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Projections of Irrigated Acreage and Water Requirements for Western Water Resource Regions*

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As a result of the effort generated by the Senate Select Committee on National Water Resources the Nation, and the West in particular, is no longer faced with even a potential shortage of regional irrigation acreage and water requirement projections.[1] Whether by 1980, or by the end of the century, the Nation, or the West, will experience a shortage of irrigated land and/or irrigation water is not obvious in spite of the extremely valuable work completed thus far by the Committee and by the agencies which have contributed the data and analysis which appear in the Committee reports.

In this progress report an attempt is made to use aggregate regional production functions computed for the water resource regions identified by the Select Committee to provide tentative answers to several questions that deserve consideration as the Nation proceeds toward the levels of development and utilization projected in the Committee reports. These questions include: First, how does the marginal productivity of irrigated land vary among the several Western Water Regions under 1954 conditions. Second, how do these marginal productivities compare with current

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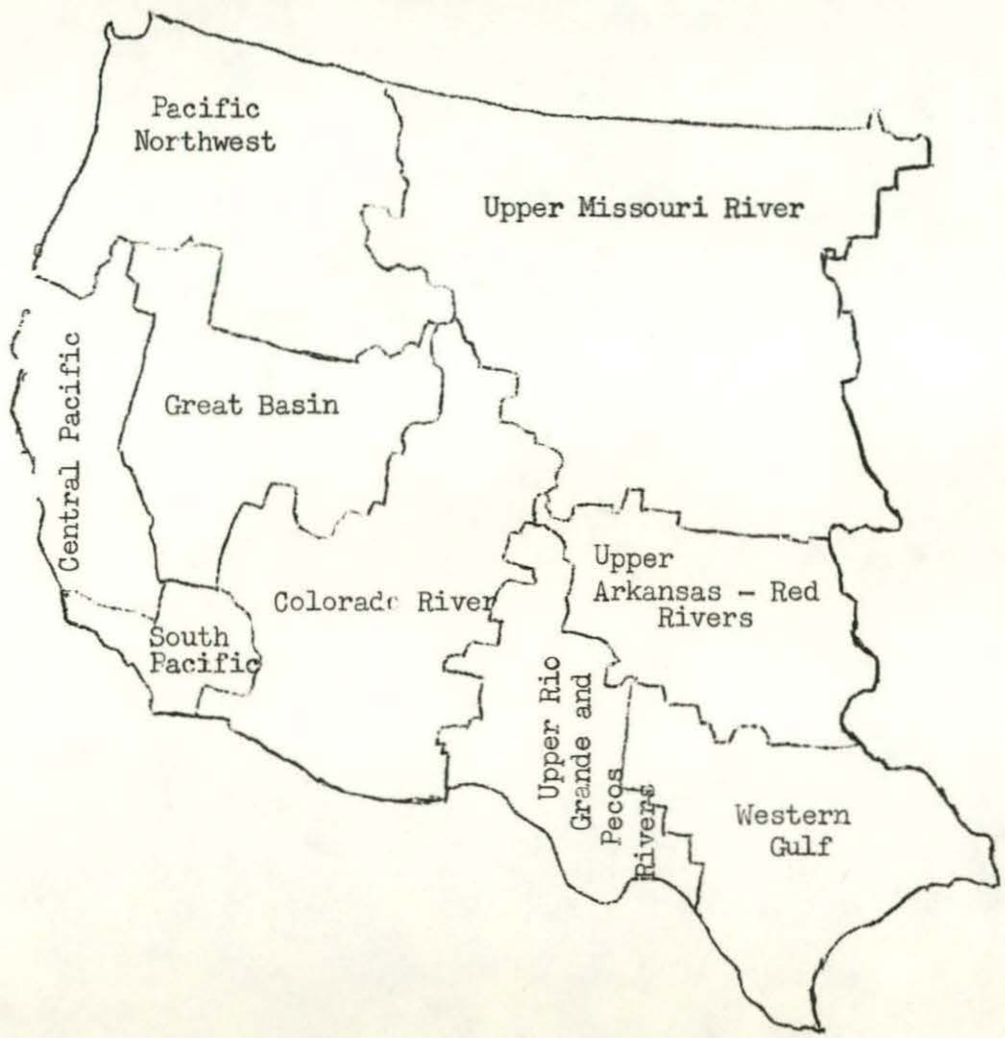
Figure 1

Western Water Resource Regions



and projected costs to farmers and/or to society that will be incurred in bringing the projected irrigated land into production. Third, how will the 1954 marginal productivities be modified as national and regional farm output expands and additional irrigated land is brought into production between now and 1980? Finally, there is a brief comment on the problem of moving from projections of irrigated acreage to projections of irrigation water requirements.

I. Output expansion, technological change and resource utilization in American Agriculture.

Rather than proceed directly to the issues posed by these questions I would like to briefly sketch some of the findings regarding the interrelationships among output expansion, technological change and resource utilization in American agriculture that have emerged out of recent research.[2] This should provide a common historical perspective on which to base a discussion of the questions identified above.

The contribution of technological change to the output explosion in American agriculture during the last decade has attracted increasing attention. The dramatic nature of these changes is emphasized when one recalls the discussion of the early 1950's which centered around the problem of meeting farm output requirements during the period 1950-75. We were warned, in the report of the President's Water Resources Policy Commission[3] that the equivalent of 100 million acres of cropland would have to be added to meet 1975 farm output requirements and that two thirds of this increase would have to come from resource development activities such as irrigation, flood protection, drainage and land clearing if we were to fill, in the Department of Agriculture's terminology, the "fifth plate"[4] resulting from population growth. By 1958 farm output had risen almost 25 percent above the 1950 level. When the 1960 farm output figures become available they will indicate that we have already filled the "fifth plate" and are on our way toward filling the sixth.

The changes in resource combinations used to produce this increase in farm output have been as dramatic as the increase in output itself.

- Between 1953 and 1958 crop acreage - mainly wheat, cotton, corn and rice acreage - was reduced by almost 30 million acres by the acreage allotment and soil bank programs. Agriculture as a whole was using approximately 5 percent fewer land inputs in 1958 than in 1950.[5]

- Labor inputs declined by more than one fourth between 1950 and 1958.

- Inputs of capital and current operating expenses rose sufficiently to approximately offset the decline in land and labor inputs, thus leaving total inputs essentially unchanged.

The experience of the 1950's is in sharp contrast to the period prior to the mid 1920's. Prior to the mid 1920's most of the year to year increases in farm output came from using more inputs. In the period prior to 1899 land and labor accounted for a major share of these increased inputs. Between 1899 and the mid 1920's increased capital inputs accounted for a major share of the output growth in agriculture. Since the mid 1920's, however, technology - in the form of skilled management and more productive capital inputs and current operating expense items - has been progressively substituted for resource inputs until during the decade of the 1950's, new technology has been substituted for resources at a sufficiently rapid rate to account for the entire increase in farm output.[6]

Current population and per capita income projections imply a growth in the demand for farm products of 40-50 percent between 1960 and 1980. If technological change continues at the level maintained during the decade of the 1950's it seems likely that the 1980 farm output will be produced with 40-50 percent less labor; around 25-30 percent more capital, a 50-60 percent increase in current operating expenses, and a further decline in land inputs of 5-10 percent.[7] These output and input changes are expected to occur with no rise in farm prices relative to the general price level. Indeed, there is ample basis for anticipating lower real prices of farm products in 1980 than at present if serious attempts are made to eliminate existing surpluses and shift agriculture to a free market basis.[8]

I will now proceed to discuss the specific questions which relate to the contribution which irrigation can make to resource utilization and output growth in the environment outlined above.

II. Regional Variations in Factor Marginal Productivities

As a first step in estimating the marginal productivity of irrigated land aggregate regional production functions[9] of the Cobb-Douglas form ($X_o = A \sum X_i^{a_i}$) were estimated by ordinary least squares procedures[10] from county data for eight Western Water Resource Regions.[11] The resulting resource productivity coefficients (presented in Table A-1) were then employed to compute marginal productivity estimates $\left[(MP_{X_i} = (X_o/X_i)a_i\right]$ for irrigated cropland and other inputs.

The results, computed at both the geometric and arithmetic means and using the productivity coefficients from both equations (2) and (3) are presented in Table 1.[12] Although major interest in this paper is on the productivity of irrigated land marginal productivity estimates for three other factor inputs-labor, non-irrigated cropland, and current operating expenses - are also presented.

Several generalizations are suggested by the data presented in Table 1.

1. The marginal productivity estimates for the four factor inputs tend, with some important exceptions, to be reasonably similar at both the arithmetic and the geometric means and when estimated from the coefficients of either equation (2) or (3). Close agreement between the marginal productivities estimated at the arithmetic and geometric means reflects similar factor-factor and factor-product ratios in large and small counties. Close agreement between the estimates based on equations (2) and (3) reflects a lack of major specification bias in the productivity coefficients as between these two equations. We are particularly concerned with achieving close agreement among the several productivity comparisons for irrigated land and current operating expenditures since, at a later stage in the analysis, regional output and the inputs of these two factors will be projected from arithmetic mean levels and aggregated to form regional totals.

2. The marginal productivity of labor is relatively high in the three southwestern (Central Pacific, South Pacific, and Colorado River) and two northern (Pacific

Table 1. Factor Marginal Productivity Estimates for Western Water Resource Regions, 1954.

Region and equation		All farm workers geometric mean (dollars/year)	All farm workers arithmetic mean (dollars/year)	Irrigated land geometric mean (dollars / acre)	Irrigated land arithmetic mean (dollars / acre)	Non-irrigated cropland geometric mean (dollars / acre)	Non-irrigated cropland arithmetic mean (dollars / acre)	Current Operating Expenses geometric mean (dollars / dollars)	Current Operating Expenses arithmetic mean (dollars / dollars)
Pacific North-									
west	(2)	1,389.82	1,429.04	67.21	60.53	53.06	31.32	2.52	2.06
	(3)	1,413.14	1,453.02	77.41	69.71	53.80	31.76	2.75	2.25
Central Pacific									
	(2)	1,527.65	1,603.21	61.61	49.10	101.17	112.46	3.77	3.71
	(3)	1,593.48	1,672.29	57.23	45.62	95.69	106.37	3.56	3.50
South Pacific	(2)	n.a.	2,259.45	n.a.	89.43	n.a.	*	n.a.	1.98
	(3)	n.a.	2,287.73	n.a.	93.29	n.a.	*	n.a.	2.15
Colorado River	(2)	n.a.	1,658.66	n.a.	26.27	n.a.	*	n.a.	4.38
	(3)	n.a.	1,679.42	n.a.	27.40	n.a.	*	n.a.	4.78
Great Basin	(2)	*	*	*	*	*	*	*	*
	(3)	*	*	23.26	37.03	*	*	*	*
Upper Rio Grande									
and Pecos	(2)	903.35	902.26	54.57	56.29	*	*	3.13	3.20
	(3)	927.67	926.56	51.42	53.04	*	*	3.64	3.71
Western Gulf	(2)	393.76	308.[illegible]	193.75	117.81	40.10	23.62	2.66	1.74
	(3)	393.17	307.52	193.71	117.78	40.09	23.62	2.68	1.75
Upper Arkansas	(2)	793.90	580.22	87.38	92.24	15.24	12.46	3.82	2.51
	(3)	827.83	605.02	87.20	92.05	15.09	12.35	3.43	2.26
Upper Missouri	(2)	*	*	60.26	69.01	7.92	4.26	*	*
	(3)	*	*	66.83	76.53	7.55	4.06	*	*

n.a. - Marginal productivity estimates at the geometric mean are available only for the combined South Pacific and Colorado River regions. A single production function was computed for these two areas since the limited number of counties in the South Pacific region (9) did not permit separate estimation.

