Innovations in Agricultural Technology: Assessment of Constraints and Performance in Benin

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6. SUMMARY, CONCLUSION AND POLICY RECOMMENDATIONS

Soil degradation due to pressure on land is one of the major problems of agricultural sector in southern and central Benin. It has been found that maize, principal food crop of Benin, yields less than half a ton per hectare in these areas where traditional ways of restoring soil fertility, namely fallow is disappearing and the adoption of new agricultural technologies is constrained by limited access to inputs and outputs markets. Research on "Adapted Farming Systems in West Africa" has been going on since 1980s in these areas. Agro-forestry technologies were suggested as one way of restoring soil fertility. In 1994 on-station research on these technologies was complemented by on-farm trials. Various leguminous, especially Acacia auriculiformis and Cassia siamea were introduced in the farming systems. Subsequently, the use of NPK-fertilizer in combination with mulch resulting from these species was recommended as technologies to stabilize crops' yield over time. However, it is not yet known whether the recommended options are able to bring to a halt the problem of decreasing soil fertility and whether they can increase farmers' income in a sustainable way. The present study tries to answer these questions.

The work is organized into six chapters. The first chapter presents the research problem and the objectives of the present study. The second chapter describes the study areas and present some socio-economic characteristics of farmers selected for the study. The third chapter assesses and compares the economic profitability of various technologies and the impact of policy changes on profitability. The fourth chapter is devoted to the analysis of production efficiency of farmers using various technologies. The fifth chapter investigates the issue of risk involved in the use of each technology and the impact of policies such as improving farmers' access to fertilizer markets on farm plans, resource allocation and crops' income. The last chapter concluded the work with some observations on policy implications.

6.1 Objectives of the study

The major objective of the present work is to assess the economic performance of various technologies developed by SFB 308 in collaboration with farmers and to identify constraints to their adoption in southern and central Benin.

The study aims specifically at:

- Assessing the economic profitability of technologies combining NPK-fertilizer with mulch resulting from Cassia siamea or from Acacia auriculiformis in crop production activities;
- Analyzing farmer's technical efficiency and its determinants in considered agricultural technologies;
- Assessing the effect of risk aversion on farmers' investment behavior in various agricultural technologies.

In line with these objectives three hypotheses are proposed:

i. Technologies combining mulch resulting from Cassia siamea or from Acacia auriculiformis with NPK-fertilizer are economically profitable and improve factors' productivity in the study areas;

ii. Farmers show technical efficiency in technologies combining mulch resulting from Cassia siamea or from Acacia auriculiformis with NPK-fertilizer. Their socioeconomic and demographic characteristics, the origin of mulch as well as characteristics of zones are the main determinants of farmers' technical efficiency;

iii. Various technologies are risk-efficient within the context of liberalized input market and at the farmers' level of technical efficiency, price and yield levels. Risk aversion differs among regions.

6.2 Data and data analysis

The data were collected in two zones, one in southern and the other in central Benin during the agricultural year 1998/1999. Structured questionnaires were administered to a sample of 140 farmers, comprised 70 farmers randomly selected per zone. Personal interviews were conducted and on-farm experiments were carried out. Information was gathered on farm income, expenditures on fertilizer, on seed, on pesticide, on herbicide, quantity and type of labor used in production activities. Detailed data on socio-economic characteristics of households were collected. These data were supplemented with secondary data from official records of institutions operating in rural areas in Benin. Various reports on SFB-308 projects were utilized.

Data on prices were collected at local and regional markets and secondary data provided time series of yields and market prices. Laboratory analyses of soils' samples collected in farmers' fields contributed to information on soil fertility.

6.3 Analytical framework

Various technologies in the study areas were assessed by analyzing their economic profitability, keeping in view the technical efficiency of farmers using those technologies and also the risk related.

The analysis of economic profitability helped identifying technologies into which typical farmers of southern and central Benin would have a comparative advantage to invest. Indicators of economic profitability such as the Domestic Resource Cost Ratio at private or social prices and the Resource Cost Ratio were generated for the analysis of the economic profitability. In addition to these, measures of policy incentive, namely the Nominal Protection Coefficient, the Effective Protection Coefficient, the Net Private Profit and the Net Social Profit were calculated in order to assess the distortionary effects of government intervention in both input and output markets.

