the most amount of irrigation in both 1st and 2nd seasons; in the 2nd season, being rainy, the intensity of irrigation is considerably less. Other seasonal crops get substantial irrigation as do sugarcane and banana but coconut and trees get hardly any. In the second season, again, most of the irrigation goes to paddy and to some extent other seasonal crops. With a few exceptions, annual and perennial crops are not given irrigation. In the third season irrigation is largely limited to these crops.

In punjai wells all crops are irrigated in the 1st season with paddy receiving the most. The intensity of watering is very high, much higher than in nanjai for paddy. The second season irrigation is also concentrated on seasonal crops, the intensity being highest in paddy. Annuals and perennials are not irrigated. In the third season, where paddy is grown the intensity is high but as in nanjai annual crops are widely irrigated and much more intensively than in Nanjai. Perennial crops are irrigated in some but at a much lower intensity.

On the basis of the area irrigated in different seasons, and the respective moisture deficits (PET minus rainfall) we can also get a rough idea of the relative rates of extraction per well across zones: The computations, presented in **Table 28** relate only to punjai wells and indicate the upper limit of volumes used during the first and third seasons (during the second season though, on the average, total rainfall exceeds evaporation, substantial areas are reported to be irrigated. But there is no way to estimate how much water is used). This varies from about 3000 cubic metres per well in use in Lower Palar to over 11000 cubic metres in Upper palar. Apart from Upper Palar, wells in Kamandalanadhi and Lower Cheyyar also yield much more than in other zones.

Table 28 Approximate Estimation of Water Extraction per Punjai Well in Different Zones of Palar Basin

Zone	Area Irrigated (acres)	I Season TIR '000M3	Area Irrigated (acres)	IIISeason TIR '000M3	TIR '000M3 (3+5)	No.of Wells in use	Estimated Extraction per well '000M3
1	2	3	4	5	6	7	8
UP	185	350	146	394	744	56	11.3
KI	177	338	98	265	603	104	5.9
UC	342	650	61	165	815	188	4.3
LC	123	180	48	139	319	52	6.1
LP	73	112	9	26	138	46	3.0
KR	237	347	39	112	460	129	3.6

Assumptions: 1.Crop water requirement in each season = difference between potential evapo-transpiration (PET) and rainfall. 2. The irrigation requirement for upper half of the basin is the rainfall and PET in Vellore; and for lower half in Chengalpet. 3. Irrigation in second season is not included for lack of basis to estimation.

Note: TIR = Total irrigation Requirement.

Source: Survey, 1993.

Water Sale

Well owners were also asked whether they sold any of their well water between 1988 and 1990, extent of area and crop that irrigated and the terms. The data summarized in Table 29 shows the following:

Table 29 Villagewise Water Sales in the Palar Basin

Zone	Village	Category of well reporting sale		No.of years water sold *	No.of farmers water sold	Total extent of sale (acres)	Crops irri-gated	Total no. of hrs. water sold	Amount per hour Cash/ kind	Year of sale	Basis of Payment
1	2	3		4	5	6	7	8	9	10	11
I (UP)	1.Aythampattu	N	-	3	3	4.5	P + C	75	2 + Free	1991	Cash
	2.Somalapuram	N	-	3	1	1.0	Ch+R	140	3	1991	Cash
	3.Vellakkuttai	N	-	1	1	2.0	P	10	kind	1991	1/4 of - buyers crop
II (KI)	4.Athiyur	-	-	-	-	-	-	-	-	-	-
	5.Goodanagaram	-	-	-	-	-	-	-	-	-	-
	6.Pasumathur	-	-	-	-	-	-	-	-	-	-
	7.Perumugai	N	-	3	2	17.0	P	90	5	88-91	Cash
		-	P	3	1	1.0	P	10	0	1991	Free
III (UC)	8.Arasanganni	-	-	-	-	-	-	-	-	-	-
	9.Chengam	-	-	-	-	-	-	-	-	-	-
	10.Kattuputhur	-	-	-	-	-	-	-	-	-	-
	11.Kayampattu	-	-	-	-	-	-	-	-	-	-
	12.Namatodu	-	-	-	-	-	-	-	-	-	-
	13.Thukkapettai	N	-	3	1	3.0	P	1200	kind	1991	1/5 of - buyers crop
IV (LC)	14.Ayilam	-	-	-	-	-	-	-	-	-	-
	15.Mariyanallur	-	P	1	1	0.5	Gnut	2	Free	1990	Nil
	16.Vilari	-	-	-	-	-	-	-	-	-	-
V (LP)	17.Agaram			-	-	-	-	-	-	-	-
	18.Brammadesam	-	P	1	1	1.0	P+Gnut	110	kind	1991	1/4 of - buyers crop
	19.Kunnavakkam	-	-	-	-	-	-	-	-	-	-
	20.Uttukkadu	-	-	-	-	-	-	-	-	-	-
	21.Vallabakkam	N	-	1	1	0.7	P	6	25	1991	Cash
VI (KR)	22.Echoor			-	-	-	-	-	-	-	-
	23.Karanai	N	-	2	3	5.5	P+Gnut	47	10 + Kind	1991	1/4 of - buyers crop
	24.Melakuppam	-	-	-	-	-	-	-	-	-	-
	25.Murukkeri	-	-	-	-	-	-	-	-	-	-
	26.Tottanaval **	N	-	3	1	1.0	P	45	NA	1991	NA
	27.Vengunam	N	-	3	1	2.0	P	300	kind	1991	1/5 of - buyers crop

