PROJECTIONS OF SUPPLY AND DEMAND FOR SELECTED FOOD CROPS IN BANGLADESH BY 2030 AND 2050

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BARC

**BANGLADESH AGRICULTURAL RESEARCH COUNCIL**

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**Bangladesh Agricultural Research Council**

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## Projections of Supply and Demand for Selected Food Crops in Bangladesh by 2030 and 2050


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## Disclaimer



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# Preface

In order to know the future supply-demand and thereby surplus/deficit of important food crops in Bangladesh, Ministry of Agriculture has instructed Bangladesh Agricultural Research Council (BARC) to conduct a study on this issue. Accordingly, BARC set up a research team as well as an advisory committee with renowned agricultural economists of National Agricultural Research System (NARS) to conduct the study. After several team and advisory committee meetings, an inception workshop was held on 17 January, 2022 and the proposed activity plan was revised based on the valuable suggestions made in the workshop.

Secondary data were collected from BBS, DAE, FAOSTAT and other sources. To validate the secondary data and to identify the modern technologies adopted by farmers, primary data were collected through regional workshops, FGDs, KIIs and consultations with NARS scientists, extension experts, farmers and various stakeholders. ARIMA model was used for forecasting supply-demand for selected food crops by 2030 and 2050. The draft report was presented in a workshop on 28 June, 2022 and after addressing necessary comments made in the workshop final reports were prepared.

Projections showed that food consumption in Bangladesh is slowly diversifying with share of cereals consumption would decrease by the period from 2030 to 2050. Under pessimistic scenario, rice deficit would be 3.62 MMT in 2030 and 1.93 MMT in 2050, while wheat deficit would stand at 5.22 and 6.85 MMT during the same period. Domestic supply of maize, pulses, mustard and spices would remain surplus, whereas groundnut, potato, sweet potato, vegetables and fruits would prevail deficit in future. Recommendations made are: development of climate resilient new rice varieties and other technologies; build a strategic rice grain reserve between 1.5 to 2.5 MMT in public warehouses; need to prepare a long term plan for technology development and transformation of agriculture; promote export of surplus potato, vegetables and fruits; and need government supports in the form of providing incentives to the exporters, investment in value chain development activities and food quality and safety certification.

I really appreciate Dr. Md. Mosharraf Uddin Molla, Member Director (AERS) and coordinator and all members of the study team and advisory committee for conducting the research and preparing the reports within very short period. I extent my sincere thanks to Agricultural Economics and Rural Sociology Division, BARC for conducting this research and to Ministry of Agriculture for financing the study. Finally, I am very much obliged to Dr. Mohammad Abdur Razzak, MP, Honourable Minister, Ministry of Agriculture for his initiative and inspiration for this study. I believe the recommendations made in the reports will be helpful to policy makers to adopt appropriate policies based on forecasted supply-demand of selected food crops in Bangladesh.