* - Indicates that the coefficient for this variable was rejected because the coefficient (a) is small relative to its standard error, (b) is negative or (c) is clearly subject to substantial specification bias.

Northwest and Upper Missouri) water resource regions and relatively low in the three southern (Upper Rio Grande and Pecos, Western Gulf, and Upper Arkansas - Red) water resource regions. These variations are consistent with regional variations in farm wage rates.13/

3. The marginal productivity of current operating expenses - primarily fertilizer and purchased feed - typically exceeds $2.00 per dollar spent. Even when consideration is given to the incorporation of the specification bias which this variable appears to pick up in some areas when the machinery investment variable is dropped from the equation and some discounting due to weather and price uncertainty it appears, in most of the Western Water Resource Regions, that the possibility exists for substantially increasing output and returns on existing acreage by increasing current operating inputs.

4. The marginal productivity of non-irrigated cropland was negative or not significantly different from zero in the major desert areas of the West (South Pacific, Colorado River, Great Basin, and Upper Rio Grande and Pecos) in 1954. This is consistent with water shortages in these regions in the early 1950's.14/ The estimates for the other water resource regions appear reasonable except in the Central Pacific Region where the estimated marginal productivity of non-irrigated cropland appears unreasonably high.

5. Marginal productivity of irrigated land is highest in the South Pacific, Western Gulf and Upper Arkansas-Red water resource regions. It is lowest in the Great Basin, Colorado River, Upper Rio Grande and Pecos regions with the estimates for the Upper Missouri, Pacific Northwest and South Pacific falling between the other two groups.

The high marginal productivities of irrigated cropland in the Western Gulf and Upper Arkansas appear to be related to the low labor productivity in these two regions. In these regions, where the ratio of labor to land inputs is relatively high, it is reasonable to expect that irrigated land, which in effect expands land inputs relative to labor inputs, should have a relatively high marginal productivity.

III. Comparison of Irrigation Cost and Productivity Estimates.

The marginal productivity estimates for irrigated land, when combined with data on the cost of adding additional acres of irrigated land, provide useful guides for public planning. It seems reasonable to expect that farmers will typically be willing to contract for the purchase of water and undertake the investment costs required to bring new irrigated land into production only if the annual marginal productivity of irrigated land and associated inputs approximates or exceeds the annual charges incurred in bringing the land into production and producing a crop. It can also be argued under certain assumptions that, regardless of the charges that are made by public agencies for water which they supply farmers for irrigation use, the annual marginal productivity of the irrigated land should approximate the sum of annual costs per acre incurred by public and private agencies in bringing the land into production and producing a crop. This procedure is the reverse of that frequently used in evaluating public resource investment where the benefit stream is discounted and compared to investment cost. In this analysis investment cost is amortized and the annual cost stream compared to annual benefits.[15]

A comparison of annual irrigation cost and productivity estimates for the 9 Western Water Resource Regions are presented in Table 2. The productivity estimates are from Table 1. Two cost estimates are presented. The first, identified as estimated current annual water charges and associated costs, represents an estimate of average annual water charges and associated costs, exclusive of labor and current operating expenses, incurred per acre of irrigated land in each Western Water Resource Region in the mid 1950's. Labor and current operating expenses are omitted from the cost side since their impact on output is incorporated separately in the production functions. Land costs are based on dry cropland values on the assumption that this represents the opportunity cost of irrigated cropland (See Table A-4 for details). The second cost estimate , identified as projected amortization and associated costs on potential Federal projects, were obtained by adjusting the costs upward to account for the higher water costs on the potential new projects identified by the Bureau of Reclamation in their report to the Select Committee (See Table A-5 for details). The substantial difference between the two estimates are based on lower costs of past than projected project and development costs, lower costs of non-Federal than Federal projects, interest subsidy, the basin account device and others.

In two regions - the Western Gulf and Upper Arkansas and Red - the marginal productivity of irrigated land exceeds the projected amoritization and associated costs on potential federal projects. In four others the Upper Rio Grande and Pecos, the Great Basin, the Pacific Northwest and the Upper Missouri - it falls between the two cost estimates. And in three regions - the Colorado River, South Pacific, and Central Pacific the estimated marginal productivity of irrigated land falls below both cost estimates. It seems likely that, in the immediate future at least, the highest returns on public and private investment in irrigation development will typically be obtained in the first two regions.

Table 2. Comparison of Irrigation Cost and Productivity Estimates for Western Water Resource Regions.

	Marginal productivity of irrigated land range 1/	Estimated current annual water charges and associated costs 2/	Projected amortization and associated costs on potential Federal projects 3/
	(dollars per acre)		
Pacific Northwest	60.53 - 77.41	44.26	80.56
Central Pacific	45.62 - 61.61	67.22	108.51
South Pacific	89.43 - 93.29	116.11	275.58
Colorado River	26.27 - 27.40	44.59	122.09
Great Basin	23.26 - 37.03	20.42	70.87
Upper Rio Grand-Pecos	51.42 - 56.29	40.35	82.41
Western Gulf	117.78 -193.75	53.02	94.98
Upper Arkansas - Red	87.20 - 92.24	28.86	93.98
Upper Missouri	60.26 - 76.53	24.89	89.09

Source:

1/ Range of estimates presented in Table 1.
2/ See Appendix Table A-4.
3/ See Appendix Table A-5.

IV. The Demand for Irrigated Land in 1980.

The same technique used to estimate the marginal productivity of irrigated cropland in 1954 can be used to estimate the marginal productivity of alternative levels of irrigation development in the future. Regional farm output estimates for 1980 were constructed by applying dampened regional output growth trends in major type of farming regions to the medium national farm output projections prepared by Resources for the Future for use by the Select Committee (a 1980 farm output index of 156 with 1954 = 100).16/ The projections for the type of farming regions were then adapted to apply to the water resource regions.

Using the productivity coefficients for irrigated land from the 1954 regional production functions and the regional output projections; estimates were constructed of the margional productivity of irrigated cropland for each of three Department of Agriculture irrigated acreage projections - low, medium and 1980 potential - and the Bureau of Reclamation estimate of irrigated acreage when acreage in potential projects is fully developed. For reference purposes estimates of the acres of irrigated cropland that would be required, at the projected output levels, if the marginal productivity of irrigated land was equated to each of the two cost estimates presented in Table 2 were also computed. In Figures 2.1-2.9 numbers are used to identify the Department and Bureau projections.* Heavy vertical lines are used to identify the irrigated acreage at the two reference points. The broken vertical line indicates irrigated acreage in each region in 1954.

The curve which connects the five points plotted in Figure 2.1-2.9 can be referred to technically as the 1980 short-run derived demand curve for irrigated

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* The Department of Agriculture projections are identified as follows:
(1) low
(2) medium
(3) 1980 potential
The Bureau of Reclamation projections are identified by (4)

land. Included in the caterus parabus conditions implicit in this designation are: (a) the projected regional output levels, (b) continuation of relative prices for farm products and inputs other than irrigated cropland at 1954 levels, (c) technological change between 1954 and 1980 that is "neutral" with respect to the productivity coefficient for irrigated land. The effect of changing these assumptions will be indicated after first discussing the implications of the several regional demand curves on the assumption that the caterus parabus conditions are approximately met.

In the Pacific Northwest an increase from the 3.32 million acres irrigated in 1954 to 4.65 million acres in 1980 is indicated if the projected amortization and associated costs on potential projects is accepted as the appropriate investment criteria and to 8.7 million acres if acreage is expanded to the point where the marginal productivity of irrigated land falls to the level of current annual water and associated costs to irrigators. The three Department of Agriculture projections imply marginal productivities somewhat below the $80.56 required to cover potential project costs while the Bureau projection implies a marginal productivity for irrigated land somewhat lower than $44.26 average under current practice.

In the Central Pacific an actual decline from the 4.96 million acres irrigated in 1954 is indicated if charges rise to the potential project cost level. 16a/ An increase to 6.2 million is indicated if acreage is expanded to the point where the marginal productivity of irrigated cropland falls to the current practice level of $67.22. The three Department projections imply marginal productivities for irrigated land somewhat lower than the current practice levels while the Bureau projection implies a substantially lower marginal productivity.

In the South Pacific a decline is also indicated from the .73 million acres irrigated in 1954 if charges rise to the potential project cost level. However, an increase to 1.08 million acres, somewhat above either the Department or Bureau

Figure 2. The Demand for Irrigated Land in Western Water Resource Regions, 1980.

