DIFFERENTIAL LAND USE CHANGE AS THE RESULT OF THE CONSTRUCTION OF THE KEYSTONE RESERVOIR*

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The construction of multiple purpose reservoirs has been one of the major claimants of public works investment funds during the post-World War II period. The research reported here estimates differential land use change associated with reservoir construction.

Differential land use change is estimated by comparing land uses in the reservoir area with projected land uses in the same area had the reservoir not been constructed. The results indicate substantial nonagricultural land use increases associated with the construction of Keystone Reservoir. Another interesting result of the analysis is that as time approaches infinity, the differential impact of reservoir construction on nonagricultural, nonresidential, land use changes slowly declined, while that of residential land use continued to increase.

The construction of multipurpose reservoirs has been one of the major claimants of public works investment funds during the post-World War II period. The justification for such reservoirs includes flood protection, provision of water for irrigation and consumption, generation of electric power, augmentation of low flows for navigation and provision of improved fishing and recreational opportunities.

Previous research indicates substantial economic impact in the immediate vicinity of a reservoir following construction. Several studies (1, 2) have shown that reservoir construction significantly influences the value of land surrounding the reservoir. Prebble found that land use change varies with the general location around the periphery of the reservoir, the specific location on a given peninsula, physical characteristics of the site and road access to the site (3). Another study found that the change in business activity in the vicinity of a reservoir was small, and that the principal impact was on the residential rather than the commercial sector (4).

There is no known research that attempts to measure the "differential" impact of reservoir construction on the pattern of land use change in the immediate vicinity. The term "differential" is used here to signify the difference between land use patterns that actually exist after the construction of the reservoir and the land use pattern that would have existed in the same time period if the reservoir had never been constructed. Also neglected is the rate of change of land transformation from agricultural to nonagricultural uses as the result of reservoir construction. With pending land use legislation (5), land use planners will be increasingly faced with questions concerning land use change associated with and resulting from reservoir construction. The analytical framework presented in this paper will provide a useful conceptual model for evaluating differential land use change.

The following discussion will develop the methodology for estimating the differential change in land use resulting from reservoir construction. In a subsequent section the differential land use change resulting from the construction of Keystone Reservoir will be estimated and discussed.

METHODS

For the most part, previous studies have used the traditional before-and-after or control-area approaches coupled with regression analysis to estimate the changes associated with reservoir construction. However, the before-and-after approach is considered inappropriate because of the difficulty of distinguishing land use change associated with reservoir construction from

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land use change associated with changing economic conditions and other factors. The control-area approach suffers from two limitations: finding a comparison area similar in all respects but without the presence of a reservoir; and, assuming that the difference in land uses between the two areas is solely due to reservoir construction.

An accurate estimation of the impact of reservoir construction requires the determination of differential land use change. Differential land use change is estimated by comparing the projected land uses had not the reservoir been constructed with actual land uses following the reservoir construction. Pre-investment patterns (patterns existing in a time period prior to reservoir construction) of land use change are used to project land use patterns that would have existed in the future if the reservoir had not been constructed.

The long-term implications of the impact of reservoir construction on surrounding land use change may also be estimated using the same basic approach. For information of this nature, a post-investment time period (time period following reservoir construction) is used to project future land use patterns existing after reservoir construction. The difference between estimates of future land use patterns based on pre-investment and post-investment time periods is a measure of the future differential impact of the investment.

An appropriate method for projecting future land use patterns is the stationary Markov chain process. A Markov process is a statistical technique which may be used to project future land use patterns based on previous observed land use change. Movements from one land-use category to another between two points in time are summarized in a transition (flow) matrix. If the transition from one category to another is regarded as a stochastic process with a known probability of occurrence, then the Markov process generates estimates of land use patterns for an infinite number of future time periods. The specific conceptual and statistical techniques employed in this study are fully explained in an earlier paper (6).

Keystone Reservoir, located approximately 20 miles west of Tulsa, Oklahoma, was authorized for construction under the Flood Control Act in 1950 by the Army Corps of Engineers. Construction of Keystone Dam began in January of 1957 and was completed for flood control operation in September 1965. Keystone Reservoir was chosen for study because it is a large multiple-purpose project located near an urban area and it has been in existence long enough to influence surrounding land uses.

The selected period of study is 1948 to 1970, with two subperiods: 1948-1958 and 1964 to 1970. The two subperiods represent respectively, the pre-investment and post-investment time periods. Land uses were defined and grouped into categories corresponding to the land uses shown in Table 1. Land use patterns in approximately 3,000 sample areas were quantified at the beginning and end of each subperiod with aerial photographs obtained from the Army Corps of Engineers. Land use transition matrices for both the pre-investment time period and the post-investment time period were derived from these data and used in the Markov model to obtain land use projections (7).