**Dr. Shaikh Mohammad Bokhtiar**
Executive Chairman
Bangladesh Agricultural Research Council

# বাংলাদেশের নিত্য প্রয়োজনীয় ফসলের (খাদ্য শস্য) ভবিষ্যৎ যোগান ও চাহিদা নিরুপণ: অভিক্ষেপ (Projection) কাল ২০৩০ ও ২০৫০

**প্রেক্ষাপট:**

জনসংখ্যার উচ্চ ঘনত্বপূর্ণ কৃষি নির্ভর অর্থনীতির দেশ হিসেবে বাংলাদেশে টেকসই খাদ্য নিরাপত্তা একটি উল্লেখযোগ্য চ্যালেঞ্জ হিসেবে বিবেচিত। আধুনিক নগরায়ন, শিল্পায়ন ও অন্যান্য অকৃষি ব্যবহারের কারণে দেশের কৃষি জমি ক্রমশ সঙ্কুচিত হচ্ছে। ক্রমবর্ধমান জনসংখ্যার সাথে সাথে বাংলাদেশের খাদ্য নিরাপত্তার চ্যালেঞ্জ মোকাবেলায় ভবিষ্যতের খাদ্য উৎপাদন এবং চাহিদা নিয়ে সঠিক পরিকল্পনা প্রণয়ন করা অতীব জরুরী। জনসংখ্যা বৃদ্ধির হারের তুলনায় কৃষির প্রবৃদ্ধি বেশি হওয়া সত্ত্বেও প্রশ্ন উত্থাপিত হয়েছে যে, বাংলাদেশের কৃষি জমি আগামী ২০৩০ ও ২০৫০ সালের মধ্যে মোট জনগোষ্ঠীর খাদ্য চাহিদা মেটাতে সক্ষম কিনা? তাই সঠিক পরিকল্পনার সুবিধার্থে নিত্য প্রয়োজনীয় ফসলের (খাদ্য শস্য) ভবিষ্যৎ যোগান ও চাহিদা নিরুপণ করা অত্যাবশ্যক। উল্লেখ্য, বাংলাদেশে কৃষি সম্প্রসারণ অধিদপ্তর নিত্য প্রয়োজনীয় ২৮টি মাঠ ফসল যেমন- চাল, গম, ভুট্টা, আলু, মিষ্টি আলু, পাট, শাকসবজি, সরিষা, চিনাবাদাম, তিসি, তিল, সয়াবীন, সূর্যমূখী, মসুর, ছোলা, মুগডাল, মাসকলাই, খেসারি, মটর, অড়হড়, ফেলন, পেঁয়াজ, রসুন, ধনিয়া, মরিচ, আদা, হলুদ এবং কালোজিরার চাষাবাদ এলাকা, উৎপাদন, ফলন পরিস্থিতি ও লক্ষ্যমাত্রা নির্ধারণের কাজটি সম্পাদন করে থাকে। কিন্তু উল্লিখিত ফসলসমূহের দেশে কি পরিমাণ চাহিদা ও যোগান বিদ্যমান এবং ভবিষ্যতে কি পরিমাণ যোগান ও চাহিদা হবে তা নিরুপণ সংক্রান্ত নির্ভরযোগ্য বৈজ্ঞানিক স্টাডি কোনো ব্যক্তি বা প্রতিষ্ঠান কর্তৃক এখনও পরিচালিত হয়নি। অধিকন্তু, এই স্টাডিতে তথ্য-উপাত্ত প্রাপ্তি সাপেক্ষে কৃষি সম্প্রসারণ অধিদপ্তরের তালিকায় উল্লিখিত মাঠ ফসলসহ (পাট, তিসি, সয়াবিন, সূর্যমুখী, অড়হড়, ফেলন ও কালোজিরা ব্যতিত) দেশে উৎপাদিত প্রধান সবজি ও ফল অন্তর্ভুক্ত করে মোট ৩৫টি খাদ্য শস্যের (দানাদার ফসল-৩টি, কন্দাল ফসল-২টি, ডাল ফসল-৬টি, মসলা-৬টি, তেল ফসল-২টি, সবজি-১০টি এবং ফল-৬টি) যোগান ও চাহিদা নিরুপণ করা হয়েছে। যোগান ও চাহিদার মধ্যে সম্ভাব্য ব্যবধানটি নির্ধারণের লক্ষ্যে কৃষি মন্ত্রণালয়ের নির্দেশনায় বাংলাদেশ কৃষি গবেষণা কাউন্সিল (বিএআরসি) কর্তৃক পরিচালিত এই স্টাডিটি ভবিষ্যদ্বাণীর জন্য একটি উল্লেখযোগ্য পদক্ষেপ। এতে দেশের যোগান ও চাহিদা বিবেচনায় নিয়ে সংশিষ্ট প্রতিষ্ঠান কর্তৃক ফসলের সঠিক উৎপাদন লক্ষ্যমাত্রা নির্ধারণ করা সহজ হবে। পাশাপাশি আমদানি-রপ্তানি সংশিষ্ট মন্ত্রণালয়/বিভাগ/সংস্থা কর্তৃক কার্যকরী পরিকল্পনা গ্রহণ সম্ভব হবে।