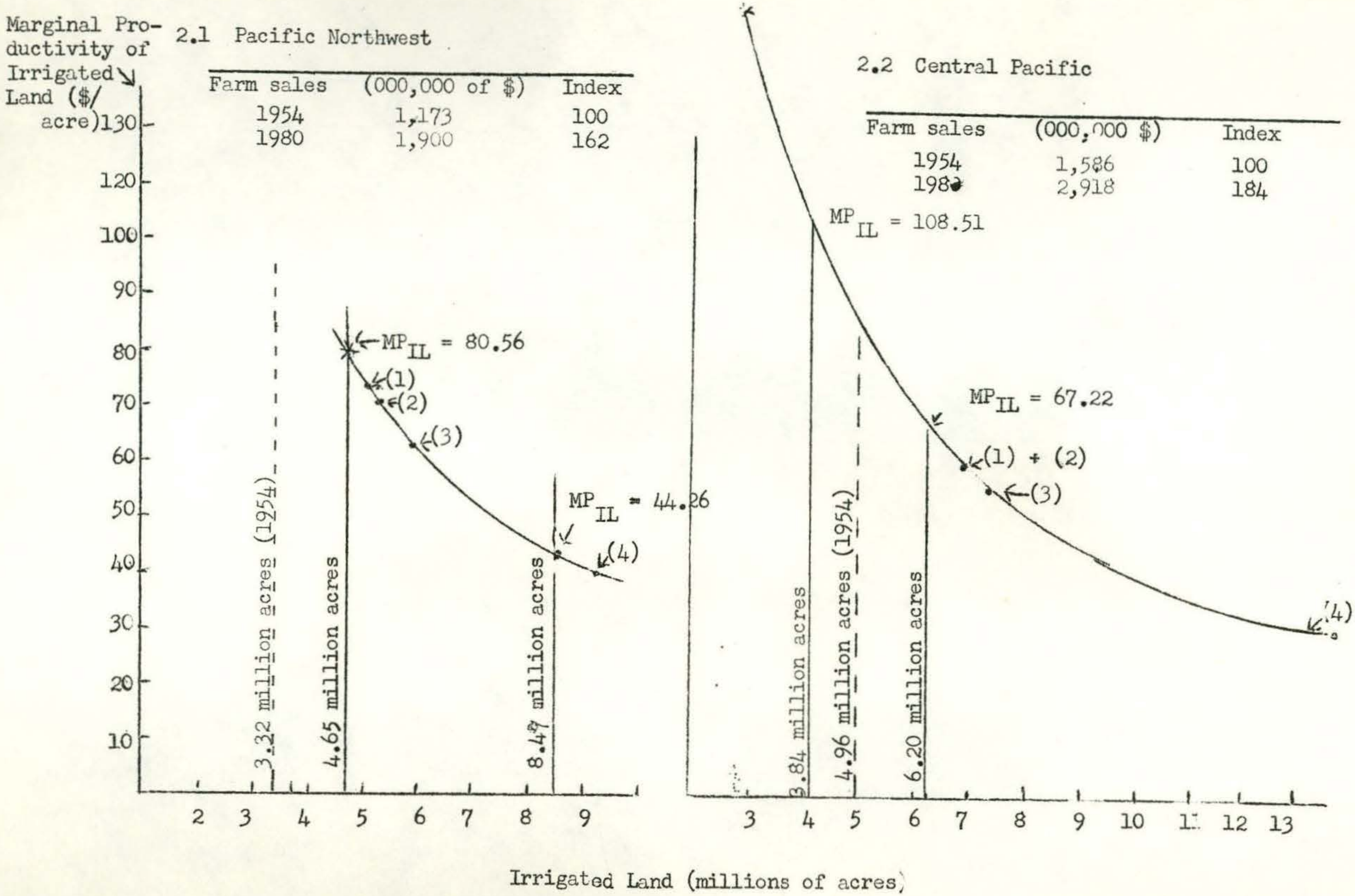


Figure 2. The Demand for Irrigated Land in Western Water Resource Regions, 1980.

2.3 South Pacific

Farm Sales	(000,000 of $)	Index
1954	579	100
1980	1,065	184

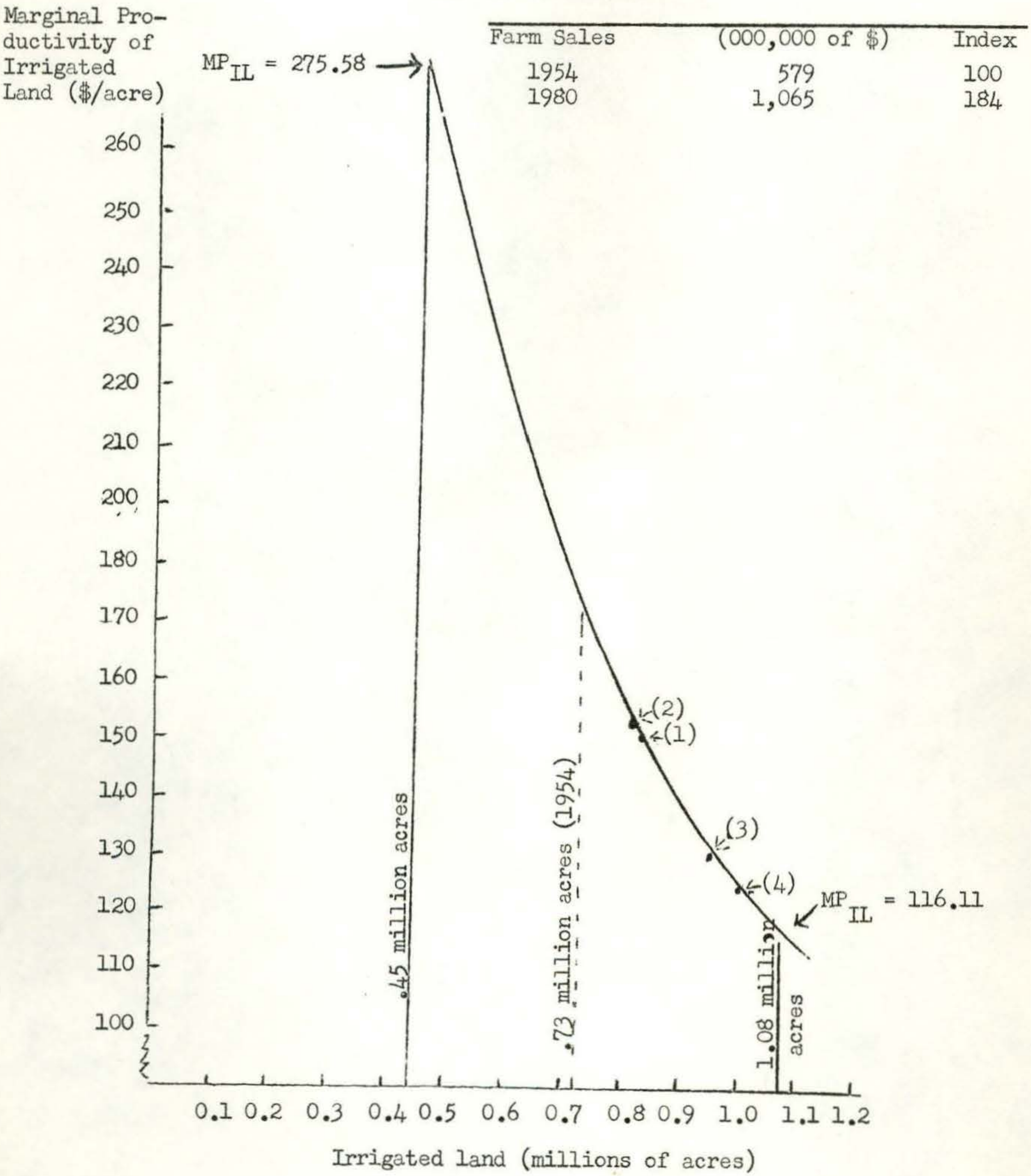
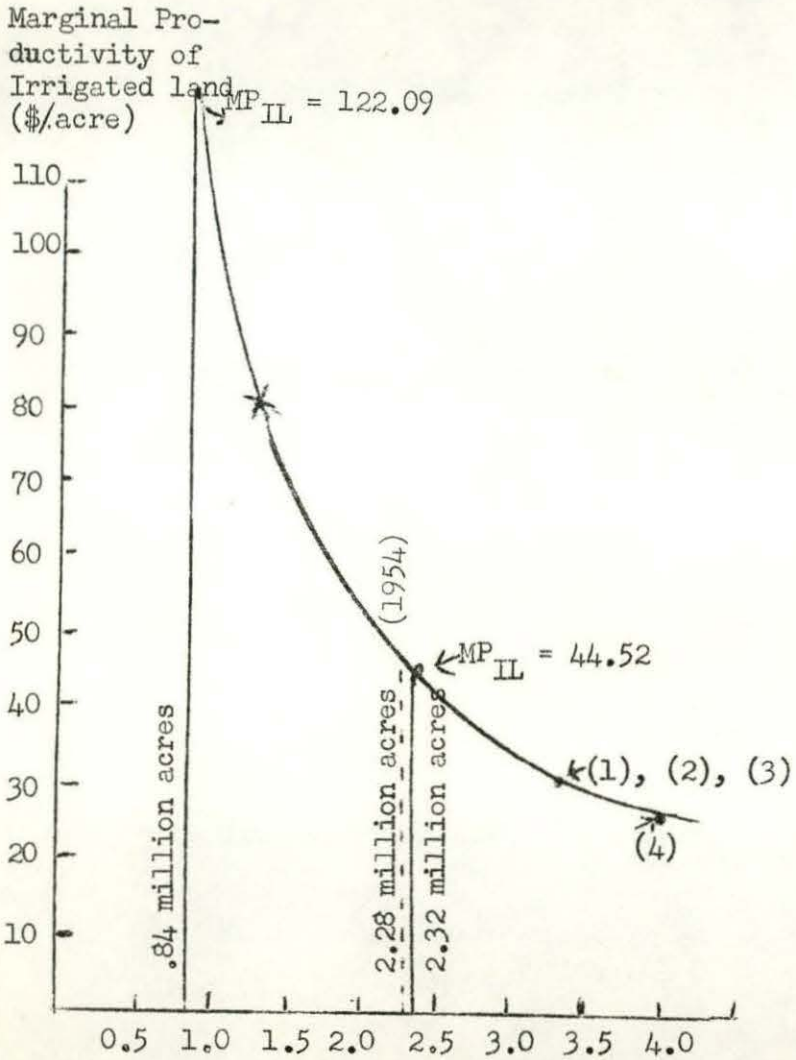


Figure 2. The Demand for Irrigated Land in Western Water Resource Regions, 1980.