An analysis of the technical efficiency provided information on the reason for failure to produce maximum output from various technologies as well as on possible over-utilization of inputs in various technologies. A stochastic frontier production approach was used to derive the level of technical efficiency of farmers in each technology, using a Maximum Likelihood Estimation technique. Determinants of technical efficiency were then investigated using a regression analysis based on Ordinary Least Squared technique.

Risk analysis was conducted to judge the sustainability of the performance of various technologies over time. Risk associated to the adoption of various technologies was evaluated within a portfolio context using a Quadratic Programming Model. Optimum farm plans were derived for each zone and the impact of changes in economic parameters on the optimum farm plans and on crops' income were investigated.

In conclusion, both positive and normative approaches were used, because the study combines ex-post as well as on ex-ante analyses for assessing past and predicting future events.

6.4 Results

The main results of the study are presented in this section by looking at soil fertility, economic profitability, technical efficiency, risk and policy implications.

6.4.1 Soils and their potentials in the study areas

The investigation of the status of soil fertility in the study areas indicates that two types of texture characterize soils of each zone. The Loamy-Sand and the Sandy textures were found in the Center while the Loamy-Sand and the Sandy-Loam textures were found in the South. The majority of soil's samples analyzed have the Sandy-Loam texture in the South whereas the Sandy texture dominates in the Center.

Features such as cation exchange capacity (CEC), organic carbon, pH and macronutrients content, which characterize the status of soil fertility, suggest that in both zones soils are of low fertility. The status of fertility varies, however, among types of soils. The Sandy-Loam soils have a relatively high value of CEC in both zones. In terms of soils' acidity, values of pH indicate that soils of the South were strongly to moderately acid (pH ranging between 5.70 and 6.20 for Sandy-Loam soils, and between 5.40 and 6.20 for Loamy-Sand soils). As a consequence, phosphorus may be less available for plants in the southern zone, because its solubility is highly pH dependent. In contrast, soils of the central zone are relatively more acid, and thus more favorable for phosphorus release. Soils of both zones have high need for potassium fertilizer and for water preserving, because of the presence of the sandy texture. The organic matter content was found to be good except for Sandy soils of the central zone. Consequently, soils with Loamy-Sand texture of the South are likely to be slightly than the Sandy-Loam soils of the same zone. The least fertile soils are likely the Sandy soils of the Center.

The great variability in soil chemical and physical characteristics requires that management practices be very location specific and appropriate to the local soil. A regional specialization in the production of crops is required, which makes use of the differences in local comparative advantages. Very efficient marketing systems are required for fully mobilizing the resources in such heterogeneous environment.

6.4.2 Economic profitability of technologies

The choice of crops and technologies used for the analysis was based on data availability and potential importance in the farming system of the southern and central Benin. Four crops (maize, groundnuts, soybeans and cotton) were found relevant and the investigation of their economic profitability was carried out in the context of assessing four different technologies. The technologies comprises (a) the traditional farming system, (b) the farming system using mulch resulting from Acacia auriculiformis or from Cassia siamea, (c) the farming system using NPK-fertilizer and (d) the farming system using NPK-fertilizer in combination with mulch resulting either from Cassia siamea or from Acacia auriculiformis. Even though yam as well as cassava production activities would have also been relevant for the study areas, sufficient data were not available. Therefore, yam and cassava could not be considered in the analysis.

The Domestic Resource Cost ratio generated for each technology at the private and social prices shows that at the prevailing prices and policies, individual farmers have comparative advantage to adopt technologies that are privately profitable and the two zones have comparative advantages in adopting technologies where these are socially profitable. Some technologies are economically profitable only for some individual farmers, while other technologies are privately and socially profitable for entire regions (Table 6-1).

Except for soybean, all other crops show private and social profitability when NPK-fertilizer and mulch are used in combination, and therefore confer to individual farmers as well as to considered regions a comparative advantage in adopting them. All technologies using mulch resulting from Acacia or Cassia, alone, are also profitable for individual farmers. But from the social point of view, some technologies using mulch for maize production are not desirable (case of maize production using mulch resulting from Acacia in the South).

Changes in economic environment affect the economic profitability of technologies differently. The social profitability of some technologies, especially traditional farming systems or those using NPK or mulch is more sensitive to changes in FOB prices, CIF prices or labor costs, than those using NPK and mulch in combination. The private profitability of various technologies reacts relatively stable to policy changes.