Note: * indicates details on water sale enquired during the period 1988-89 to 1990-91. NA = Not Available. – indicates nil.

In Aythampattu, cash payment is very flexible. Two farmers sold water free of cost while one farmer levied Rs.2 per hour. P = Paddy. G.nut = Groundnut. C = Coconut. Ch = Cholam. R = Ragi.

Source: Survey, 1993.

Water sales from nanjai wells were reported in 9 of the 27 villages. All three villages in the Upper Palar and 3 of the five villages in Kiliyar reported sales and all these six reported sales in all three years. Only three villages –one each in Kamandalanadhi, Lower Cheyyar and Lower Palar- reported sales from punjai wells. Of these two reported sales in one of the three years and the third for all three years. The number of farmers reporting sale is very small: 12 in nanjai (out of a total of 416 wells in use) and only three in punjai (out of 585 in use). The total area irrigated by the water sold is estimated at 34 acres of nanjai and 2.5 acres in punjai.

Number of hours of water sale is limited to less than 150 hours in all the zones except the two, UC and KR. In the former zone a maximum of 1200 hours of water sale is reported and in the latter it is 300 hours. It may be noted that due to this larger number of hours of purchase of water the payment to the sellers is restricted to one fifth of buyers crop yield. Water sold is reported to be used mainly for paddy in the case of nanjai wells and paddy and groundnut in punjai wells. Rates and modes of payment Vary: In 1991, four villages reported hourly rates in cash; five in kind and three for free. Kind payments is usually in terms of a share in the crop grown by water purchased from the well owner, one-fifth in two cases and one-fourth in three. It is apparent that water markets do not exist in most villages and where they do they are extremely limited in scope and extent.

Characteristics by Size of Holding

Between 30 and 45 per cent of nanjai wells and 25 to 42 per cent of punjai wells are owned by farmers with less than 2.5 acres. Those with less than one acre account for less than 10 per cent of well owners in most cases. Over 80 percent of all nanjai wells and over 60 per cent of all punjai wells and in some cases more than 90 per cent are with those owning less than 5 acres. The proportion of punjai wells owned by larger farmers (>5 acres) is higher than in Nanjai in 3 zones, but lower in others. The share of large land owners in nanjai well ownership is relatively high in Kamandala Nadhi, Lower Cheyyar, and Kiliyar. In punjai wells, this feature is more noticeable in Upper Palar, Lower Cheyyar and Lower Palar **(Table 30)**.

In most zones and in both categories of wells, the number of wells per acre of land owned declines as holding size increases. Larger farmers tend to have fewer wells per acre relative to the area they own. The relation between current holding size and current mean depth of wells shows a mixed picture: In some zones mean depth increases with holding size but in varying degrees. In some others there is no clear or sustained relation between the two. The average horsepower per nanjai well shows no systematic relation to holding size in most zones. In

punjai wells, however, there is a positive relation between the two in four zones. There is some indication that depth and horsepower are positively correlated in nanjai wells but not in punjai wells.