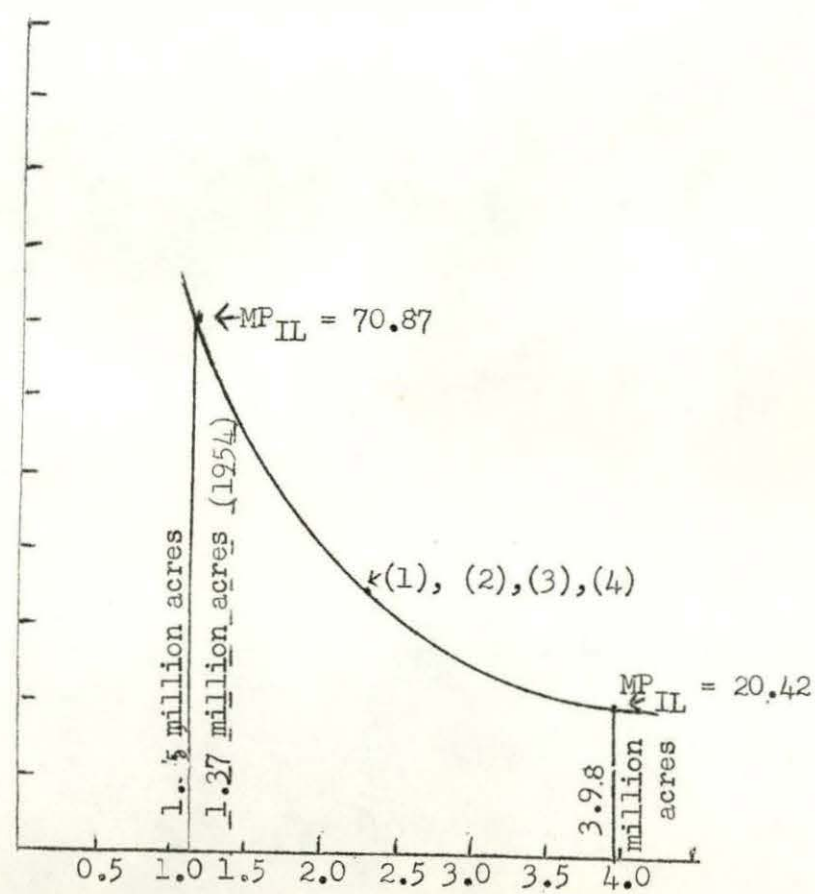
2.4 Colorado River

Farm Sales	(000,000 of $)	Index
1954	534	100
1980	881	16·5



2.5 Great Basin

Farm Sales	(000,000 of $)	Index
1954	170	100
1980	272	160



Irrigated land (Millions of acres)

Figure 2. The Demand for Irrigated Land in Western Water Resource Regions, 1980.

2.6 Upper Rio Grande and Pecos

Farm Sales	(000,000 of $)	Index
1954	232	100
1980	371	160

2.7 Western Gulf

Farm Sales	(000,000 $)	(Index)
1954	1,406	100
1980	2,011	143

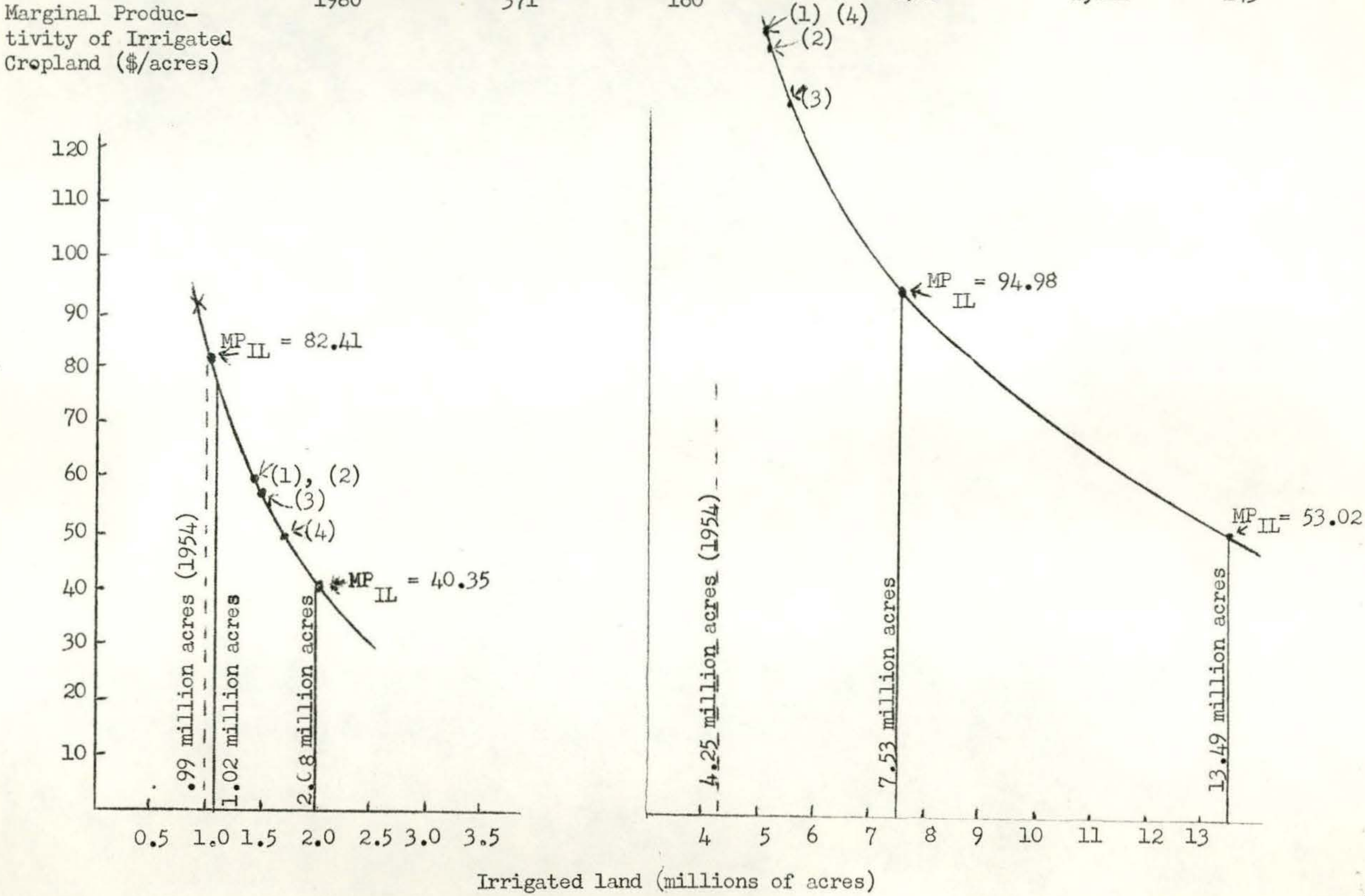


Figure 2.

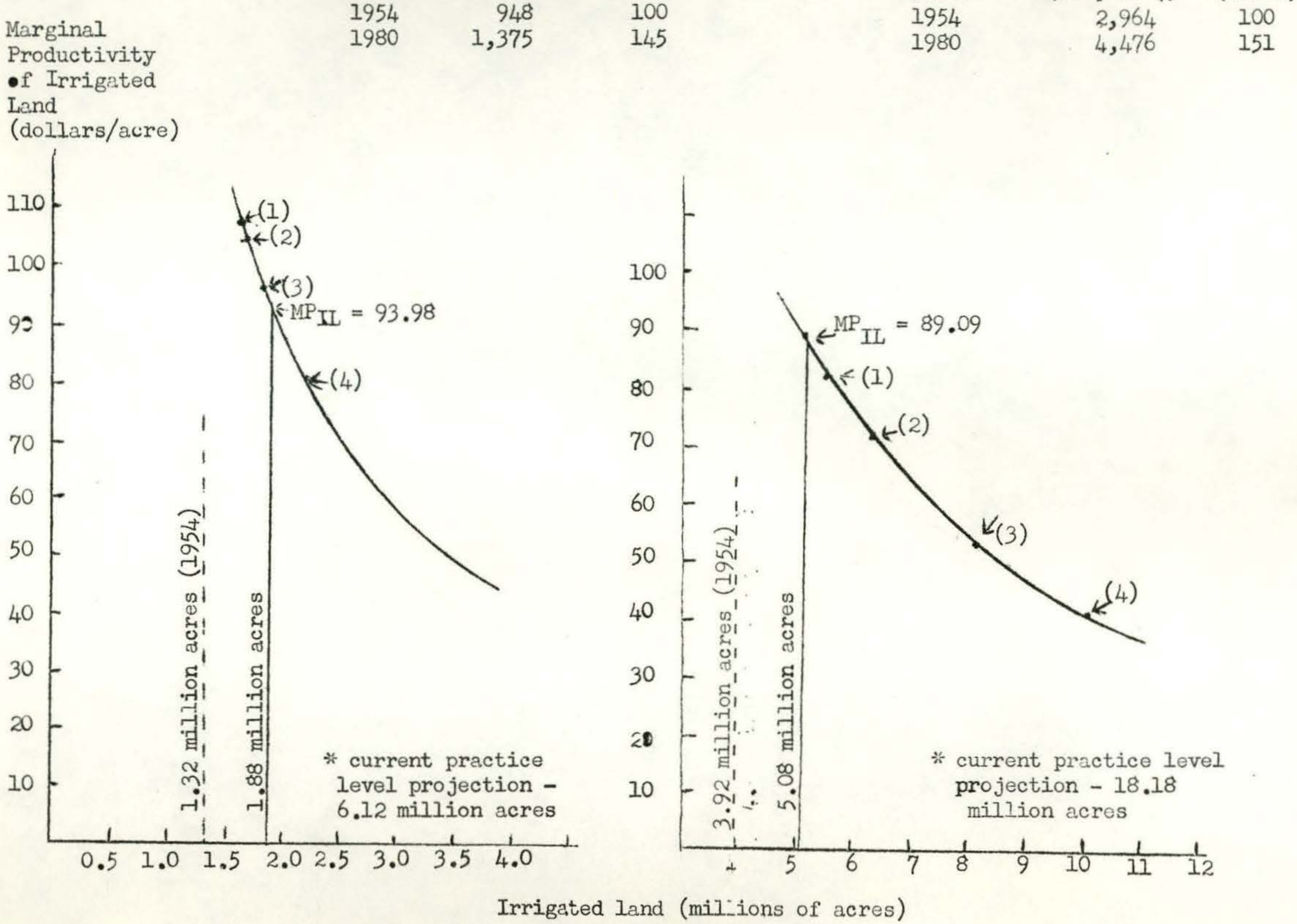
The Demand for Irrigated Land in Western Water Resource Regions, 1980.

2.8 Upper Arkansas - Red

Farm Sales	(000,000 $)	(Index)
1954	948	100
1980	1,375	145

2.9 Upper Missouri

Farm Sales	(000,000 $)	(Index)
1954	2,964	100
1980	4,476	151



projections is indicated if acreage is expanded to the point where the marginal productivity of irrigated cropland falls to the current practice level of $116.11.

In the Colorado River a decline is also indicated from the 2.28 million acres irrigated 1954 if charges rise to the potential project cost level. Even at the current practice level little increase above the 1954 level is indicated. The marginal productivity of irrigated land that would result if development is carried to the levels projected by the Department and the Bureau fall below current practice levels.

To the extent that any reliance can be given to the demand curve computed for the Great Basin a slight decline is indicated from the 1.37 million acres irrigated in 1954 if marginal productivity is to reach the potential project cost level. Th- Department and Bureau projections which converge at about 2.25 million acres are all considerably less than the 3.98 million acres that would have to be irrigated to bring the marginal productivity of irrigated land down to the current practice level of $20.42.