Table 6-1 Agricultural technologies according to their economic profitability in the study areas

Items	Private profitability	Social profitability
South		
Maize Traditional	-	-
Maize Acacia	+	-
Maize Cassia	+	+
Maize NPK	+	-
Maize Acacia + NPK	+	+
Maize Cassia + NPK	+	+
Soybean traditional	-	-
Soybean Cassia	+	+
Soybean NPK	-	-
Soybean Cassia +NPK	+	+
Groundnuts traditional	+	-
Groundnut Cassia	+	+
Groundnuts NPK	+	-
Groundnuts Cassia +NPK	+	+
Center		
Maize Traditional	-	-
Maize Cassia	+	+
Maize NPK	-	-
Maize Cassia + NPK	+	+
Soybean traditional	-	-
Soybean Cassia	-	-
Soybean NPK	-	-
Soybean Cassia + NPK	-	-
Groundnuts traditional	+	-
Groundnuts with Cassia	+	+
Groundnuts NPK	+	+
Groundnut Cassia + NPK	+	+
Cotton NPK	+	+
Cotton NPK + Cassia	+	+

Note: + = Profitable; - = non-profitable.

The results of the investigation suggest that opportunities for diversifying production activities exist in the study areas if technologies are appropriate. As a consequence, Benin does not need to restrict its export economy only on cotton. Judicious combinations of mulch resulting from leguminous with NPK-fertilizer for food crops production will ameliorate considerably the contribution of these crops to the economy of the country and thereby, help to diversify the sources of income. This would also help in guarding against the risk of fluctuating cotton prices in the world market.

6.4.3 Managerial skill of farmers in various technologies

The production efficiency of farmers using various technologies is examined through a stochastic frontier production function approach. In this analysis, only maize- and cotton-based technologies are included while groundnut- and soybean-based could not be considered, because of a relatively small sample size.

Results indicate that farmers in both regions are not fully technically efficient in the use of various technologies. However, the level of technical efficiency was on average higher than 65% and ranged between 65.2 and 97.2% (Table 6-2).

Table 6-2 Average technical efficiency of farmers under various agricultural technologies in the study areas

Technologies	Average Technical Efficiency (in %)	
	Southern Region	Central region
Maize traditional	83.30	68.70
Maize with Cassia	92.30	97.20
Maize with Acacia	68.90	
Maize with NPK	81.80	77.80
Maize with Cassia +NPK	80.00	87.50
Maize with Acacia +NPK	65.20	-
Cotton with NPK		91.70
Cotton with Cassia +NPK		90.90
All traditional technologies together (both regions)	76.0	
All improved technologies together (both regions)	83.30	

Farmers in the Center as well as in the South are technically more efficient in maize-based technology using mulch resulting from Cassia. In the South they show lower level of technical efficiency in the technology where maize is cultivated using mulch from Acacia in combination with NPK-fertilizer. In cotton-based technologies, farmers in the Center show relatively high levels of technical efficiency.

Econometric analysis of the factors determining technical efficiency shows that farmers' socio-economic characteristics such as age of the head of household, level of education, experience in using mulch resulting from Cassia or from Acacia and access to credit are factors contributing significantly to the technical efficiency of farmers in both study areas. The influence of these factors varies however among agro-ecological zones.

In the South farmers who have access to credit are technically more efficient than farmers who have no access to credit. In the Center however, farmers' access to credit does not influence significantly their technical efficiency in the use of various technologies. As in the case of credit, farmers' experiences in using agro-forestry technologies significantly affect their technical efficiency only in the South. The estimated coefficient for age in the efficiency models was negative and significant in both regions, indicating that the technical efficiency decreases with age. Therefore, as technology users younger farmers are technically more efficient compared to older farmers.

Both study areas show potentials for higher crop yields. It is possible to produce more with existing technologies through the improvement of farmers' technical efficiency, because not all of them are using fully the potential of these technologies. Thus, the production can be increased by 3 to 35 % through the improvement of technical efficiency in the study areas, without introducing additional innovations. This is possible through the improvement of resource allocation by farmers. Efforts should focus more on the provision of appropriate and adequate on-farm research for better education of farmers in the use of existing technologies, the creation of better conditions of credit in the South, the raising of the level of education in both zones and the creation of conditions for better access to NPK and mulch resulting from Cassia or from Acacia. If efforts are concentrated on these, farmers' technical inefficiency can be minimized and thereby their living standard can be improved considerably.