RESULTS

The estimated differential land use change resulting from the construction of Keystone Reservoir for years 1964 and 1970 is shown in columns 7 and 8 in Table 1. Reservoir construction significantly increased nonagricultural uses of land with the

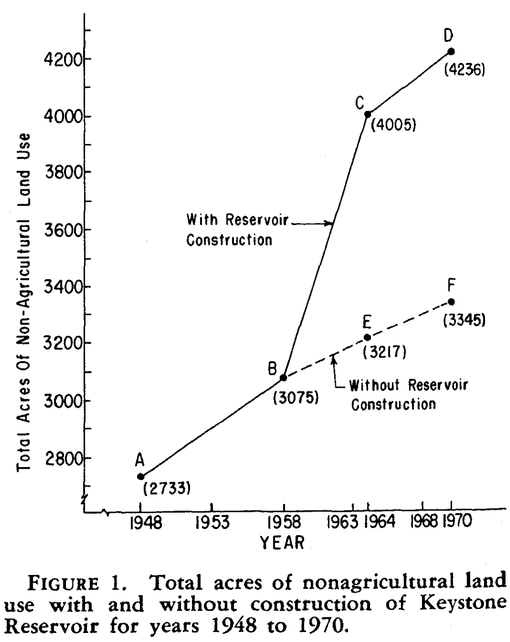

FIGURE 1. Total acres of nonagricultural land use with and without construction of Keystone Reservoir for years 1948 to 1970.

TABLE 1. *Actual and projected land use and differential land use change, Keystone Reservoir, Oklahoma.*

Land use	Actual land use (acres)				Projected land use (based on pre-investment time period 1948-1958) (acres)		Estimated actual differential land use change (acres)	
	1948	1958	1964	1970	1964	1970	1964[a]	1970[b]
Nonagricultural uses.								
Commercial	48	76	197	189	85	92	112	97
Extractive	78	280	313	347	345	399	−32	−52
Transportation	1,232	1,277	1,475	1,491	1,302	1,327	173	164
Utilities	507	495	714	689	490	485	224	204
Institutional	40	48	66	66	50	52	16	14
Residential	828	899	1,240	1,454	945	990	295	464
Subtotal	2,733	3,075	4,005	4,236	3,217	3,345	788	891
Agricultural uses								
Impoundments	237	318	441	422	346	369	95	53
Cultivated	6,108	6,485	3,493	2,883	6,693	6,883	−3,200	−4,000
Pasture	29,983	34,404	33,154	32,847	36,057	37,507	−2,903	−4,660
Woodland	52,610	47,389	50,577	51,282	45,358	43,566	5,219	7,716
Subtotal	88,938	88,596	87,665	87,434	88,454	88,325	−788	−891
Total	91,670	91,670	91,670	91,670	91,670	91,670		

Note: Column totals may not equal column sums because of rounding error.
Column subtotals may not equal column subtotal sums because of rounding error.
[a]Third column of data minus the fifth.
[b]Fourth column of data minus the sixth.

exception of extractive land uses. The decrease in extractive land uses such as oil drilling probably reflects the impact of increased easement costs for drilling rights associated with the shift to nonagricultural uses in the area. Increases in transportation and utilities land uses reflect the necessary rerouting of roads, highways, power lines, and railroads within the reservoir area. There were large increases in residential land uses; moreover, in 1970 residential uses accounted for more than half of the increase in nonagricultural uses. As might be expected, commercial and institutional land uses increased in the area as the result of increased recreational and residential activities.

The data in Table 1 are summarized graphically in Figure 1. Actual nonagricultural land use from year 1948 to 1970 follows line ABCD. Line segment BC reflects the sharp increase in nonagricultural uses of land that occurred during the construction phase of the reservoir. Estimated nonagricultural land use—assuming that reservoir construction had not occurred—is represented by line ABEF. The comparison of the two lines reflects the increase in nonagricultural land use as a consequence of reservoir construction.

Agricultural land use decreases necessarily correspond to nonagricultural land use increases. However, within the agricultural land uses, the differential impact caused a decrease in cultivated and pasture lands while woodland acreage increased. This phenomenon suggests that after reservoir construction more emphasis was placed on the esthetic attributes of the area as a complement to the newly created residential, recreational, and leisure opportunities.