In the Upper Rio Grande and Pecos it appears that it will be possible to achieve a marginal productivity of irrigated land equal to the potential project cost level with a slight increase in irrigated acreage from the .99 million acres irrigated in 1954. An increase to 2.08 million acres, well above the projections of the Department and the Bureau would be required to push the marginal productivity of irrigated land to the present practice level of $40.35.

In the Western Gulf both the potential project cost criteria at $94.98 and present practice criteria at $53.02 imply a demand for irrigated land well above the 4.25 million acres irrigated in 1954 and the levels projected by either the Department or the Bureau.

In the Upper Arkansas substantial increases above the 1.32 million acres irrigated in 1954 are also implied by both criteria. An increase to 1.88 million acres, somewhat above any of the Department projections, would be required at the potential project cost level of \$93.98 while a rise to over 6 million acres would be required to push the marginal productivity of irrigated land to the current practice level of \$28.86.

In the Upper Missouri an increase from the 3.92 million acres irrigated in 1954 to 5.08 million acres is implied by the potential project cost criteria of \$89.09. This is less than any of the Department or Bureau projections and far below the acreage required to push the marginal productivity of irrigated land to the current practice level of \$24.89.

Some modification of the above results can be obtained by relaxing the caterus parabus conditions outlined earlier.

More rapid increase in the demand for national farm output than assumed in this paper would shift the demand for irrigated land in most regions to the right. For any given level of national output, however, a shift to the right in the demand curve for farm output in any region or group of regions must be accompanied by a shift to the left in the demand curve in at least one other region.

A change in product prices relative to factor prices may also act to shift the demand curve for irrigated cropland. Since the prospects for a decline in product prices relative to factor prices seems more likely than a rise the net effect of price changes, if any, will probably be to shift the demand curve for irrigation to the left.

The demand for irrigated land will also be affected by the pattern of technological change that occurs over the next several decades. If technological change (reflected by a rise in the productivity coefficient for irrigated land relative to other inputs) lowers costs or increases output possibilities for irrigated crop production more rapidly than for agriculture as a whole it is possible (but not necessary) that the demand for irrigated land would shift to the right.

On the other hand if technological change is on balance "neutral" (leaving the productivity coefficients approximately unchanged relative to each other) the demand curve for irrigated land will, for any projected level of output, shift to the left.

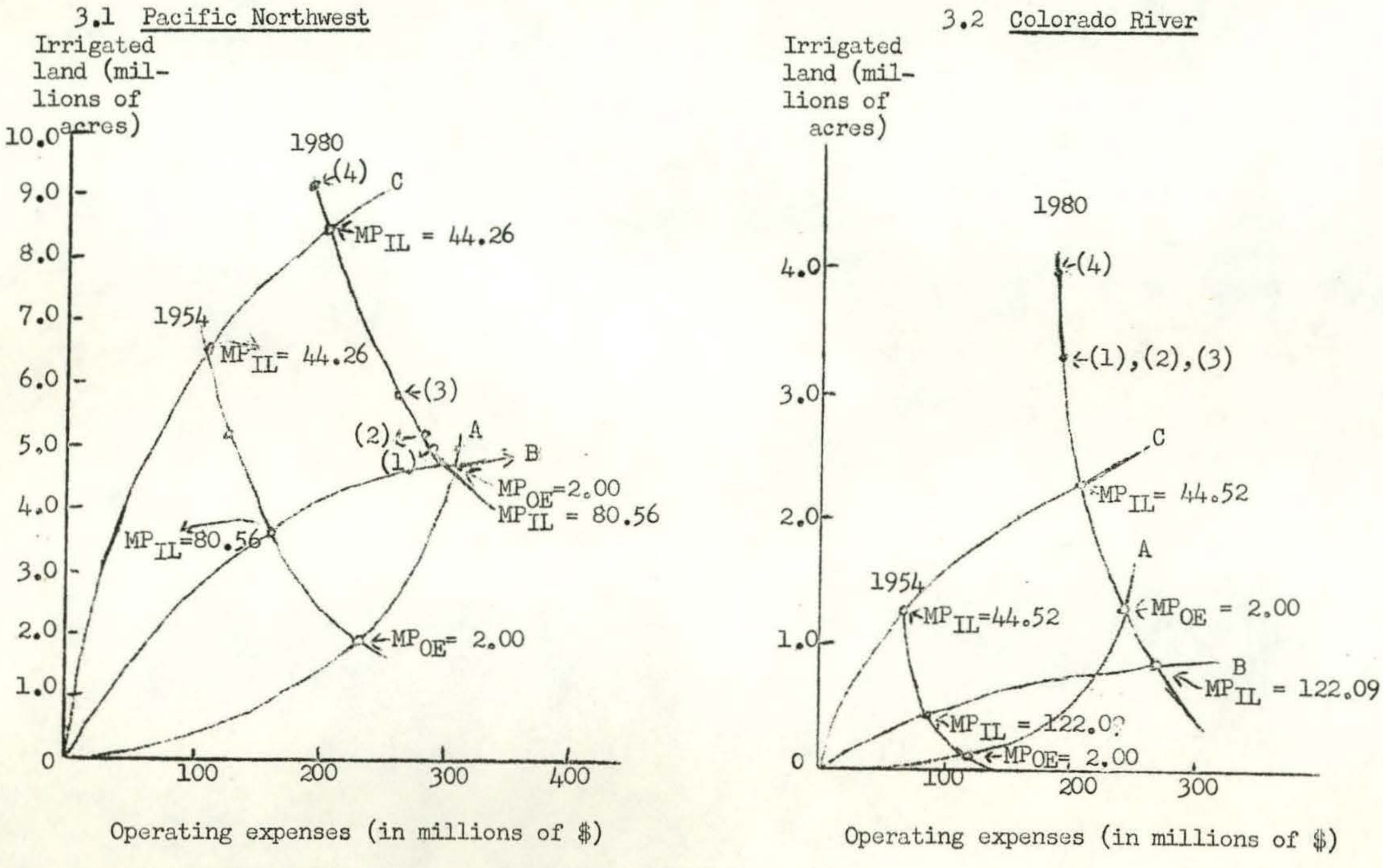
After the qualifications resulting from the difficulty of attaching precise probabilities to potential shifts in the demand curve for irrigated land are taken into consideration however, one firm conclusion does emerge. The amount of land "required" to produce the projected 1980 output will depend, to a major extent, on the degree to which water charges cover projected amorization costs on potential projects.[17/] If these charges are set at or near the projected amortization costs, demand for irrigated acreage can be expected to increase less than anticipated by the Department and the Bureau in 6 of the 8 Western Water Resource Regions (all except Western Gulf and Upper Arkansas and Red). If, on the other hand, charges are set near or only slightly above present practice levels, the demand for irrigated acreage will exceed the Department projections in all but 2 regions (Central Pacific and Colorado River) and the Bureau projections in all but three regions (Central Pacific, Colorado River and Pacific Northwest).

V. Optimum Acreage of Irrigated Land in 1980.

In the previous section comparisons were made between the marginal productivity of irrigated land at the levels projected by the Department and the Bureau and the levels that would result in a marginal productivity of irrigated land sufficient to cover annual amortization and associated costs on potential Federal projects. Identification of the acreage of irrigated land that would result in equating annual marginal productivities and annual potential project cost flows as the optimal level of irrigation development has, however, been carefully avoided. Definition of an optimal level of irrigated acreage within the restricted framework of modern welfare economics requires, among other conditions, that marginal productivities and costs be equated for all factor inputs.[18/] The limitations of the data and measurement techniques employed in this and other empirical studies is perhaps an even more important factor precluding any such precise balancing of marginal equalities. In spite of these limitations it is frequently useful to employ certain limited optimality assumptions to explore the nature of the production surface and the impact of factor substitution on factor productivities at alternative output levels.

In Figures 3.1 and 3.2 the iso- or constant revenue and iso-or constant marginal value lines are plotted for irrigated land and current operating expenses on the assumption that inputs of labor and non-land capital are held constant at their 1954 arithmetic mean values (or alternatively, that variations in these two factors approximately offset each other as in the recent past). Three iso-marginal value curves and two iso-reserve curves are plotted. Curve OA indicates all those combinations of irrigated land and operating expenses for which the marginal productivity of operating expenses is equal to \$2.00 per dollar spent.[19/] To the left of OA the marginal productivity of operating expenses will exceed \$2.00 and to the

Figure 3. Iso-Revenue and Iso-Marginal Value Maps for Irrigated Land and Current Operating Expenses.



right of OA it falls below $2.00. Curve OB indicates all those combinations for which the marginal productivity of irrigated land equals the projected amortization and associated costs on potential Federal projects. And line OC indicates all of those combinations for which the marginal productivity of irrigated land equals the estimated current annual water changes and associated costs.

The marginal productivity of irrigated land and current operating expenses are simultaneously equated with projected amortization and associated costs on potential federal projects and the assumed equilibrium productivity level for operating expenses (2.00/dollar spent) at the point where lines OA and OB intersect. Intersection of OA and OC would identify the equilibrium combination of irrigated land and operating expenses if water charges were adjusted to maintain the sum of estimated annual water charges and associated costs at current levels.

While recognizing the emotional content that is often attached to such terms, it is convenient, and perhaps not too inaccurate, to refer to the OA-OB intersection as the social optimum and the OA-OC intersection as the private optimum. The difference between OB and OC for any given iso-revenue curve indicates the excess demand for irrigated land created by pricing water at below social cost levels. And the difference between the two iso-reserve curves passing through the intersections OA-OB and OA-CC represents the discrepancy between the social and private optimum output levels brought about by pricing water below social cost levels.

In the Pacific Northwest the social optimum output level computed in this manner, coincides (by chance) with the output level projected earlier. In two other regions (Central Pacific, and Upper Rio Grande and Pecos) the social optimum and projected levels also approximately coincide. In the Colorado River and South Pacific regions the projected output level exceeds the social optimum. In two regions (Western Gulf and Upper Arkansas-Red Rivers) the social optimum level of output exceeds the projected level. And in two regions (the Great Basin and Upper Missouri) the estimated production function does not permit the indicated comparisons.

In spite of the restricted meaning which can be given to the optimum positions defined by the technique employed above the iso-reserve and iso-marginal productivity curves that have been calculated do indicate that in most Western Water Resource Regions (except the Great Basin, South Pacific and the Colorado River) substantial possibilities for substitution between irrigated cropland and operating expenses are possible in meeting anticipated 1980 output levels.

