Forage Production on a Clay Upland Range Site in Western Kansas[1]

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Highlight

Forage production on clay upland range sites is related to seasonal precipitation, with May + June precipitation the most reliable predictor of total forage production. Annual carrying capacities, based on May + June precipitation, for a clay upland site range from 2 acres/AUM in wet years through 3 acres/AUM in average years to 4 acres/AUM in dry years.

Effects of climatic factors on plant growth have been intensively studied and general influences of such factors on anatomical, morphological, and physiological development of plants are well known. Plant and moisture relationships have been particularly emphasized because of the influence of precipitation and soil moisture on forage production, vigor of growth, seed production, chemical composition, vegetative composition, and ecological succession.

Professional range and livestock managers, conservationists, and ranchers are interested in forage production since grazing capacity of a range and livestock production are intimately related to the quantity of usable forage produced. Since the grasslands of western Kansas are generally deficient in precipitation, production is closely related to the effective moisture that penetrates the soil.

Tomanek and Albertson (1957) studied production of native prairies during 1952 and 1953, during which precipitation was below normal. Production declined with increased grazing intensity and with prolonged abnormal climatic conditions. Tomanek (1948) reported that yields on moderately grazed ranges were markedly greater than on ungrazed or heavily grazed ranges. Albertson et al.

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(1953) reported results of a six-year study of the effects of different intensities of clipping on prodution. A close relationship was noted between amount and time of growth and precipitation. Yield, where not influenced by clipping, was approximately 100 lb/acre for each inch of summer rainfall.

Such production records become more important when related to some easily discernible natural environmental factor and when used to predict future range conditions and stocking capacities. If range condition and production can be predicted with confidence, ranchers can adjust herd size early in the season and thus much damage to forage and soil from overgrazing may be avoided.

The Great Plains is a risky production area for agriculture partially because of variable forage supply. As long-time production records have accumulated and because ranching operations and management decisions are dependent on forage production, many investigators have attempted to correlate climatic factors with production.

Smoliak (1956) investigated the influence of six meteorological factors on forage produced in 1953 on shortgrass rangeland and found that May + June precipitation was significantly correlated with yield. By using a regression equation, forage production and grazing capacity was estimated as early as July 1.

Reinert (1962) studied the influence of temperature, precipitation, and soil moisture on wheat yields and shortgrass production in Ellis County, Kansas and found early season precipitation important in influencing shortgrass yields but not as important in influencing wheat yields.

Currie and Peterson (1966) used regression analyses to determine the influence of monthly precipitation on forage yields of crested wheatgrass grazed at different seasons of the year. Precipitation accounted for 88 to 97% of the differences in yields. When ranges were grazed in both spring and fall, April and May precipitation governed spring yields while June and July precipitation influenced fall yields.

The present study was conducted in the Mixed Prairie near Hays, Kansas. Production has been recorded on three range sites since 1940, but only the clay upland site is reported upon in this paper. The data have been analyzed with the following objectives in mind: (1) prediction of forage yield from a known climatic factor, (2) description of vegetational responses to climatic conditions on a long-term basis and (3) interrelations between climatic conditions.

Methods and Procedures

At least five 9.6-ft^2 plots on the clay upland sites, and in many years 10 to 12, were clipped monthly from May 1 to September 1. Vegetation was clipped with hand shears, leaving a stubble of approximately one inch, and separated into mid-grass, shortgrass, forbs, and weeds. Each year different plots were clipped on the site. All plots were protected from grazing livestock by portable exclosures. Herbage was air-dried, weighed, and converted to pounds per acre.

Precipitation data are taken from the monthly and annual summaries of reports issued by the U.S. Department of Commerce.[2] The official weather station from which the precipitation data were compiled is maintained at the Fort Hays Experiment Station, slightly over two miles from the study location.

All statistical procedures followed generally accepted methods as presented in introductory texts on the subject.