Table 30 Distribution of Area Irrigated per Well under Nanjai and Punjai Holdings (area in acres)

Zone	<1	1.01-2.5	2.51-5	5.01-7.5	>7.5	N Total	<1	1.01-2.5	2.51-5	5.01-7.5	>7.5	P Total
	Nanjai Wells						Punjai Wells					
UP Well/Acre (Land owned)	0.97	0.53	0.27	0.17	0.08	0.30	1.00	0.50	0.30	0.17	0.07	0.23
Area Irri./Well (S1Area)	3.07	1.40	2.54	6.00	3.43	2.27	2.20	2.05	2.11	5.75	5.72	2.81
Area Irri./Well (Gross Area)	6.58	3.31	6.04	18.00	10.28	5.61	4.56	5.26	4.90	14.75	17.17	7.26
Area Irri./Well (Adj.Gr.Area)	3.58	1.40	2.75	6.00	3.43	2.40	2.20	2.13	2.11	5.75	6.50	2.95
KI Well/Acre (Land owned)	1.09	0.55	0.24	0.17	0.06	0.25	1.25	0.55	0.27	0.16	0.09	0.32
Area Irri./Well (S1Area)	0.77	1.34	2.70	2.50	2.67	1.86	2.19	1.12	1.71	2.13	6.13	1.70
Area Irri./Well (Gross Area)	1.55	2.26	6.40	5.50	8.00	4.09	3.57	2.18	3.87	4.38	15.88	3.61
Area Irri./Well (Adj.Gr.Area)	0.77	1.43	2.85	2.67	2.67	1.95	2.74	1.13	2.04	2.13	7.08	1.91
UC Well/Acre (Land owned)	1.30	0.54	0.28	0.15	0.10	0.34	1.05	0.50	0.29	0.16	0.10	0.33
Area Irri./Well (S1Area)	0.75	1.38	2.00	3.70	4.00	1.74	1.23	1.34	2.11	3.06	3.91	1.82
Area Irri./Well (Gross Area)	1.03	1.96	2.84	6.90	5.60	2.54	1.54	1.92	3.12	5.56	8.64	2.83
Area Irri./Well (Adj.Gr.Area)	0.74	1.69	2.28	4.10	4.40	2.01	1.40	1.66	2.97	3.06	5.73	2.38
LC Well/Acre (Land owned)	1.00	0.50	0.29	0.16	0.08	0.21	0.00	0.58	0.26	0.15	0.06	0.16
Area Irri./Well (S1Area)	4.00	2.65	2.76	2.67	1.12	2.56	0.00	2.04	2.14	2.06	2.83	2.36
Area Irri./Well (Gross Area)	4.00	5.70	3.67	7.50	1.45	4.41	0.00	5.43	5.15	3.96	4.11	5.12
Area Irri./Well (Adj.Gr.Area)	3.00	2.65	3.12	3.17	1.45	2.82	0.00	2.38	3.20	3.18	4.06	3.32
LP Well/Acre (Land owned)	1.00	0.46	0.25	0.14	0.08	0.22	1.11	0.42	0.27	0.17	0.11	0.26
Area Irri./Well (S1Area)	0.00	1.16	2.35	1.85	2.08	1.86	0.08	1.17	1.67	2.60	1.83	1.59
Area Irri./Well (Gross Area)	0.00	1.85	3.66	2.23	3.75	2.87	0.08	1.67	2.67	4.20	3.83	2.56
Area Irri./Well (Adj.Gr.Area)	0.00	1.28	3.08	2.23	3.75	2.42	0.08	1.31	2.11	4.20	3.83	2.17
KR Well/Acre (Land owned)	1.00	0.54	0.26	0.18	0.06	0.14	1.11	0.55	0.27	0.17	0.07	0.19
Area Irri./Well (S1Area)	1.67	1.53	1.93	3.64	3.41	2.41	2.00	1.38	1.79	1.71	2.65	1.84
Area Irri./Well (Gross Area)	3.00	1.98	3.19	6.32	6.22	4.02	2.00	2.21	3.42	2.76	4.73	3.18
Area Irri./Well (Adj.Gr.Area)	2.00	1.98	2.85	4.77	5.30	3.46	2.00	2.16	2.72	2.45	3.85	2.72
Basin Well/Acre (Land owned)	1.13	0.53	0.26	0.16	0.06	0.22	1.08	0.52	0.28	0.16	0.07	0.25
Area Irri./Well (S1Area)	1.30	1.40	2.29	3.08	3.07	2.04	1.69	1.41	1.93	2.47	3.53	1.94
Area Irri./Well (Gross Area)	2.35	2.33	4.07	6.13	6.11	3.70	2.59	2.59	3.66	4.79	7.81	3.73
Area Irri./Well (Adj.Gr.Area)	1.39	1.61	2.76	3.65	4.29	2.48	1.88	1.71	2.60	3.07	4.80	2.50