উল্লেখ্য, দেশের বিশিষ্ট কৃষি অর্থনীতিবিদ ও গবেষকের নেতৃত্বে নার্সভুক্ত প্রতিষ্ঠানের বিজ্ঞানীদের (কৃষি অর্থনীতিবিদ) সমন্বয়ে গঠিত গবেষণা দলের মাধ্যমে এ স্টাডি পরিচালিত হয়। আশাকরি গবেষণার ফলাফল টেকসই কৃষির উন্নয়নের লক্ষ্যে গবেষক ও নীতিনির্ধারকদের নতুন ফসলের বিভিন্ন জাতসমূহের বিকাশ, প্রযুক্তিসমূহ উদ্ভাবন এবং ২০৩০ ও ২০৫০ সালের প্রেক্ষিতে প্রযোজ্য নীতিমালা প্রণয়ন ও যথাযথ কার্যক্রম গ্রহণে সহায়ক ভূমিকা রাখবে।

**উদ্দেশ্যসমূহ:**

ক) নিত্য প্রয়োজনীয় ফসলের (খাদ্য শস্য) অভ্যন্তরীণ যোগান ও চাহিদা নিরুপণ সহ ২০৩০ এবং ২০৫০ সাল পর্যন্ত ভবিষ্যদ্বাণী (forecast) করা;

খ) ২০৩০ এবং ২০৫০ সালে ফসলের (খাদ্য শস্য) অভ্যন্তরীণ যোগান ও চাহিদার ঘাটতি/উদ্বৃত্ত প্রাক্কলন করা;

গ) প্রাপ্ত প্রযুক্তি, সম্পদ এবং জলবায়ু পরিবর্তনের বিকল্প পরিস্থিতিতে নির্বাচিত ফসলের যোগান ও চাহিদার সংবেদনশীলতা বিশ্লেষণ (sensitivity analysis) করা; এবং

ঘ) পরিস্থিতির উন্নয়নের জন্য প্রয়োজনীয় কর্মসূচি এবং নীতি সম্পর্কিত প্রস্তাবনা/সুপারিশ প্রণয়ন করা।

**গবেষণা পদ্ধতি:**

এই স্টাডিতে মূলত মাধ্যমিক (secondary) তথ্য-উপাত্ত ব্যবহার করা হয়েছে। অর্থনৈতিক মডেলিংয়ের জন্য নির্বাচিত ফসলের মাধ্যমিক তথ্য-উপাত্তের গুণমান যাচাই এর জন্য দেশের কৃষি অঞ্চল ভিত্তিক ৪টি আঞ্চলিক কর্মশালা (রাজশাহী, বগুড়া, যশোর ও পটুয়াখালী) ও ৭টি ফোকাস গ্রুপ ডিসকাসন (এফজিডি) আয়োজনের মাধ্যমে প্রাথমিক (primary) তথ্য-উপাত্ত সংগ্রহ করা হয়েছে। দেশে ২০৩০ এবং ২০৫০ সাল পর্যন্ত নির্বাচিত ফসলের যোগান ও চাহিদার পূর্বাভাসের (prediction) জন্য অ্যারিমা (ARIMA) মডেল ব্যবহার করা হয়েছে যা পূর্বাভাসের (prediction) ক্ষেত্রে বিশ্বে একটি জনপ্রিয় ও বহুল ব্যবহৃত অর্থনৈতিক মডেল। মডেল ব্যবহার করে সংগৃহীত তথ্য-উপাত্তের সত্যতা যাচাই (validation) করা হয়েছে। এছাড়াও, তথ্য গ্যাপগুলো প্রমাণিত মডেলের মাধ্যমে বিশ্লেষণ করা হয়েছে। এই মডেলটি যথার্থভাবে পরিচালনার জন্য আধুনিক এনসিএসএস (NCSS) সফটওয়্যার ব্যবহার করা হয়েছে। অধিকন্তু, কৃষি প্রযুক্তিসমূহ, সম্পদ এবং জলবায়ু নিয়ত পরিবর্তনশীল বিধায় প্রাপ্ত প্রযুক্তি, সম্পদ এবং জলবায়ু পরিবর্তনের বিকল্প পরিস্থিতিতে (যেমন- বিদ্যমান পরিস্থিতি, অনুকূল এবং প্রতিকূল পরিস্থিতি) দেশটিতে ভবিষ্যৎ খাদ্য যোগান ও চাহিদার মাঝে উদ্বৃত্ত বা ঘাটতির পরিবর্তনের প্রকৃতি পরীক্ষার জন্য সংবেদনশীলতা বিশ্লেষণ করা হয়েছে। দেশের প্রধান খাদ্য শস্য চালের ভবিষ্যৎ যোগান ও চাহিদা প্রক্ষেপণের ক্ষেত্রে ৩টি বিকল্প পরিস্থিতি (alternative scenario) বিবেচনা করা হয়েছে। যেমন- স্বাভাবিক পরিস্তিতি (BAU scenario- Business as usual case in crop production), সমন্বিত পরিস্থিতি (Adjusted BAU scenario-Considering yield differences) এবং প্রতিকূল পরিস্থিতি (Pessimistic scenario- Crop failure due to flood, draught and other natural calamities)। অন্যান্য ফসলের ক্ষেত্রে স্বাভাবিক পরিস্থিতি (BAU scenario) বিবেচনা করা হয়েছে। উল্লেখ্য, যোগান বলতে নির্বাচিত ফসলের মোট উৎপাদনকে বুঝানো হয়েছে।