The over-all, long-term differential land use changes associated with reservoir construction are shown in columns 5 and 6 of Table 2. Each entry is the difference between the estimated land uses for the appropriate years projected by the post-investment and pre-investment transition matrices.

The bar graph analysis in Figure 2 traces the pattern of nonagricultural land use change with and without reservoir construction. Without reservoir construction the additional nonagricultural land use immediately following the construction was 128 compared to 279 additional acres that would have been added after the year 2000. However, with reservoir construction, the increase in nonagricultural land use is estimated to be much larger for both time periods. This suggests that reservoir con-

TABLE 2. ***Projected land use and projected differential land use change, Keystone Reservoir, Oklahoma.***

	Projected land use (acres)					
	Based on pre-investment time period (1948-1958)		Based on post-investment time period (1964-1970)		Projected-differential land use change (acres)	
Land use	2000	∞	2000	∞	Projected 2000[a]	Projected ∞[b]
Nonagricultural uses						
Commercial	102	104	188	201	86	97
Extractive	494	513	399	412	−95	−101
Transportation	1,420	1,516	1,548	1,624	128	108
Utilities	473	465	617	575	144	110
Institutional	56	57	62	60	6	3
Residential	1,168	1,337	2,146	2,804	978	1,467
Subtotal	3,713	3,992	4,960	5,676	1,247	1,684
Agricultural uses						
Impoundments	414	427	372	351	−42	−76
Cultivated	7,394	7,586	2,441	2,401	−4,953	−5,185
Pasture	40,795	41,927	31,187	30,462	−9,608	−11,465
Woodland	39,353	37,737	52,709	52,779	13,356	15,042
Subtotal	87,956	87,677	86,709	85,993	−1,247	−1,684
Total	91,670	91,670	91,670	91,670	----	----

Note: Column totals may not equal column sums because of rounding error.
[a]Third column of data minus the first.
[b]Fourth column of data minus the second.

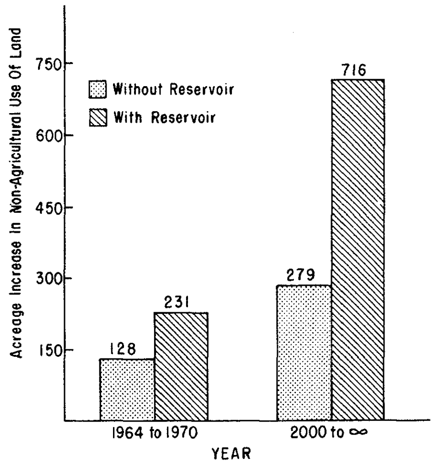

FIGURE 2. Change in nonagricultural uses of land with and without reservoir construction during two time periods: Keystone Reservoir.

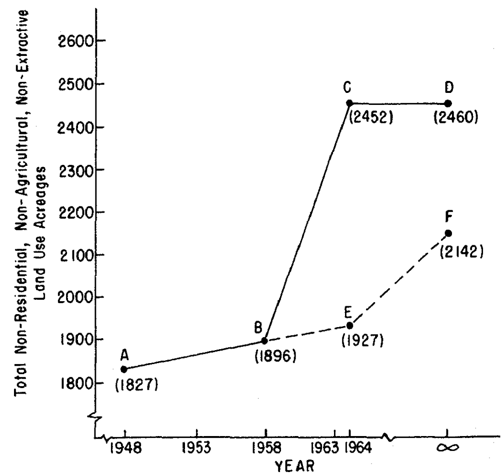

FIGURE 3. Total nonresidential, nonagricultural, nonextractive land uses in the Keystone Reservoir area for selected years.

struction does significantly increase the rate of change from agricultural to nonagricultural land uses. Moreover, the rate of increase with reservoir construction is relatively greater in the after-2000 period, indicating that the total differential impact will be realized over an extended time period.

The estimated differential land use results of Table 2 are generally similar to those of Table 1; however, there is one interesting difference. The differential land use changes in Table 2 indicate that for the long-term agricultural uses the pattern observed between 1964 and 1970 generally continues, but in the nonagricultural uses the previous pattern of change does not continue. In fact most of the significant nonagricultural change after 2000 occurs in the residential category. The other nonagricultural land uses remain relatively constant.