Detailed description of habitat and vegetation may be found in Albertson (1937). In general, the clay upland range site supports primarily blue grama (*Bouteloua gracilis*)[3] and buffalo grass (*Buchloe dactyloides*). Other species contributing to total vegetative cover are western ragweed (*Ambrosia psilostachya*), slimflower scurfpea (*Psoralea tenuiflora*), sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus crytandrus*), western wheatgrass (*Agropyron smithii*), and, in years of ample moisture, Japanese brome (*Bromus japonicus*). Soils of the upland are deep and heavy textured. Forbs and weeds characteristic of the site are: salmon-colored mallow (*Malvastrum coccinium*), prairie coneflower (*Ratibida columnifera*), western ragweed, few-flowered scurfpea (*Psoralea tenuiflora*), and annual sunflower (*Helianthus annuus*). The last species, along with Japanese brome, is the main weedy annual.

Results and Discussion

Vegetational Fluctuations

The grasslands of the Central Great Plains are subject to dramatic fluctuations in the composition and productivity, which result from drought periods that are characteristic of a highly variable continental climate. Changes in the composition and cover of upland shortgrass communities have been well documented (Albertson and Tomanek, 1965).

Growth conditions were poor in the period from 1931–1937, just prior to the start of this study. In 1941, the grasslands of western Kansas were recovering from the severe drought of the 1930's. Thus, the project began at a time when the productivity of the grasslands was probably depleted in vigor.

During the 1940's the growing conditions were good (Table 1), with no periods of marked drought,

[2] Climatological data for Kansas, vol 53 to 76, 1939–1962.

[3] Common and scientific names follow those of Anderson (1961).

Table 1. Selected precipitation values and forage production estimates for clay upland range site near Hays, Kansas, 1941–1964.

Years	Apr-Sept	April	May	June	July	May + June	Mar-June	Annual	Previous season	Forbs prod.	Weeds prod.	Mid-grass prod.	Short-grass prod.	Total prod.
1941	21.66	4.61	2.86	6.40	0.63	9.26	6.98	28.13	16.99	43.6	3296.6	0.0	848.2	4188.4
1942	23.42	4.74	4.92	7.04	2.90	11.96	8.87	29.61	21.66	29.3	1436.9	7.3	1637.2	3110.7
1943	12.82	1.45	2.52	1.01	2.83	3.53	1.76	16.19	23.42	130.8	59.4	2.8	672.7	865.7
1944	21.21	4.71	2.77	1.08	6.78	3.85	3.14	29.70	12.82	7.4	200.2	1.3	1775.6	1984.5
1945	17.46	3.63	3.78	5.29	1.67	9.07	5.37	20.34	21.21	147.8	0.0	0.0	1315.0	1462.8
1946	17.38	1.03	6.47	1.05	2.18	7.52	2.53	26.48	17.46	41.8	2.5	0.0	520.5	564.8
1947	17.52	2.22	5.31	6.98	0.87	12.29	8.13	22.65	17.38	139.5	1385.2	25.1	1605.7	3155.5
1948	19.53	0.40	3.04	7.72	5.57	10.76	10.15	26.19	17.52	258.4	443.4	12.4	2839.6	3553.8
1949	17.13	1.80	3.31	8.32	0.86	11.63	9.98	23.62	19.53	81.9	384.4	8.5	1963.2	2438.0
1950	21.57	0.76	6.12	1.04	6.00	7.16	1.63	25.59	17.13	25.2	1211.3	64.1	2592.1	3893.3
1951	37.45	3.47	7.29	13.13	4.69	20.42	14.88	43.34	21.57	290.2	402.1	74.0	2877.1	3643.4
1952	9.06	2.92	1.98	0.17	1.87	2.15	2.06	13.39	37.45	459.1	0.0	82.9	1359.5	1901.6
1953	14.11	1.25	1.64	2.67	5.22	4.31	4.66	21.07	9.06	391.9	0.0	59.4	1601.5	2052.8
1954	15.65	1.73	5.57	2.65	1.06	8.22	2.87	18.56	14.11	115.8	339.5	105.4	2056.8	2617.5
1955	19.42	3.01	2.48	3.70	2.09	6.18	3.85	21.16	15.65	17.9	688.6	184.8	1420.7	2298.2
1956	7.00	1.28	1.42	0.38	2.79	1.80	0.55	9.21	19.42	27.6	584.7	44.0	852.7	1509.0
1957	23.48	2.14	4.08	6.74	3.11	10.82	9.18	28.33	7.00	123.8	336.0	120.7	2491.7	3072.2
1958	24.82	1.62	6.81	2.33	7.82	9.14	6.31	31.21	23.48	166.3	456.3	49.7	4221.0	4893.3
1959	19.04	0.53	6.40	1.55	3.62	7.95	2.38	24.43	24.82	349.5	50.7	51.6	2043.9	2495.7
1960	14.05	2.34	2.87	3.20	0.09	6.07	4.14	20.47	19.04	261.4	517.0	225.1	1407.7	2411.2
1961	23.70	1.27	4.52	4.70	3.45	9.22	6.03	28.31	14.05	295.1	956.8	177.3	2197.3	3626.5
1962	20.15	0.64	1.57	5.79	7.17	7.36	6.77	23.09	23.70	362.9	307.4	82.7	1952.5	2705.5
1963	18.51	0.05	0.95	3.07	5.00	4.02	4.77	22.17	20.15	123.0	78.9	167.7	1735.7	2105.3
1964	16.32	0.49	2.42	6.76	1.28	9.18	7.64	19.76	18.51	58.6	190.9	152.0	1249.7	1651.2
Average	18.85	2.00	3.79	4.28	3.31	8.07	5.60	23.87	18.88	164.5	555.4	70.8	1801.5	2591.7