পারিবারিক জীবনযাত্রার ব্যয়, খাদ্য উৎপাদন এবং আমদানি বিবেচনায় যুক্তিসঙ্গত ফলাফল পেতে বিদ্যমান পরিস্থিতি থেকে ফসলের চাহিদার ৫ শতাংশ হ্রাস বা ৫ শতাংশ বৃদ্ধি অনুমান (assumption) করা হয়েছে। উদ্ভুত পরিস্থিতি যেমন- জলবায়ু পরিবর্তন, রোগ ও কীটপতঙ্গ, দুর্যোগ এবং অনিয়ন্ত্রণ বাজার সৃষ্টির ফলে যোগানের (supply) সংকট প্রেক্ষাপট অনুমান করা হয়েছে। অর্থাৎ চলমান যোগান থেকে ভবিষ্যতে ৮ শতাংশ অথবা ১০ শতাংশ কম হলে যোগানের ফলাফল কি হবে তা দেখা হয়েছে।

**গবেষণা ফলাফল:**

অর্থনৈতিক মডেল বিশ্লেষণে প্রতিয়মান হয় যে, বাংলাদেশের জনগণের খাদ্য গ্রহণের তালিকা ধীরে ধীরে বৈচিত্রময় হচ্ছে। দানাদার খাদ্য থেকে সিংহভাগ ক্যালরি গ্রহণ করলেও মোট ক্যালরি গ্রহণের হার অনেক কমে গেছে। ১৯৯০ সালে দানাদার খাদ্য থেকে মোট ক্যালরি গ্রহণের হার ছিল ৮৯.৬ শতাংশ যা ২০১০ সালে হ্রাস পেয়ে ৮৩.০ শতাংশ এবং ২০২১ সালে ৮০.৫ শতাংশ হয়েছে। গবেষণার ফলাফল থেকে বলা যায়, ২০৩০ এবং ২০৫০ সালে দানাদার খাদ্য থেকে মোট ক্যালরি গ্রহণের হার হ্রাস পেয়ে যথাক্রমে ৭৯.৬ শতাংশ এবং ৭৭.৫ শতাংশ হবে।