Source: Derived from Annexure 10.

On the average, the proportion of area owned by sample well owners, which is served by wells in season I, varies between a third and 70 per cent across the zones. In each zone this proportion, and the pattern of inter-zonal variation, is roughly the same for nanjai and punjai wells. In most zones, and in both categories of wells, the proportion of owned area irrigated by wells tends to

fall as holding size increases. An interesting feature is that in three zones area irrigated in season I is larger than the area owned in the case of farmers owning less than one acre. This pattern is also noticed in the case of punjai wells – all of them in the upper half of the basin. It suggests that in several areas, well owners with very small land holdings either lease in extra land for using the well water or may be sharing it with others (as we have seen that sales are not significant).

Net area irrigated per well is generally more in large holdings (more than five acres) compared to that in small holdings (less than 2.5 acres). In punjai wells, net irrigated area per well increases progressively with holding size in five zones. A similar pattern is also noticeable in the gross irrigated area per well, it being more consistent and widespread when differences in the extent of perennial crops are taken into account. This suggests that lower well density on larger holdings is offset to some extent by larger water supplies. These tendencies are, however, more pronounced in the upper segments of the basin where the cropping intensities and the incidence of perennial and annual crops is markedly higher than in the lower half.

The relation between indicators of water use on the one hand and depth and horsepower on the other, based on simple multiple regressions, are set out in **Table 31**. There is a significant positive correlation across selected villages between mean depth and mean horsepower per well in use. The area irrigated per well (net area, gross adjusted and gross unadjusted) seems to depend more on the horsepower of pumps than well depth. Both depth and horsepower have a significant bearing on adjusted cropping intensity; deeper wells tend to have lower cropping intensities while more powerful pumps tend to increase cropping intensity. Unadjusted cropping intensity on the other hand seems to depend on depth and not on horsepower of the pumps.

Table 31 Relation between Mean Depth of Wells and Mean Horsepower of Pumps on Water Use Across Villages[1] in the Palar Basin

Dependent Variable	**R^2**	**Regression Coefficient %**	
		Mean Depth	**Mean Horsepower**
Net Irrigated Area	0.182	-ns	0.64^{xxx}
Gross Irrigated Area Adjusted	0.339	-ns	3.60^{xxx}
Gross Irrigated Area Unadjusted	0.248	+ns	1.78^{xxx}
Cropping Intensity Adjusted	0.239	-0.02^{x}	0.22^{xxx}
Cropping Intensity Unadjusted	0.356	$+0.18^{x}$	+ns

Note: 1 = Across 27 villages.
Correlation coefficient between depth and horsepower = 0.649. Significant at 1 %.
X Significant at 5-10% , XX Significant at 1-5 %, XXX Significant at 1 %

Net irrigated area as a proportion of area owned is generally higher in Nanjai wells and tends to fall as the holding size increases. The variations in this respect across size of holdings are less marked and the inverse relation between size and extent of irrigation does not hold in all zones. The relation between current size of holding and current well depth **(Table 32)** shows a mixed picture: In some zones mean depth shows a tendency to increase with holding size but in varying degrees; there is no clear or sustained pattern in others. Horsepower of pumps has no systematic relation to farm size in nanjai wells in most zones; in punjai wells there is a positive relation between the two in 4 zones. There is some indication that depth and horsepower are positively correlated in nanjai but not in punjai wells.

Thus the survey data provide some, but not strong, corroboration for the belief that larger the farm, the greater the command over resources for investment and therefore deeper wells and more powerful pumps. This, and the weak association between depth and horsepower, suggests that variations in these respects are not solely a function of farm size; other factors like subsurface geology are probably as important.