just the highly variable annual rainfall typical of western Kansas. Production exhibited concomitant variations during these years.

The second major drought of the century occurred in western Kansas in the early 1950's. From 1952–1956, the precipitation was considerably below normal and the vegetation on clay upland sites responded in a predictable fashion. Cover, vigor and composition changes occurred, but not as dramatically as in the 1930's drought (Albertson and Tomanek, 1965).

The growing season of 1957 marked the beginning of two extremely productive years of grass growth. Seasonal and annual precipitation were above average, temperatures were cooler with consequent lowered evaporation. The results of these favorable years were culminated in 1958 when over 2 tons/acre of forage were produced on the clay upland range site.

During 1959, 1960, 1961, 1962, and 1963, the precipitation was variable from year to year and production figures reflected the total precipitation variations as well as variations in distribution of rainfall throughout the growing season.

The last year included in this project, 1964, was a dry year with seasonal and annual precipitation figures below average (Table 1). In particular, April, May and July were below average, while June was the only month in which above average precipitation was recorded. This dry spring was accompanied by a total yield on the upland range site that was below the previous year and the long-time average production for the site.

Climatic Interrelations

Several climatic interrelationships that ecologists have suspected to exist on the Kansas Plains were illustrated when the climatic factors were analyzed in a correlation matrix (Table 2).

The season of greatest precipitation is found in May and June. The coefficient of determination (r^2) between May and June precipitation and seasonal precipitation (April–September) was .63, indicating about two-thirds of the variations in seasonal precipitation could be accounted for by variations in May and June precipitations.

Mean annual temperature and seasonal evaporation are reduced when seasonal precipitation is high. This is a fairly apparent interrelationship in that rainy summers are usually cooler and have less evaporation. Augmenting the lessened evaporation is a reduction in wind velocity. Since wind velocity and evaporation are correlated (+ .41), a lowered velocity in seasons of high precipitation means less evaporation and thus more effective utilization of moisture by growing vegetation. The relationship of increased average seasonal temperature and sea-

Table 2. Simple correlation coefficients between climatic characteristics, 1941–1964, Hays, Kansas.