VI. The Demand for Irrigation Water in 1980.

While the demand for irrigated land is clearly derived from the demand for farm output the demand for irrigation water can be treated either as derived from the demand for irrigated land or as derived directly from the demand for farm output. If irrigation water is regarded as a strict complement to irrigated land then it is clearly appropriate to treat the demand for water as derived from the demand for irrigated land and, for planning purposes, to project irrigation water requirements for specific alternative levels of irrigated acreage. If, on the other hand, an independent output response can be obtained for irrigation water while holding land input constant the demand for irrigation water should be derived directly from the demand for farm output rather than from the demand for irrigated land and the concept of irrigation water requirements for specific levels of irrigated acreage looses it validity is a planning tool.

The calculations on which the projections prepared for the Select Committee are based carry the implicit assumption that irrigation water is a strict complement to irrigated land and hence that the demand for irrigation water is derived from the demand for irrigated land. Calculations of water use are constructed by aggregating estimated water requirements per acre for individual crops modified to account for variations in efficiences of application and delivery and, in the case of the Department's projections, anticipated improvements in efficiency resulting from technological change. An assumption that the demand for water is derived from the demand for irrigated land is also employed in this paper. Water was not entered directly into the production function but was treated as a perfect complement to irrigated land. And in the cost estimates it is assumed that a constant quantity of water per acre is used in each region.

A substantial amount of research, based on procedures developed by Blaney and Criddle in the West and Thornothwaite in the East has been directed to the development of methods for estimating irrigation water "requirements" per acre for specified crops grown under specified climatic and soil conditions.[20] All of this work carries the assumption that the optimum amount of water "required" per acre can be defined in purely physical terms. Experimental data, particularly that developed by Veihmeyer and his associates in California, has been interpreted as supporting this assumption. Beringer, however, has shown that this experimental work, when re-interpreted within the framework of production economics supports the hypothesis that crop response to incremental water inputs clearly is subject to the principal of diminishing marginal productivity.[21] Thus, optimum application levels cannot be defined on the basis of purely physical criteria. Even at the enterprise or firm level an optimum can be defined only on by equating the incremental costs and returns associated with the incremental output resulting from incremental water inputs. And at the macro or regional level where possibilities of substitution among enterprises and among geographic sub-areas exist the irrigation water "requirement" concept becomes even less valid as a planning tool than at the enterprise or firm level.[22]

However, attempts to work directly with the demand for irrigation water rather than irrigation water "requirements" for specified irrigated acreage levels have been relatively limited. Dawsons work in the Ainsworth, Nebraska area is the only study at the micro level with which I am familiar.[23] Attempts which I have made to enter water as a separate variable in an aggregate regional production function have been unsuccessful.

It appears therefore that we are forced to work with the irrigation "requirement" tool in spite of its limited validity on both conceptual and empirical grounds. In using it, however, we should be careful to recognize that for any given level of irrigated acreage the optimal application of irrigation water may vary widely depending on the incremental cost of water and the incremental return obtained from additional water. Perhaps the most realistic procedure at the present stage of our work would be to attach high, medium and low irrigation water projections to each (high, medium and low) irrigated acreage projection.

No attempt has yet been made in this study to modify or test the specific irrigation water requirement projections contained in the reports to the Select Committee by the Department and the Bureau.

VII. Some Policy Implcations

I would now like to emphasize the implications of three points made earlier in this paper which are of particular relevance to irrigation policy.

1. Current and anticipated rates of growth in demand for farm products and in technological change in agriculture will apparently result in a decline in land inputs used in agriculture to 5-10 percent below current levels by 1980. Calculations of the social costs and returns to irrigation development should, therefore, include the costs of adjustment stemming from more rapid declines in land utilization in other regions than would be required in the absence of publicly financed investment in irrigation development. Tolley's recent studies have indicated that these interregional adjustments occur quite rapidly and that the South has been forced to absorb much of the impact of irrigation development in the West.[24] Statements to the effect that crops produced on irrigated land do not contribute to current farm price and income difficulties because they are not subject to price supports must be regarded as evidence of lack of analytical skill or as deliberate attempts to mislead.

2. The marginal productivity of irrigated land in 1954 tended to be highest in the Southern Plains where the ratio of farm workers to land was relatively high rather than in the desert areas of the West where water is more limited relative to land. Although, in most areas of the West, the marginal productivity of irrigated land exceeds current water charges and associated costs it exceeds projected amortization costs on potential Federal projects only in the Southern Plains regions.

These observations provide a basis for suggesting that during the immediate future - the next decade or so - Federal resource development policies should be directed to creating a better balance between land and labor resources in the Southern Plains by emphasizing rapid irrigation development in this area relative to other areas and by encouraging movement of labor out of agriculture. In the desert areas, where limitations of water supply for all purposes is greatest and where urban-industrial development is occurring rapidly it would seem desirable to avoid committing substantial additional water resources to irrigation.

3. The problem of future irrigation development cannot be meaningfully cast in terms of land and water "requirements".[25/] The possibilities of factor substitution to achieve projected output levels are substantial, even at the farm level. It is clear from both this study and from the reports prepared for the Select Committee that at the regional and national levels these substitution possibilities are immensely magnified. These facts, combined with the extremely rapid rate of technological change in agriculture that has occurred in the recent past and is anticipated through at least the next decade reduce the relevant planning horizon for agricultural resource development to something in the neighborhood of ten years.

Public investment in irrigation development should, therefore, be directed to completion of those current and potential projects where there is a strong possibility that the marginal productivity of irrigated land will at least equal projected amortization and associated costs in the near future rather than being geared to potential "requirements" in 1980 or at the end of the century. Irrigation development in the West is clearly a case where early decisions may, by failing to take advantage of time as a resource, result in substantial waste of alternative physical, capital and labor resources.

Table A-1. Alternative Factor Productivity Estimates for Western Water Resource Regions, 1954.

Region and Equation	a. Constant Term (in $\log_{10}$)	X_1 All farm workers	X_2 Machinery investment	X_3 Livestock investment	X_4 Irrigated land	X_5 Non-irrigated cropland	X_6 Current operating expandes	Sum of coefficients	R^2 Cofficient of determination	$\bar{S}$ Standard error of estimate (in $\log_{10}$)
Pacific Northwest (1)	.9567	.2568	.2186	.0361	.1779	.1967	.2901	1.1762	.7987	.2023
		(.1653)	(.2137)	(.1111)	(.0506)	(.0382)	(.0866)			
(2)	1.5070	.3970	-	.1019	.1713	.2077	.2903	1.1681	.7966	.2024
		(.0981)	-	(.0914)	(.0500)	(.0372)	(.0866)			
(3)	1.8730	.4037	-	-	.1973	.2104	.3166	1.1280	.7940	.2026
		(.0897)	-	-	(.0409)	(.0308)	(.0782)			
Central Pacific (1)	.8834	.1938	.3361	- .1401	.1056	.1346	.5048	1.1348	.9497	.1513
		(.1522)	(.1718)	(.1375)	(.0543)	(.0595)	(.1420)			
(2)	1.6876	.3375	-	- .0646	.1536	.1455	.5367	1.1087	.9435	.1581
		(.1485)	-	(.1368)	(.0543)	(.0621)	(.1477)			
(3)	1.4754	.3520	-	-	.1427	.1376	.5057	1.1380	.9431	.1564
		(.1326)	-	-	(.0415)	(.0541)	(.0966)			
South Pacific and Colrado River (1)	1.1150	.3233	.0705	.1412	.0897	- .0095	.4847	1.0999	.9715	.1259
		(.1037)	(.1443)	(.0803)	(.0667)	(.0155)	(.0981)			
(2)	1.3222	.3489	-	.1387	.1123	- .0058	.4965	1.0905	.9714	.1250
		(.0908)	-	(.0794)	(.0489)	(.0134)	(.0955)			
(3)	1.9455	.3532	-	-	.1171	- .0029	.5410	1.0083	.9695	.1277
		(.0778)	-	-	(.0471)	(.0136)	(.0611)			
Great Basin (1)	.7455	.9231	.3016	.5769	- .1387	- .0543	- .3355	1.2732	.8940	.2111
		(.2135)	(.3095)	(.2749)	(.2263)	(.0438)	(.1827)			
(2)	1.7311	.9985	-	.5313	- .0548	- .0316	- .2369	1.2065	.8908	
		(.2083)	-	(.2676)	(.2086)	(.0366)	(.1470)			
(3)	3.2416	.9328	-	-	.2984	- .0052	- .1488	1.0772	.8760	.2217
		(.1160)	-	-	(.1309)	(.0356)	(.1416)			

Table A-1. (Continued)

Region and Equation		a_o Constant term (in $\log_{10}$)	X_1 All farm workers	X_2 Machinery investment	X_3 Livestock investment	X_4 Irrigated land	X_5 Non-irrigated crop-land	X_6 Current operating expenses	Sum of coefficients	R^2 Cofficient of determination	$\bar{S}$ Standard error of estimate (in $\log_{10}$)
Upper Rio Grande and Pecos	(1)	.4890	.3877	.1239	.1683	.1966	- .0674	.4100	1.2192	.9127	.1715
			(.1280)	(.1996)	(.1530)	(.1140)	(.0358)	(.1326)			
	(2)	.9094	.4122	-	.1583	.2392	- .0601	.4341	1.1837	.9116	.1698
			(.1230)	-	(.1503)	(.0936)	(.0330)	(.1279)			
	(3)	1.5457	.4233	-	-	.2254	- .0513	.5028	1.1003	.9084	.1702
			(.0987)	-	-	(.0827)	(.0302)	(.0799)			
Western Gulf	(1)	.6710	- .0462	.5509	- .0036	.2922	.1512	.1474	1.0919	.8859	.1441
			(.1022)	(.1765)	(.0990)	(.0491)	(.0550)	(.0936)			
	(2)	2.0309	.1370	-	.0017	.3556	.2717	.2742	1.0402	.8668	.1546
			(.0942)	-	(.1061)	(.0525)	(.0519)	(.0957)			
	(3)	2.0368	.1368	-	-	.3556	.2717	.2752	1.0392	.8668	.1535
			(.0911)	-	-	(.0298)	(.0398)	(.0599)			
Upper Arkansas	(1)	1.2513	.0958	.2940	- .0024	.1190	.2624	.2607	1.0294	.9008	.1123
			(.0666)	(.1211)	(.0986)	(.0284)	(.0446)	(.0918)			
	(2)	2.3738	.1900	-	- .0562	.1288	.3165	.3565	.9356	.8923	.1162
			(.0600)	-	(.0999)	(.0294)	(.0445)	(.0905)			
	(3)	2.2044	.1981	-	-	.1285	.3135	.3202	.9603	.8920	.1157
			(.0538)	-	-	(.0253)	(.0250)	(.0484)			
Upper Missouri	(1)	- .3836	- .1667	.8906	.0307	.0422	.0667	.1812	1.0447	.8714	.1060
			(.1122)	(.1249)	(.0463)	(.0179)	(.0211)	(.0390)			
	(2)	2.6113	.6444	-	.1175	.0912	.1162	.0760	1.0453	.8081	.1291
			(.0907)	-	(.0558)	(.0215)	(.0256)	(.0419)			
	(3)	3.2124	.6992	-	-	.1011	.1108	.0776	.9887	.8025	.1305
			(.0707)	-	-	(.0199)	(.0240)	(.0419)			

Table A-2. Measures of Total Farm Output and Inputs for All Counties in Western Water Resource Regions, 1954.