6.4.4 Risk-efficiency of various technologies

Farmers in both zones dislike risk, as their risk aversion coefficient was found to be positive (1.2 for farmers in the South and 1.4 for farmers in the Center). Monetarily expressed, this risk aversion reduces by more than 30% the income from crop production activities in each zone.

Improved technologies using external inputs represent the largest component of the farm plans and contribute significantly to the crop income and to their stability in both areas. Therefore, the adoption potential of these technologies is high. But it was not possible to evaluate the performance of technologies using NPK-fertilizer in combination with mulch resulting from Acacia or Cassia in the South. For this reason, the adoption potential of technologies using mulch resulting from these trees without NPK-fertilizer should be interpreted with caution. In the situation of better access to markets offering fertilizer and thus allowing combining both inputs, mulch- only- technologies may play relatively minor role than they do at the moment.

All in all, three groups of technologies were identified from the results of the basic model in each zone:

i. Technologies that are individually non-economically profitable but contribute to reduce or to eliminate the risk of the portfolio of activities. Groundnut production in the traditional farming system in the South fits in this group.

ii. Technologies that contribute to increase the risk of the portfolio of activities. To this group belong activities such as maize production using NPK-fertilizer in the Center and soybean production in the traditional farming system in both zones.

iii. Technologies that have relatively small value of risk in the portfolio of activities. In the study areas the technologies using NPK-fertilizer and Cassia mulch in combination (for cotton production) or using Cassia mulch only (for maize production) fall in this group of technologies.

The analyses led to also investigate the implications of changes in economic and institutional conditions on optimum farm plans and on crop incomes. Results indicate that the optimum crop combination for each region is sensitive to variations in farmers risk attitudes, in availability of inputs and in the size of agricultural land. Farm plans are less diversified as the risk aversion decreases while the income from crop production activity increases. This illustrates that risk aversion can influence the relative profitability of a technology. Also, a better access to fertilizer markets increases the acceptability of improved technologies using mulch from Cassia siamea or from Acacia auriculiformis in combination with NPK-fertilizer.

Special emphasis is needed from the government or other development agencies to create incentives that facilitate an efficient use of the potential of improved technologies. Price and yields stabilizing policies are required for maintaining over time the profitability of these technologies. Conditions for better access to inputs market are necessary.

6.4.5 Desirability of existing technologies

Decision on the desirability of technologies considered throughout this study is complicated, because only a few numbers of technologies were found to be economically profitable and at the same time risk-efficient at a satisfactory level of technical efficiency of farmers using them. Also, some technologies that showed private profitability or social profitability or both but could not be included in the model of technical efficiency or in the model of risk evaluation

may also have the above desirable qualities. For simplification it was decided to classify all technologies into two groups (improved and traditional) and to draw conclusions on their relative desirability. Traditional technologies are those for which no external inputs are needed while improved technologies are technologies where mulch from leguminous, or NPK-fertilizer or both are used.

Considering the economic profitability, all improved technologies were found to be economically profitable for private farmers for maize, groundnuts as well as for cotton production. They were found to be non-profitable for private farmers only in soybean-based farming systems. In contrast, traditional technologies were economically profitable for private farmers only in groundnut-based technologies. From the social point of view, only maize and groundnut production using NPK in the South are economically non-profitable among improved technologies while all traditional technologies were found to be economically non-profitable. Based on these results we can conclude that improved technologies are desirable for individual farmers for central as well as southern Benin in maize-, groundnut- or cotton-based farming systems according to their economic profitability. Traditional technologies cannot be recommended for the improvement of the welfare in both zones.

With regard to the performance of farmers in these two groups of technologies, the lowest as well as the highest performance occurs in improved technologies as given by the value of the average technical efficiency of farmers (Table 6-2). However, when considering all improved technologies together, the average level of technical efficiency for improved technologies (83.30%) is higher than the average level of technical efficiency for traditional technologies (76%). Hence, it can be concluded that improved technologies add more value to inputs used, i.e., outputs obtained from a certain combination of inputs in improved technologies is on average higher than that obtained with traditional technologies. For this reason, improved technologies can be considered as more desirable than traditional one.