	May precip.	June precip.	May-June precip.	June-Mar precip.	Annual precip.	Seasonal average temp.	Mean annual temp.	Seasonal evapor. in inches	Seasonal wind veloc.
Seasonal precip. Apr-Sept	.585**	.647**	.792**	.695**	.961**	-.660**	-.452*	-.736**	---
April precip.	---	---	---	---	---	---	---	-.430*	---
May precip.	---	---	.625**	---	.607**	-.486*	---	.510*	---
June precip.	---	---	.885**	.965**	.597**	-.417*	---	-.433*	---
July precip.	---	---	---	---	---	---	---	---	-.397*
May-June precip.	---	---	---	.875**	.763**	-.562**	-.399*	-.586**	---
Mar-June precip.	---	---	---	---	.682**	-.455*	---	-.514*	---
Annual precip.	---	---	---	---	---	-.640**	-.412*	-.769**	---
Seasonal ave. temp. Apr-Sept	---	---	---	---	---	---	.727**	.772**	.493*
Mean annual temp.	---	---	---	---	---	---	---	.513**	.494*
Seasonal evapor. in inches	---	---	---	---	---	---	---	---	.412*
Seasonal wind vel. in mph	---	---	---	---	---	---	---	---	---

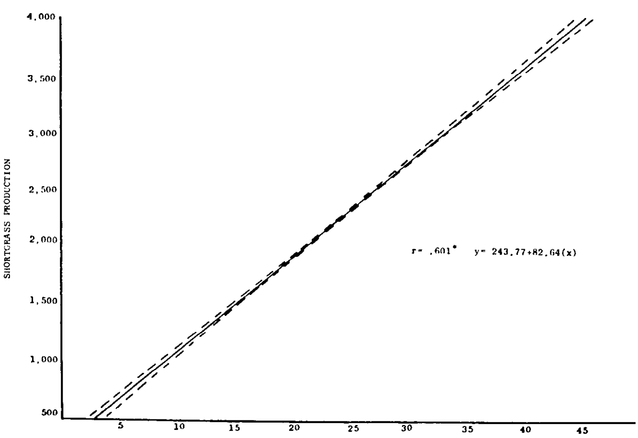
** P = 0.01

* P = 0.05

sonal evporation and seasonal wind velocity is apparent in Table 2.

Climate–Production Interrelations

Correlation analysis between selected climatic factors and vegetational production components indicated that precipitation in early months of the growing season was a major controlling influence on plant growth (Table 3). Seasonal precipitation (April–September) appears to determine the productivity of the vegetation on the upland site more than does preseasonal or winter precipitation (October–March). Reinert (1962) found similar results in comparing the production of wheat and perennial grassland as influenced by winter and summer precipitation. He found that the winter precipitation was correlated with the productivity of wheat (annual) but that winter precipitation was not correlated with the production of perennial grassland. The implication is that if insufficient



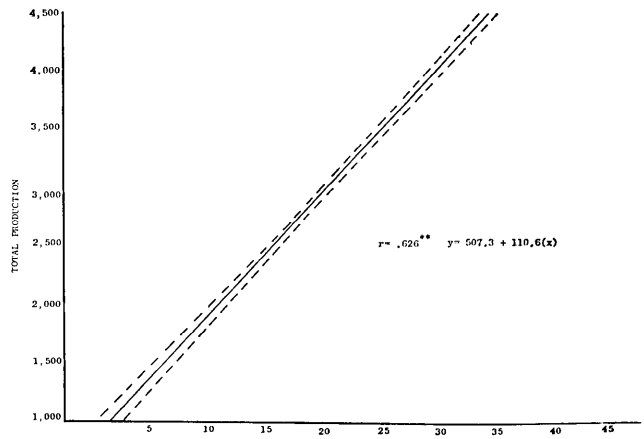


FIG. 1. Estimated shortgrass (left) and total production (right) in lb/acre on clay upland range site near Hays, Kansas, based on seasonal (April-September) precipitation (inches). Fiducial limits at 95% level.

Table 3. Simple correlation coefficients between climatic factors and production on clay upland range site, 1941–1964.