Water Resource Region	Number of counties	Farm Sales (000,000's $)	All farm workers (000's of persons)	Irrigated Land (000's of acres)	Non-irrigated crop land (000's of acres)	Operating Expenses (000,000's of $)
Central Pacific	43	1,585.9	333.8	4,961.7	2,052.2	228.6
Pacific Northwest	125	1,173.4	326.0	3,320.5	7,776.8	165.3
South Pacific	7	579.4	89.5	727.3	369.3	145.4
Colorado River	52	533.8	112.3	2,281.1	395.2	60.4
Total*	59	1,113.2	201.8	3,008.4	764.5	205.8
Great Basin	41	170.4	53.4	1,372.5	671.6	29.8
Upper Rio Grande and Pecos	46	232.7	106.3	988.8	396.5	31.6
Western Gulf	199	1,406.6	625.7	4,246.3	16,176.5	221.6
Upper Arkansas - Red Rivers	153	948.3	310.5	1,323.8	24,087.3	134.5
Upper Missouri	361	2,964.0	729.3	3,915.4	80,890.2	389.9
West Total	1,027	9,594.5	2,686.8	23,137.4	132,815.6	1,407.1

Source: U. S. Bureau of the Census, United States Census of Agriculture: 1954 (Washington, USGPO, 1956, Vol. I Counties and State Economic Areas).

* Total for South Pacific and Colorado River.

Table A-3. Measures of Arithmetic and Geometric Average Farm Output and Inputs for Counties in Western Water Resource Regions, 1954.

Water Resource Region		Number of Counties	Farm Sales (000's of $)	All Farm Workers (persons)	Irrigated Land (acres)	Non Irrigated Crop Land (000's of acres)	Operating Expenses (000's of $)
Central Pacific	A	43	36,880.4	7,762	115,388	47.7	5,315.6
	G	42	18,265.0	4,035	45,548	26.3	2,598.2
Pacific Northwest	A	125	9,386.9	2,608	26,564	62.2	1,322.5
	G	106	6,700.0	1,914	17,074	26.2	773.8
South Pacific	A	7	82,772.7	12,779	103,894	52.8	20,778.5
Colorado River	A	52	10,265.1	2,158	43,867	7.6	1,162.4
Total	A	59	18,867.8	3,420	50,989	13.0	3,488.1
	G	56	4,048.5	1,228	27,423	0.1	453.0
Great Basin	A	41	4,155.3	1,303	33,476	16.4	727.5
	G	39	2,642.4	759	33,902	1.0	458.4
Upper Rio Grande and Pecos	A	46	5,058.2	2,311	21,496	8.6	685.9
	G	38	3,313.4	1,512	14,524	1.1	457.7
Western Gulf	A	199	7,068.3	3,144	21,338	81.3	1,113.8
	G	75	7,708.7	2,682	14,150	52.2	793.3
Upper Arkansas - Red Rivers	A	153	6,197.7	2,029	8,652	157.4	878.9
	G	82	4,998.6	1,198	7,366	103.8	466.6
Upper Missouri	A	361	8,210.6	2,020	10,846	224.1	1,080.0
	G	161	6,723.8	1,418	10,171	98.7	693.7
West Total	A	1,027	9,342.1	2,616	22,529	129.3	1,370.2

A - arithmetic mean for all counties
G - geometric mean for major irrigation counties
Source: U. S. Bureau of the Census, United States Census of Agriculture: 1954 (Washington, USGPO, 1956, Vol. I. (Counties and State Economic Areas).

Table A-4. Average Water and Other Associated Costs[1/] to Irrigators Per Acre of Irrigated Land, Western Water Resource Regions.

	Water[2/]	Other[3/]	Total
Pacific Northwest	3.36[a/]	40.90	44.26
Central Pacific	8.82[b/]	58.40	67.22
South Pacific	18.41[c/]	97.70	116.11
Colorado River	7.09[d/]	37.50	44.59
Great Basin	2.02[e/]	18.40	20.42
Upper Rio-Grande Pecos	2.85[f/]	37.50	40.35
Upper Missouri	1.99[g/]	22.90	24.89
Upper Arkansas and Red	2.52[h/]	26.34*	28.86*
Western Gulf	7.82[i/]	45.20	53.02

* Estimated from data for the Upper Missouri and Western Gulf.

1/ Exclusive of labor, fertilizer or purchased feed. These estimates are computed with the objective of comparison with marginal productivity estimates for irrigated land computed from an equation in which labor and current operating expenses are held constant at the mean.

2/ From U. S. Bureau of the Census, U. S. Census of Agriculture; 1950, Vol. III, Irrigation of Agricultural Lands. USGPO; Washington, 1952, Summary Table 55, p. 88. Total costs in areas listed below:

a/ North Pacific
b/ Central Valley, total
c/ Santa Maria River and Basins, South
d/ Gulf of California, total
e/ Great Basin, total
f/ Rio Grande above Fort Quitman, Texas
g/ Missouri River, total
h/ Missouri River, total
i/ Rio Grande below Fort Quitman, Texas

3/ Nathaniel Wollman and Karl Gertel, "Pricing and Assessment Guides to Water Allocation", Journal of Farming Economics, forthcoming, December 1960. The authors have emphasized that the estimates presented above should be regarded as approximations.

Table A-5. Estimated Costs Allocated to Irrigation for Potential Projects in Western Water Resource Regions.

Water Resource Region	Irrigation cost per equivalent acre 1/	Estimated annual amortization cost per equivalent acre 2/	Associated costs per acre: Operation and maintenance of irrigation facilities 3/	Associated costs per acre: Other 4/	Total amortization and associated costs per acre
	(dollars per acre)				
Federal Projects					
Pacific Northwest	646	35.53	4.13	40.90	80.56
Central Pacific	681	37.46	12.65	58.40	108.51
South Pacific	2,780	152.90	24.98	97.70	275.58
Colorado River	1,374	75.57	9.02	37.50	122.09
Great Basin	906	49.83	2.64	18.40	70.87
Upper Rio Grande and Pecos	750	41.25	3.66	37.50	82.41
Upper Missouri	1,160	63.80	2.39	22.90	89.09
Upper Arkansas and Red	1,167	64.19	3.45	26.34*	93.98
Western Gulf	730	40.15	9.63	45.20	94.98
Average	921	50.65			
Non Federal Projects					
Pacific Northwest	484	26.62	4.13	40.90	71.65
Central Pacific	384	21.12	12.65	58.40	92.17
South Pacific	425	23.38	24.98	97.70	146.06
Colorado River	140	7.70	9.02	37.50	54.22
Great Basin	251	13.80	2.64	18.40	34.84
Upper Rio Grande and Pecos	na	na	3.66	37.50	-
Upper Missouri	200	11.00	2.39	22.90	36.29
Upper Arkansas and Red	207	11.39	3.45	26.34*	41.18
Western Gulf	659	36.25	9.63	45.20	91.08
Average	313	17.22			

* Estimated from data for the Upper Missouri and Western Gulf.

Sources:

1/ Bureau of Reclamation, United States Department of Interior, Reclamation in the West, Present and Future, and its Effect on Water Supplies, U. S. Senate Select Committee on National Water Resources, 80th Congress 2nd Session, Committee Print No. 14, USGPO, Washington 25, October 1959, Table 11.

2/ Computed from Irrigation Cost per Equivalent Acre assuming an interest rate of 5.5 percent per year. For justification of this assumption see J. V. Krutilla and Otto Eckstein, Multiple Purpose River Development, Johns Hopkins, Baltimore, 1958, pp. 78-130.

3/ Operation and maintenance costs only. See footnote 2, Table A4 for source. The reported data were adjusted upward by 50 percent to more closely approximate current costs.

4/ Nathaniel Wollman and Karl Gertel, "Pricing and Assessment Guides to Water Allocation" Journal of Farm Economics, (forthcoming, December 1960).

Table A-6. Comparison of Bureau of Reclamation and Department of Agriculture Irrigated Acreage Projections for Western Water Resources Region.

	1954 Irrigation Acreage (1)	Department of Agriculture 1957 Irrigated Acreage Estimate (2)	Bureau of Reclamation 1958 Irrigated Acreage Estimates (3)	Bureau of Reclamation Projections: New Acreage in Potential Projects (4)	Bureau of Reclamation Projections: Projected Irrigated Acreage (5)	Department of Agricultural Projections: 1980 Low Projection (6)	Department of Agricultural Projections: 1980 Medium Projection (7)	Department of Agricultural Projections: Estimated 1980 Potential (8)	Estimated 2,000 Potential (9)
			(in thousand of acres)						
Pacific Northwest	4,352	5,057	4,600	4,685	9,285	5,022	5,261	5,904	7,730
Central Pacific	6,067	7,044	7,100	6,465	13,565	6,875	6,869	7,335	7,889
South Pacific	789	917	800	200	1,000	827	816	953	999
Colorado River	2,818	3,268	2,900	1,090	3,990	3,283	3,280	3,300	3,500
Great Basin	1,926	2,249	1,950	295	2,245	2,242	2,257	2,300	2,400
Upper Rio Grande and Pecos	1,133	1,315	1,650	35	1,685	1,400	1,416	1,464	1,649
Western Gulf	4,430	5,148	3,100	1,970	5,070	5,022	5,126	5,517	7,071
Upper Arkansas-Red	1,410	1,637	1,600	970	2,570	1,625	1,681	1,823	2,202
Upper Missouri	4,623	5,369	6,800	4,000	10,800	5,500	6,287	8,147	9,779
West Total	27,548	32,004	30,500	19,710	50,210	31,797	32,993	36,743	43,218

Source:

(1) Tabulated from U. S. Bureau of the Census, United States Census of Agriculture 1954 (Washington: Gov't.Print. Off., 1956), Vol. 1 (County and State Economic Areas).