Risk affects the performance of both improved and traditional technologies, however, the model used does give information only on the relative risk aversion coefficient associated with each type of technology. Therefore, it is difficult to identify which technology has higher or lower risk. Nevertheless, the adoption potential of improved technologies in optimum farm plan was found to be significantly higher than for traditional technologies. Since the objective function incorporates risk and the farm plan derived from the basic model takes into account the relative

risk of each option, it can be concluded that improved technologies contribute positively to the minimization of the risk.

Based on the observations above, the study can conclude that improved technologies are more desirable than traditional technologies in southern and central Benin; improved technologies are economically profitable for individual farmers as well as for the society, they add more value to the use of inputs and they are more efficient in both increasing crop income and reducing income variability, i.e. risk related to farming activities.

6.4.6 Technical and Policy recommendations for future development

Results of soil analyses suggest that soils of the southern and central Benin are of low fertility and have a high need for Potassium (K) fertilizer and for water preserving, because of the presence of the sandy texture. In addition, indicators of soil texture and macronutrients content of existing soils are not satisfactory. In this sense, fertilizing with organic residues for mulching in combination with NPK-fertilizer is required in both zones in order to improve their texture, their macronutrients content, to prevent erosion losses and thereby ameliorate their productivity.

Various improved technologies, especially those using NPK-fertilizer in combination with organic residues, introduced in the study areas show substantial economic profitability for individual farmers as well as to society in both regions. However, farmers have not been given incentives necessary to expand the use of these technologies. Benin may gain considerably by using the potential of improved technologies more fully. Therefore the following actions need to be considered:

- Improved technologies should be expanded on a larger scale with adequately trained research and extension advisers or "knowledge brokers" who should be committed to assist farmers to increase sufficiently their technical efficiency in various technologies according to location specific needs.

- Organic matter should be used more in addition to NPK-fertilizer for cotton, maize and groundnut production. This will contribute to the diversification of export products.

- To make farmers willing to take up the risks related with these technologies, the government should find ways and means to reduce some of these risks. Subsidizing innovations via food guarantees may be an option for farmers to adopt new

technologies; they will have access to minimum food in case technologies adopted fail to satisfy the expectation.

- Efforts are required to narrow the gap between private and social profitability of cotton in other to make cotton more attractive for individual farmers. For this to be done, a reform of inputs and output markets for cotton and other crops is needed.

- Benin government should improve the market structure for agricultural inputs and products with price signals giving clearer incentives to producers. This will lead to the improvement of farmers' resource allocation and increase technical efficiency in various technologies.

- The results of the study show that better access to credit and to education enhances the technical efficiency of farmers. Thus, one way of improving the living standard of farmers in the study areas should be to increase their accessibility to credit and education facilities.

- Individual farmers in southern as well as central Benin have no comparative advantage in producing soybean or maize in the traditional farming system. This implies that if individual farmers or both zones were to continue producing these crops under this farming system, individual farmers will incur private costs and regions will incur social losses, because under this farming system, theses crops compete for scarce resources which could be more profitably used for other activities.

- Changes of allocative efficiency as well as of technical efficiency over time have not been addressed in this study. Policy analysts, researchers and developers would benefit from studies incorporating these issues. Therefore, further researches are needed on this issue.

ZUSAMMENFASSUNG

Schwindende Bodenfruchtbarkeit aufgrund von Übernutzung des Bodens ohne ausreichende Düngung ist eines der Hauptprobleme der Landwirtschaft in Süd- und in Zentralbenin. Forschungen der Universität Hohenheim im Rahmen des Sonderforschungsbereichs (SFB) 308 in Westafrika zeigen, dass agroforstwirtschaftliche Technologien Möglichkeiten zur Wiederherstellung der Bodenfruchtbarkeit liefern. Verschiedene Leguminosen, besonders Acacia auriculiformis und Cassia siamea konnten in das bestehende Farmsystem integriert und geprüft werden. Später wurde auch der Gebrauch von NPK-Dünger in Kombination mit Mulch empfohlen, um den Ertrag von landwirtschaftlichen Kulturen langfristig zu stabilisieren. Jedoch fehlte eine gründliche ökonomische Bewertung dieser Anbau-Technologien. Das Hauptziel der Studie ist, die verschiedenen Technologien, die durch den SFB 308 in Zusammenarbeit mit Landwirten entwickelt wurden, ökonomisch zu bewerten und Grenzen ihrer Anwendung im südlichen und zentralen Benin aufzuzeigen.