	Prod. of forbs	Prod. of weeds	Prod. of short-grass	Prod. total forage
Seasonal precip. Apr-Sept	---	---	.601**	.626**
April precip.	---	.434*	---	---
May precip.	---	---	.475*	.413*
June precip.	---	---	---	.403*
July precip.	---	---	.612**	---
May-June precip.	---	---	.451*	.516*
Mar-June precip.	---	---	.434*	.481*
Annual precip.	---	---	.567**	.592**
Seasonal ave. temp. Apr-Sept	---	---	-.566**	-.575**
Mean ann. temp.	---	---	-.609**	-.566**
Seasonal evapor. in inches	---	---	-.535**	-.550**
Seasonal wind vel. in mph	-.580**	---	-.480*	---
Prod. weeds	---	---	---	.573**
Prod. short-grass	---	---	---	.759**

** p = 0.01

* p = 0.05

precipitation is received in the early growing season months, there is not going to be high perennial productivity, even though the previous winter's precipitation might have been above average.

Our regression equations for the relationships between seasonal precipitation and shortgrass and total production indicate that with the average seasonal precipitation of 18.85 inches, shortgrass production is about 1800 lb/acre while total production from the upland site is about 2600 lb/acre (Fig. 1).

The difference between shortgrass production and total production is made up by three vegetational components of the upland range site: (1) weedy species (2) forb species and (3) other perennial grasses. The production of weedy species was most closely related to April precipitation (Table 3, Fig. 2). This may reflect the need for adequate early spring precipitation in order for germination of the seeds of weedy annuals. Field observation of fluctuations in growth of weedy species due to fluctuations in early spring precipitation indicate that this correlation is not spurious.

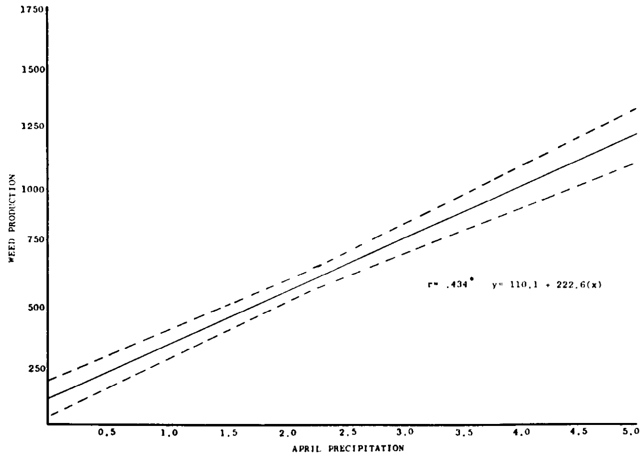


FIG. 2. Estimated weed production (lb/acre) on clay upland range site near Hays, based on April precipitation (inches). Fiducial limits at 95% level.

The contributions of forbs to the total production on the upland site varies greatly (Table 3). The only correlation between forb production and a climatic factor was with seasonal wind velocity. This may be a real association or it may reflect an intercorrelation of forb production and wind velocity with another determining factor. The latter explanation seems more plausible at this time.

Launchbaugh (1967) stated that high western ragweed yields were favored by moderate and light grazing and by moisture in excess of amounts the grasses could utilize in spring and early summer development.

The precipitation that occurs in the early months of the growing season, particularly May, is correlated with total and shortgrass production (Table 3). However, the major determinant of total production appears to be the total May + June precipitation. The correlation coefficient of + .516 was the highest observed between early season precipitation and total production. The linear regression equation (Fig. 3) indicates some degree of reliability in predicting total production based on precipitation received in this early segment of the growing season.

Considering an average May + June rainfall figure, the production estimate on the clay upland range site is $\hat{y} = 1{,}501.7 + 139.9\ (8.07)$ or about 2580 lb/acre, thus the error in this regressed estimate is less than 100 lb/acre. The annual carrying capacity of the clay upland range site is related to the May + June precipitation (Fig. 3). These carrying capacities are based on the following premises: (1) a 1,000-lb animal consuming 600 lb/month of forage and (2) a forage utilization figure of 50% or a "take half–leave half" policy, and (3) a grazing season of 6 months. Under a regime of 14 inches of precipitation in May and June, the carrying capacity for a six months grazing season would