(2) U. S. Department of Agriculture, Land and Water Potentials and Future Requirements for Water (Committee Print No. 12, Select Committee on National Water Resources, U. S, Senate, 86th Congress, 1st session) USGPO, Washington, 1960, p. 32 (Table 11).

(3 & 4) U. S. Bureau of Reclamation, Reclamation in the West, Present and Future, and Its Effect on Water Supplies, p.3 and p. 11 and Table 6.
Allocation of California water plan acreage based on data in California Water Resources Board, Water Utilization and Requirements of California Sacramento, June 1955, Vol. 1 (California Water Resources Board, Bulletin No. 2). Substantially larger irrigated acreages are projected for the South Pacific in the California Water Plan. The projections in Bulletin No. 2 indicate an ultimate irrigated acreage of 1,500 acres in the South Pacific area excluding lands having right in and to waters of the Colorado River (p. 223).

(5) Sum of (3) and (4)

(6) U. S. Department of Agriculture, op.cit., p. 71, (Table 44).

(7) U. S. Department of Agriculture, op. cit., p. 72 (Table 45).

(8 & 9) U. S. Department of Agriculture, op. cit. , p. 32 (Table 11).

Footnotes

1/ The projections of irrigated acreage and irrigation water requirements are presented primarily in two reports to the Committee:

(a) U. S. Department of Agriculture, Land and Water Potentials and Future Requirements for Water, (United States Senate Select Committee on National Water Resources 76th Congress, 1st session, Committee Print No. 13), USGPO, Washington, 1960,

(b) U. S. Bureau of Reclamation, Reclamation in the West, Present and Future, and its Effect on Water Supplies. (United States Senate Select Committee on National Water Resources, 86th Congress, 2nd Session, Committee Print No. 14), USGPO, Washington, 1960.

2/ This section relies heavily on material presented in greater detail in V. W. Ruttan, "The Contribution of Technological Progress to Farm Output; 1950-75", the Review of Economics and Statistics, Vol. 37, #1, February 1956, pp. 61-69; T. T. Stout and V. W. Ruttan, "Regional Patterns of Technological Change in American Agriculture", Journal of Farm Economics, Vol. 40, No. 2, May 1958, pp. 196-207; V. W. Ruttan, "Our Growing Farm Output Potential", Economic and Marketing Information for Indiana Farmers, January 1960, pp. 2-4; and V. W. Ruttan and J. C. Callahan, "Resource Inputs and Output Growth: The Contrast Between Agriculture and Forestry" (forthcoming). See also, Donald D. Durost and Glenn T. Barton, Changing Sources of Farm Output, United States Department of Agriculture, Washington, February 1956, (Production Research Report No. 36) and J. T. Bonnen, "American Agriculture in 1965" in Joint Economic Committee, Policy for Commercial Agriculture, USGPO, Washington, November 1957.

3/ President's Water Resources Policy Commission, A Water Policy for the American People, Vol. I, USGPO, Washington, 1952, pp. 156-159.

4/ The Fifth Plate, U. S. Department of Agriculture, Washingtion, December 1951.

5/ Current discussion in agricultural policy circles implies that an additional 30 million acres would have to be withdrawn from production to reduce agricultural surpluses to managable proportions. My own estimates, bases on the possibilities of input substitutions implicit in recent production function estimates is that something over 100 million acres would have to be withdrawn.

6/ See V. W. Ruttan, "Our Growing Farm Output Potential", op. cit.

7/ Based on a revision and extension to 1980 of the projections presented in V. W. Ruttan, "The Contribution of Technological Progress to Farm Output: 1950-75", op. cit.

8/ For the prospects for the next several years see, U. S. Senate Committee on Agriculture and Forestry, Farm Price and Income Projections, 1960-65, Under Conditions Approximating Free Production and Marketing of Agricultural Commodities, (A Report from the United States Department of Agriculture and a statement from the Land Grant Colleges IRM-1 Advisory Committee), Senate Document No. 77, 86th Congress 2nd Session, USGPO, Washington 1960.

9/ No attempt is made here to review the extensive literature on the aggregation problem. See, however, the two articles, L. R. Klein, "Macro-economics and the Theory of Rational Behavior" Econometrica, Vol. 14, No. 2, April 1946, pp. 93-108; and Yehuda Grenfeld and Zvi Griliches, "Is Aggregation Necessarily Bad?" The Review of Economics and Statistics, Vol. 42, February 1960, pp. 1-13.

10/ The limitations involved in (a) use of the Cobb-Douglas function, (b) the particular econometric model of production used to generate the marginal productivity estimates, and (c) the statistical estimation procedures employed are discussed and evaluated in greater detail in previous reports. See V. W. Ruttan, "The Impact of Irrigation on Farm Output in California,"Hilgardia, (Journal of the California Agricultural Experiment Sation), forthcoming; and J. C. Headley and V. W. Ruttan, "Regional Differences in the Impact of Irrigation on Farm Output", Proceedings of the 1960 Annual Meeting of the Western Regional Committee on the Economics of Water Resources, Berkeley, California, (forthcoming).

11/ There are actually 9 western water resource regions. Because of the small number of counties in the South Pacific region it was combined with the Colorado River region, a production function was constructed for the combined region and a production.

12/ The marginal productivity estimates presented in this report differ in several major respects from the estimates presented by Headley and Ruttan in "Regional Differences = = - - - - ". op.cit. (1) the estimates presented in "Regional Differences . . . ." are based on production functions computed for major type of farming regions. For this report the production functions have been re-computed for water resource regions. (2) On the basis of analysis presented in "Regional Differeces . . . ."a decision was made to base the production function estimates on data for major irrigation counties only. In the West, major irrigation counties are defined to include only those counties with 1,000 acres or more of irrigated cropland harvested in 1954. (3) In "Regional Differences . . . . . . " irrigated cropland harvested and irrigated pasture were entered as separate variables in the production functions for the western regions. In this study the two variables are combined into a single variable, irrigated land. As a result the productivity coefficients and marginal productivity estimates presented in this paper for all irrigated land will be lower than the estimates for irrigated cropland only presented in "Regional Differences . . . . . "

13/ S. T. Maitland and D. A. Fisher, Area Variations in the Wages of Agricultural Labor in the United States, U. S. Department of Agriculture Technical Bulletin No. 1177, Washington, March 1958.

14/ This shortage was apparently responsible for substantial declines in irrigated land between 1949 and 1954 in parts of Nevada, Utah, Colorado, New Mexico and Wyoming. See for example, the map on page XIII of U. S. Bureau of the Census, U. S. Census of Agriculture: 1954, Vol. III, Special Reports, Part 6, Irrigation in Humid Areas, USGPO, Washington, 1956.

15/ No attempt is made to provide an exhaustive discussion of the issues involved in evaluating public resource investment. For a discussion of these issues see the Inter-Agency Committee on Water Resources Subcommittee in Evaluation Standards", Proposed Practices for Economic Analysis of River Basin Projects, Washington, May 1958 (The Green Book); S. V. Ciriacy-Wantrup, Resource Conservation Economics and Policy, University of California Press, Berkeley, 1952, pp. 230-267; Otto Eckstein, Water-Resource Development, Harvard University Press, Cambridge, 1958, pp. 19-109, 192-236; J. V. Krutilla and Otto Eckstein, Multiple Purpose River Development, Johns Hopkins Press, Baltimore, 1957, pp. 15-75; G. S. Tolley, "Analytical Techniques in Relation to Watershed Development" Journal of Farm Economics, Vol. 40, No. 3, August 1958, pp. 653-665; J. S. Bain, "Criteria for Undertaking Water-Resource Development", American Economic Review, Vol. 50, No. 2, May 1960, pp. 310-320.

16/ The regional projections procedure employs the assumption that the annual change in each regions share of national farm output between 1925-29 and 1953-57 will decline linearly to zero by 1975-80. For those who are interested in a detailed statement of the methods used to construct the regional output projections a working paper "National and Regional Output Projections for United States Agriculture, 1980" is available from the author.

16a/ Because of the fixed cost component in existing projects it is not anticipated, of course, that prices will actually rise sufficiently, to result in a decline in irrigated acreage except in areas where irrigation is based on declining ground water supplies which cannot be economically recharged.

17/ Demand will also vary with the institutional arrangements used to cover any given level of total "charges". For any level of charges, the higher the proportion of total "charges" met by assessment procedures and the smaller met through payments based on the quantity of water used the higher will be the demand for irrigated land.

18/ In addition to the references identified in footnote 15 see J. V. Krutilla, "Some Thoughts on the Welfare Basis of Cost-Benefit Analysis" (Mimeo, May 18, 1960).

19/ According to D. B. Ibach and R. C. Lindberg, The Economic Position of Fertilizer Use in the United States, U. S. Department of Agriculture, Information Bulletin No. 202, "The last dollar spent for fertilizer at the 1954 average rates of application on all crops and pasture returned $2.93 . . . . The comparable marginal return was $3.40 for intertilled crops and $1.96 for close growing crops and hay and pasture", p. 7.

20/ No attempt is made to review the extensive literature in this field. The basic documents are, Harry F. Blaney and Wayne D. Criddle, "A Method of Estimating Water Requirements in Irrigated Areas from Climatological Data," U. S. Department of Agriculture, Soil Conservation Service, Washington 1947 (Revised edition, 1950); C. W. Thornthwaite, "An Approach Toward a Rational Classification of Climate" Geographical Review, Vol. 38, 1948, pp. 55-94.

21/ Christoph Beringer, "Some Conceptual Problems Encountered in Determing the Production Function for Water " The West in a Growing Economy (Proceedings of the 32nd Annual Meeting of the Western Farm Economic Association, Logan, Utah, July 14-17, 1959, pp. 58-70.

22/ George R. Tolley and U. S. Hastings, "Optimal Water Application: The North Plate River" Quarterly Journal of Economics, Vol. 64, No. 2, May 1960, pp. 279-295.

23/ John A. Dawson, "The Productivity of Water in Agriculture", Journal of Farm Economics, Vol. 34, No. 5, December 1957, pp. 1244-1252.

24/ G. S. Tolley, "Reclamation, Influence on the Rest of Agriculture" Land Economics, Vol. 35, No. 2, May 1959, pp. 176-180. Also, G. S. Tolley and L. M. Hartman, "Inter-Area Relations in Agricultural Supply" Journal of Farm Economics, Vol. 42, No. 2, (May 1960, pp. 453-473).

25/ For discussion of this point from a somewhat different perspective see, S. V. Ciriacy-Wantrup, Conceptual Problems in Projection The Demand for Land and Water. Giannini Foundation Paper No. 176, University of California Agricultural Experiment Station, Berkeley, May 1959. To be published in H. Halcrow (ed) Modern Land Economics, (forthcoming 1960).