Die Studie zielt im Einzelnen auf Folgendes:

1) Ermittlung der ökonomischen Rentabilität der Technologie des Einsatzes von NPK-Dünger in Kombination mit Mulch aus Acacia auriculiformis oder aus Cassia siamea.

2) Analyse der technischen Effizienz der Leistungsfähigkeit der Landwirte und wichtige, effizienzbestimmende Determinanten für ausgewählte landwirtschaftliche Technologien.

3) Messung der Risikoaversion von Landwirten bei verschiedenen landwirtschaftlichen Technologien.

Die Daten wurden in Süd- und Zentralbenin in den Jahren 1998/1999 gesammelt. 140 Landwirte wurden per Fragebogen befragt, wobei 70 in jeder Region nach dem Zufallsprinzip ausgewählt wurden. Die Persönlichenbefragungen wurden mit standardisierten Fragebögen durchgeführt und bei ca. 50% der befragten Landwirte wurden Versuchsflächen der verschiedenen Technologien angelegt.

Die ökonomische Rentabilität wurde über eine „Domestic Resource Cost" Analyse ermittelt. Weiter wurde die „Stochastic Frontier" Analyse von Produktionsfunktionen angewendet, um die technische Effizienz der Leistungsfähigkeit der Landwirte bei verschiedenen Technologien herzuleiten. Die Determinanten der technischen Leistungsfähigkeit wurden anschließend mittels

einer Regressionsanalyse, basierend auf der „Ordinary Least Squares" Technik, untersucht. Das mit der Annahme von verschiedenartigen Technologien verbundene Risiko wurde durch eine Portfolioanalyse unter Verwendung der „quadratischen Programmierung" berechnet und ausgewertet. Optimale Anbaupläne wurden für jede Zone berechnet sowie der Einfluss von Änderungen in ökonomischen Parametern auf Anbauplanung und auf das Einkommen aus pflanzenbaulicher Produktion abgeschätzt.

Die wichtigsten Ergebnisse der Studie wurden aus der gleichzeitigen Betrachtung von Bodenfruchtbarkeit, ökonomischer Rentabilität von technischen Alternativen und Politikentscheidungen gewonnen.

Eigenschaften in der Bodenfruchtbarkeit, wie die Kationenaustauschkapazität (CEC), die Menge an organischem Kohlenstoff und an Makronährstoffen und der pH-Wert, zeigen, dass beide Zonen einen erhöhten Bedarf an Kaliumdünger und intensiverer Bewässerung haben, was angesichts der sandigen Textur der Böden im Untersuchungsgebiet nahe liegt.

Vier Kulturen - Mais, Erdnuß, Sojabohnen und Baumwolle - wurden in die Untersuchung der wirtschaftlichen Rentabilität bestimmter Technologien einbezogen. Die Technologien umfassen: (a) traditioneller Anbau, (b) Anbau mit Mulch von Cassia siamea oder Acacia auriculiformis, (c) Anbau unter Verwendung von NPK und (d) Anbau unter Verwendung von NPK kombiniert mit Mulch von Cassia siamea und/oder Acacia auriculiformis.

Zu gegebenen Preisen und politischen Rahmenbedingungen sind einige Technologien nur für einzelne Landwirte wirtschaftlich rentabel, während andere Technologien sowohl für einzelne Landwirte als auch für die gesamte Region rentabel sind. Bei der Verwendung von NPK-Düngern in Kombination mit Mulch haben sich alle Kulturen außer Sojabohnen sowohl für einzelne Landwirte als auch für die gesamte Region als profitabel erwiesen. Alle Technologien, die allein Mulch von Acacia oder Cassia ohne Dünger verwenden, sind für einzelne Landwirte profitabel, aber aus gesamtregionaler Sicht nicht wünschenswert. Die gesellschaftliche Rentabilität mancher Technologien, speziell die der traditionellen Anbausysteme, oder die, in denen NPK-Dünger oder Mulch allein angewendet wurden, reagieren empfindlicher auf Preis- und Lohnkostenveränderungen als solche, die NPK-Dünger in Kombination mit Mulch verwenden. Die private Rentabilität verschiedener Technologien reagiert dagegen verhältnismäßig stabil auf politische und Preisveränderungen.