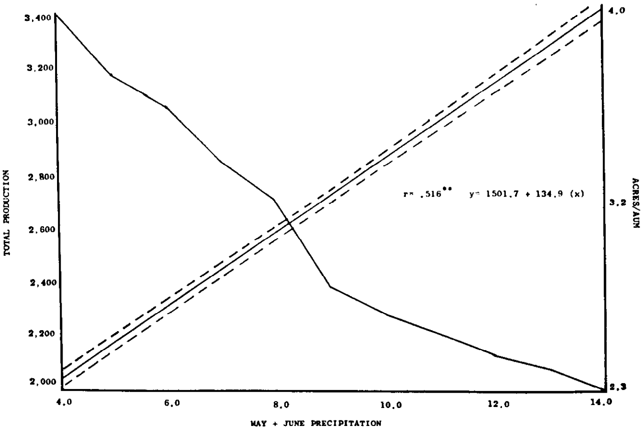


FIG. 3. Estimated total production (lb/acre) and carrying capacity (acres/AUM) on Clay upland range site near Hays, based on May + June precipitation (inches). Fiducial limits at 95% level.

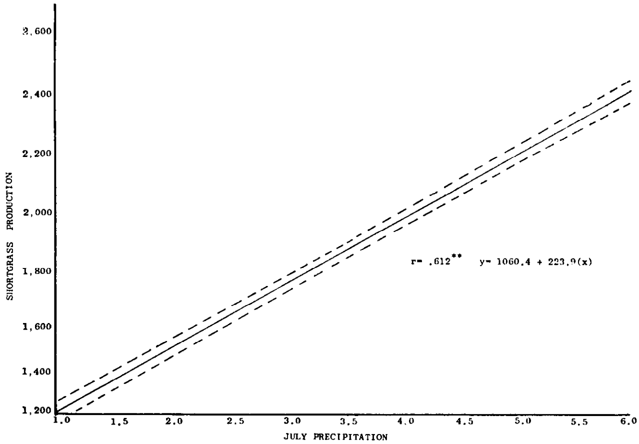


FIG. 4. Estimated shortgrass production (lb/acre) on clay upland range site near Hays, based on July precipitation (inches). Fiducial limits at 95% level.

be about 2.3 acres/animal-unit-month. This carrying capacity would correspond to the heavy grazing treatment of 2 acres/steer reported by Launchbaugh (1967) in his study of the clay upland range site. It would appear that Launchbaugh's estimate of 2 acres/steer as being heavy grazing is correct since the present study indicates a May + June precipitation of 14 inches would be needed to support such an intensity of grazing. In years of average May + June precipitation (8.07 inches) the carrying capacity is about 3 acres/AUM (Fig. 3), thus a stocking rate of 2 acres/steer would overgraze the site in "normal precipitation" years. The moderate grazing intensity of 3 acres/steer reported by Launchbaugh (1967) agrees with our figure of 3 acres/AUM for average May + June precipitation years. We estimated the lightest grazing intensity or carrying capacity at 4 acres/AUM; this would occur under the drought years when May + June precipitation was 4 inches. Launchbaugh reports his lightly grazed areas at a carrying capacity of 5 acres/steer. In general, the results of this investigation give stocking rates that are commensurate with May + June precipitation and in agreement with those reported by Launchbaugh.

Reinert (1962) and Launchbaugh (1967) reported on the prediction of shortgrass yields using precipitation as the predictor. Their data agree closely with the present investigation in that preseason precipitation did not seem to be correlated with shortgrass yields. Reinert found September temperatures to be the best indicator of shortgrass production on clay uplands for the coming year. He reported a significant r value of + .46 between September temperature and shortgrass yields. The regression equation for his data was $\hat{y} = 125.8 + 1.49$ (x) where y = shortgrass yields in hundreds of lb/acre and x = September average temperature. The regressed values were subject to considerable error in the above equation due to wide fiducial limits at all levels of x. Nevertheless, Reinert's data are of interest because of the early date at which forage yields could be predicted. It is axiomatic that the earlier the date that forage production can be determined, the more flexible and utilitarian the relationship is to a rancher since he could then adjust his grazing management to the potential production for the coming season.