১৯৯০ সালে শুধু চাল থেকে ক্যালরি গ্রহণের হার ছিলো ৮০.৪ শতাংশ যা ২০২১ সালে হ্রাস পেয়ে ৭০.৫ শতাংশ হয়েছে এবং আগামী ২০৩০ এবং ২০৫০ সালে হবে যথাক্রমে ৭২.৬ শতাংশ এবং ৭০.৪ শতাংশ। তবে ২০১০ থেকে ২০২১ সাল সময়কালীন প্রাপ্ত তথ্য-উপাত্তে চাল থেকে ক্যালরি গ্রহণের ধারা (trend) ক্রমহ্রাসমান নির্দেশ করলেও অর্থনৈতিক বিশ্লেষণে দেখা যায় যে, পরবর্তী সময় বিশেষ করে ২০৫০ সাল পর্যন্ত চাল থেকে ক্যালরি গ্রহণের হার স্থির হবে। তবে গম থেকে ক্যালরি গ্রহণের হার ক্রমান্বয়ে বাড়বে। গম থেকে ক্যালরি গ্রহণের হার ২০১০ সালে ছিলো ৬.৬ শতাংশ, ২০৩০ সালে বৃদ্ধি পেয়ে হবে ৬.৭ শতাংশ যা অব্যাহত থেকে ২০৫০ সালে ৬.৮ শতাংশে পৌঁছাবে। অনুরুপভাবে ২০১০ থেকে ২০৩০ সালের মধ্যে ভুট্টা থেকে ক্যালরি গ্রহণ দৈনিক মাথাপিছু ৬.০ ক্যালরি থেকে ৬.৫ ক্যালরিতে বৃদ্ধি পাবে এবং তারপর স্থিতিশীল হবে।

উল্লেখ্য, দানাদার খাদ্যের মধ্যে চাল থেকে ক্যালরি গ্রহণ সর্বাধিক স্তরে পৌঁছেছে বলে প্রতীয়মান হচ্ছে। এরপর আয় বৃদ্ধি পেলেও চাল থেকে ক্যালরি গ্রহণের হার বাড়বে না। অর্থনৈতিক প্রবৃদ্ধির সাথে সাথে এশিয়ার অন্যান্য দেশের অনুরূপ বাংলাদেশেও মাথাপিছু দৈনিক চাল গ্রহণের প্রবণতা কমতে থাকবে। ১৯৯০ থেকে ২০১০ সালের তথ্য থেকে সুস্পষ্ট যে, আলু, শাকসবজি এবং প্রাণীজ খাবার থেকে ক্যালরি গ্রহণের হার দিন দিন বেড়েছে। আগামী ২০৩০ ও ২০৫০ সালের প্রক্ষেপণেও এগুলো থেকে ক্যালরি গ্রহণের হার বৃদ্ধির প্রবণতা পরিলক্ষিত হচ্ছে।

**চাল:** অর্থনৈতিক মডেলের ফলাফল অনুসারে ২০৩০ সালে মানুষের খাদ্য হিসেবে এবং অন্যান্য প্রয়োজনে (বীজ, প্রাণি ও মৎস্য খাদ্য, শিল্প, অপচয়, ইত্যাদি) চালের মোট চাহিদা হবে ৩৯.১ মিলিয়ন টন এবং ২০৫০ সালে ৪২.৬ মিলিয়ন টন। বর্তামান উৎপাদন অবস্থা (BAU scenario) বিদ্যমান থাকলে আগামী ২০৩০ ও ২০৫০ সাল নাগাদ চালের মোট যোগান হবে যথাক্রমে ৪৩.২ এবং ৫৪.৯ মিলিয়ন টন। কিন্তু ফসল কাটায় ফলনের পার্থক্য (crop cutting error) বিবেচনায় নিয়ে সমন্বিত পরিস্থিতি (adjusted BAU scenario) অনুসারে ২০৩০ সালে চালের যোগান দাঁড়াবে ৪১.০ মিলিয়ন টন এবং ২০৫০ সালে ৫২.১ মিলিয়ন টন। আগামী কয়েক দশক দেশের কৃষি উৎপাদন জলবায়ু পরিবর্তনের বিরূপ প্রভাব, মাটির লবণাক্ততা বৃদ্ধি, সেচের পানির অভাব ইত্যাদি চ্যালেঞ্জের সম্মুখীন হবে। প্রতিকূল পরিস্থিতি সৃষ্টি হলে ধান উৎপাদন ব্যাপক ব্যহত হবে। তাই আবহাওয়া এবং অন্যান্য কারণে উৎপাদনে প্রতিকূল অবস্থা (Pessimistic scenario) সৃষ্টি হলে ২০৩০ সালে চালের মোট যোগান হবে ৩৫.৫ মিলিয়ন টন এবং ২০৫০ সালে ৪০.৭ মিলিয়ন টন।