Resultate der Effizienzanalyse zeigen, dass die Landwirte in beiden Regionen nicht vollkommen effizient sind. Im Durchschnitt ergab sich eine technische Effizienz von 65%. Landwirtschaftliche Betriebe, die Mais in Kombination mit Acacia-Mulch anbauen, sind technisch effizienter, als die, die Mais mit Cassia-Mulch anbauen. Die ökonometrische Analyse technischer Effizienzfaktoren zeigt, dass sozioökonomische Eigenschaften wie das Alter des Familienoberhauptes, das Niveau der Ausbildung, die Erfahrung bei der Nutzung von Mulch aus Cassia oder aus Acacia und der Zugang zu Kredit signifikant die technische Leistungsfähigkeit der Landwirte in beiden Forschungsregionen beeinflussen.

In beiden Regionen neigen Landwirte dazu, Risiken zu vermeiden. Die Risikoaversion betrug 1.2 für Landwirte im Süden von Benin und 1.4 in Zentralbenin. Monetär ausgedrückt reduziert diese Risikoaversion das Einkommen um mehr als 30% in jeder Region. Verbesserte Technologien, die externe Inputs benutzen, tragen bedeutsam zur Stabilität in beiden Gebieten und damit auch zum Einkommen bei. Anbaupläne werden vereinfacht, wenn die Risikoaversion sinkt, und damit das Einkommen aus den unterschiedlichen Kulturen zunimmt. Risikoaversion kann die relative Rentabilität einer Technologie beeinflussen. Außerdem verbessert ein ungehinderter Zugang zu Düngermärkten die Akzeptanz von verbesserten Technologien, welche den Mulch von Cassia siamea oder Acacia auriculiformis in Verbindung von NPK-Dünger benutzen.

Gestützt auf die Beobachtung der Studie im südlichen und zentralen Benin kann man schließen, dass Landwirte verbesserte Technologien den Traditionellen vorziehen. Verbesserte Technologien sind sowohl für einzelne Landwirte als auch für die Gesellschaft lukrativer einzustufen als die Traditionellen, da sie die Wertschöpfung von Inputs steigern, das Einkommen vermehren und das Risiko mindern. Die große Variabilität der Böden bezüglich chemischer und physikalischer Eigenschaften erfordert ein Management, welches an den jeweiligen Boden angepasst ist. Eine, den örtlichen Standortbedingungen angepasste Spezialisierung in der Produktion ist erforderlich, um vollen Gebrauch der unterschiedlichen lokalen komparativen Vorteile zu machen. Es werden sehr effiziente Marktsysteme verlangt, um die Ressourcen unter solch heterogenen Umweltbedingungen vollauf zu mobilisieren.

Benin braucht eine Exportwirtschaft, die nicht nur auf Baumwolle beschränkt ist. Es bestehen Möglichkeiten, die Produktionstätigkeiten auszuweiten, wie am Beispiel der Studiengebiete bereits gezeigt wurde. Die Anwendung von Mulch aus Leguminosen in Kombination mit einer NPK-Düngung in der Nahrungsmittelproduktion kann einen großen Beitrag zur Verbesserung

der Wirtschaft des Landes leisten und das Einkommen auf eine breitere Grundlage stellen. Damit würde auch der Einfluss schwankender Weltmarktpreise für Baumwolle auf die wirtschaftliche Lage Benins gemindert werden.

Beide Studiengebiete zeigen Potenzial für höhere Erträge. Es ist möglich, allein durch eine Verbesserung der technischen Leistungsfähigkeit der Landwirte, die landwirtschaftliche Produktion mit den bereits existierenden Technologien zu erhöhen. Dies geschieht im wesentlichen über eine Verbesserung der Ressourcenallokation durch die Landwirte. Ein Schwerpunkt der Regierung oder nationaler bzw. internationaler Entwicklungsinstitutionen sollte es sein, Anreize zu schaffen und bereits existierende, verbesserte Technologien effizienter anzuwenden. Preis- und ertragsstabilisierende Maßnahmen sind erforderlich, um die Rentabilität dieser Technologien nachhaltig zu steigern. Ein besserer Zugang zu den Märkten für Outputs und Inputs ist eine ganz entscheidende Voraussetzung für die Mobilisierung bisher ungenutzter Ressourcen.