Launchbaugh (1967) found only the precipitation of the current year to be associated with total forage yield. He reported a coefficient of determination of 70.6 between the two variables. He did not analyze monthly precipitation records in his study.

Although the May + June precipitation predicted the forage production best in the present study, there was a close association between July precipitation and shortgrass production (Fig. 4). This results from the normal dormancy cycle of blue grama and buffalo being deterred by July rainfall.

The influence of soil moisture reserves on grass production was not analyzed in the present study. Reinert (1962) found no correlation between soil moisture level and shortgrass yields.

Conclusions

Forage production on clay upland range sites is more related to seasonal precipitation than to preseasonal or winter precipitation. May + June precipitation values are most reliable in predicting total forage production from clay upland sites. The production of weedy species is correlated with early spring (April) precipitation.

July precipitation is highly correlated with shortgrass production, a phenomenon probably related to a later entrance into dormancy by blue grama and buffalo grass.

Carrying capacities for a clay upland range site, based on May + June precipitation range from 2 acres/AUM in wet years through 3 acres/AUM in average years to 4 acres/AUM in dry years.

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Scientific and Technical Communication

Fifty-five recommendations for coping with the accelerating growth of technical information—the main product of much of the $27 billion research and development enterprise in the United States—were issued today by the National Academy of Sciences and National Academy of Engineering.

Completing a three-year study of the complex processes by which the results of research are disseminated throughout the scientific world, a special joint committee of the two Academies called for steps to avert under-utilization of our scientific and technical knowledge —"a waste that we must not tolerate."

In a 30-page synopsis of its full report, the Committee on Scientific and Technical Communication (SATCOM) emphasized the need for maintaining the pluralistic, diverse nature of communication activities in science and engineering—as opposed to the creation of any monolithic, centralized system.

During most of this century the amount of new research published has been doubling every 10 to 15 years. Roughly 40,000 research papers are published each year in physics, several times that number in chemistry, biology, and agriculture. SATCOM estimates that in all fields of science and technology, the number of papers annually may total two million. They appear in some 30,000 different specialized journals.

The communications process includes not only publication of original findings in journals but also reviews, surveys, abstracts, indexes, bibliographies, library services, reprints, meetings, and personal contact.

The scientific and technical information that flows through this system is the main product of research, for which the annual expenditure in the United States exceeds $5 billion. It is also the main product of certain areas of development (which accounts for an additional $22 billion) and is an essential input to all new research, all new developement, and most practical applications of the two.

Despite many criticisms directed at the present system, SATCOM found no evidence of critically inefficient operation or catastrophic failure. The basic structure is sound. Nevertheless, the many problems brought about by expanding needs make necessary measures directed toward more effective coordination, planning, and management.

SATCOM's first recommendation calls for the establishment of a Joint Commission on Scientific and Technical Communication. Its role would be to stimulate greater coordination among private groups and to bring them into closer touch with government agencies. The NAS and the NAE, with their established prestige, nongovenmental status, and close working ties with scientists, private organizations, and federal agencies, are the best possible base for the Commission.

The second recommendation outlines a philosophy of shared responsibility among government and private organizations for the effective communication of scientific and technical information. Those who support research-and-development work have a responsibility to see to it that the information generated becomes truly available. This should go beyond "mere publication of isolated tidbits scattered through a multitude of journals" toward acceptance of a broader responsibility to recognize the preparation and dissemination of information as *an integral part of the research work.*

Inherent in many of SATCOM's recommendations is the conviction that the scientific and technical societies—which were established to provide more effective channels of communication—have a crucial role to play. SATCOM challenges them to accept greater responsibilities.

Such responsibilities include improving the quality, timeliness, and techniques of producing and distributing primary literature; assuring adequate basic abstracting and indexing of the primary information; stimulating reprocessing and repackaging of information for special user groups; and conducting "exploratory and innovative studies," using qualified scientists, engineers, and practitioners to evaluate the performance of their information services.

The societies should take it upon themselves to encourage the preparation of more critical review articles and data compilations, an effort "which often requires great intellectual creativity." There is great need for such works, which organize and evaluate what is known about a subject and present it in language that can be understood.