This result is particularly apparent in Table 3, which shows the percentage distribution of the total nonagricultural differential land use impact in selected years. The results in Table 3 indicate that the early differential impact on nonagricultural, nonresidential land uses is relatively important, but that over time the projected differential change of these land use categories steadily declines. What this suggests is that reservoir construction immediately stimulates infrastructure or facilitative investments asso-

TABLE 3. *Incidence of actual and projected nonagricultural differential land use, Keystone Reservoir, Oklahoma.*

Land use	Total land use differential within selected land uses, %			
	Actual Differential land use, %		Projected Differential land use, %	
	1964	1970	2000	
Commercial	14.21	10.89	6.90	5.76
Extractive	—4.06	—5.84	—7.62	—6.00
Transportation	21.95	18.41	10.26	6.41
Utilities	28.43	22.90	11.55	6.53
Institutional	2.03	1.57	0.48	0.18
Residential	37.44	52.08	78.43	87.11
Total	100.00	100.00	100.00	100.00

Note: Each entry shows the proportion of the estimated total differential increase in nonagricultural land use resulting from the construction of the reservoir for each land use category.

ciated with land uses such as transportation and utilities. These land uses increase at a rate far in excess of the pre-investment rate causing a relatively large, relatively early differential impact illustrated by line segment BC in Figure 3. Line segment CD in Figure 3 shows that after the construction of the reservoir is completed, there is little additional land use conversion to these uses. In later time periods, the land use pattern that would have existed if the reservoir had not been constructed gradually catches up with the post-investment land use pattern as shown by line segment EF. Over time this catch-up process reduces the differential impact for nonagricultural, nonresidential uses.

The projected patterns of residential land use change are shown in Figure 4. Lines ABCD and ABEF represent residential land use with and without reservoir construction respectively. Line ABCD shows that an increase in residential activity accompanies reservoir construction and continues into the indefinite future. This secular increase in residential activity over time suggests that the construction of a reservoir significantly improves the esthetic qualities of the area, thereby increasing the desirability of the area for suburban and/or second homesite construction.

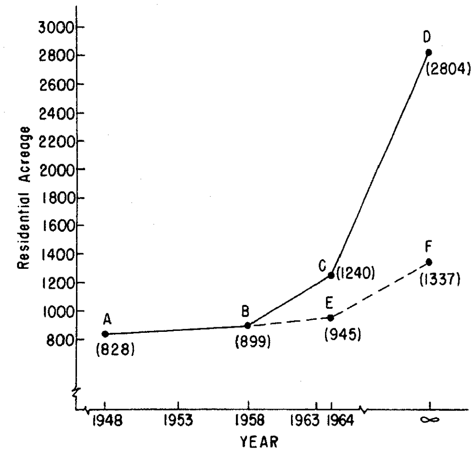

FIGURE 4. Residential land use in the Keystone Reservoir area for selected years.

DISCUSSION

Estimates generated by a Markov model of differential land use change predict a substantial change in land use and a significant increase in the rate of change of nonagricultural land use associated with the construction of Keystone Reservoir. The results of the study also provided valuable insights into the additional or differential long-term land use changes resulting from reservoir construction. Such information should supply professional planners with an improved conceptual understanding of the land use change impacts of reservoir construction. The study also illustrates a technique for producing improved estimates of reservoir-impacted land use change. Such a technique should provide professional planners with a land use change estimation tool which should be beneficial in benefit-cost analyses of project feasibility.

At the heart of the method used for projecting land uses in this study is the assumption that transition probabilities remain constant through time; that is, trends in land uses in the base period continue in the future. Future research should include an investigation of how transition probabilities change over time to allow the development of a system of nonstationary transition probabilities which would compensate for changing economic conditions.

REFERENCES

1. JACK L. KNETSCH, J. Farm Econ. 46: 231-43 (1964).
2. W. A. SCHUTJER and M. C. HALLBERG, Am. J. Agri. Econ. 50: 572-83 (1968).
3. BILLY R. PREBBLE, *Patterns of Land Use Change Around a Large Reservoir,* Water Resource Institute, University of Kentucky, Res. Report No. 22, 1959.
4. DONALD J. EPP, *The Economic Impact of Recreational Water Reservoir Development on Land Use, Business Enterprises, and Land Values,* Pennsylvania Agricultural Experiment Station Bull. 764, 1970.
5. COUNCIL OF ENVIRONMENTAL QUALITY, *Environmental Quality: The Fifth Annual Report of the Council on Environmental Quality,* Washington, D.C., 1974, Chapter 1.
6. LONNIE R. VANDEVEER and H. EVAN DRUMMOND, Oklahoma Experiment Station Professional Paper forthcoming, in press.
7. O. A. CLEVELAND, RICHARD E. JUST, and MICHAEL S. SALKIN, *Application of Markov Chain Analysis,* Oklahoma Agricultural Experiment Station Res. Report P-707, 1974.