এমতাবস্থায়, অধিক উৎপাদনশীল নতুন ধান প্রযুক্তি কৃষক পর্যায়ে জনপ্রিয় করা অত্যাবশ্যক- যাতে মোট উৎপাদন বৃদ্ধির ধারা অব্যাহত রাখা যায়। আশা করা যায়, দীর্ঘমেয়াদে নতুন ধান প্রযুক্তি পাওয়া যাবে এবং কৃষক পর্যায়ে গ্রহণযোগ্য হবে। বিশ্লেষণে দেখা যায় যে, স্বাভাবিক অবস্থা (BAU scenario) বিবেচনায় ২০৩০ ও ২০৫০ সালে উদ্বৃত্ত চালের পরিমাণ দাঁড়াবে যথাক্রমে ৪.১ ও ১২.৩ মিলিয়ন টন। কিন্তু প্রতিকূল পরিস্থিতি (বিরূপ আবহাওয়া, উৎপাদন উপকরণ সংকট, ইত্যাদি) সৃষ্টি হলে ২০৩০ সালে ৩.৬ মিলিয়ন টন এবং ২০৫০ সালে ১.৯ মিলিয়ন টন চালের ঘাটতি দেখা দিতে পারে।

**গম:** মানুষের খাদ্য হিসেবে এবং অন্যান্য চাহিদা (বীজ, প্রাণি ও মৎস্য খাদ্য, শিল্প, অপচয়, ইত্যাদি) বিবেচনায় ২০২১ সালে গমের চাহিদা ছিলো ৪.১ মিলিয়ন টন। ২০৩০ ও ২০৫০ সালে গমের চাহিদা বেড়ে হবে যথাক্রমে ৪.৬ ও ৫.২ মিলিয়ন টন। অপরদিকে, ২০৩০ ও ২০৫০ সালে যোগান অনেকটা স্থিতিশীল হয়ে প্রায় ১.২ মিলিয়ন টনে পৌঁছাবে। প্রক্ষেপণে দেখা যায়, ২০৩০ সালে ৩.৪ মিলিয়ন টন এবং ২০৫০ সালে ৪.০ মিলিয়ন টন গমের ঘাটতি হতে পারে।

**ভুট্টা:** অর্থনৈতিক মডেলের ফলাফল অনুসারে মানুষের খাদ্য হিসেবে এবং অন্যান্য চাহিদা (বীজ, প্রাণী ও মৎস্য খাদ্য, শিল্প, অপচয়, ইত্যাদি) বিবেচনায় ২০২১ সালে ভুট্টার চাহিদা ছিলো ৫.৭ মিলিয়ন টন যা ২০২১ সালের যোগানের (৪.১ মিলিয়ন টন) তুলনায় ১.৬ মিলিয়ন টন বেশি। অর্থাৎ ২০২১ সালে ভুট্টার যোগানের ঘাটতি থাকলেও প্রক্ষেপণে দেখা যায়, চাহিদার তুলনায় যোগান বৃদ্ধির কারণে ২০৩০ ও ২০৫০ সালে যথাক্রমে ০.৪ ও ৩.৫ মিলিয়ন টন ভুট্টা উদ্বৃত্ত থাকতে পারে। একক প্রতি ফলন বৃদ্ধি ও চাষের জমির সম্প্রসারণের কারণে উৎপাদন বৃদ্ধি পেতে পারে।

**ডাল:** প্রক্ষেপণে দেখা যায়, মানুষের খাদ্য হিসেবে সকল প্রকার (মসুর, মুগ, মাসকলাই, খেসারি, ছোলা ও মটর) ডাল ফসলের চাহিদা ২০৩০ ও ২০৫০ সালে বৃদ্ধি পাবে। এ সময়ে শুধু মসুর, মুগ ও খেসারি ডালের যোগান উল্লেখযোগ্য পরিমাণে বৃদ্ধি পেলেও অন্যান্য ডালের ক্ষেত্রে কমবেশি স্থিতিশীল থাকবে। তবে চাহিদার তুলনায় যোগান সেরকম না বাড়ার কারণে সব ধরণের ডালের যোগানের ঘাটতি পরিলক্ষিত হতে পারে। তবে মসুর, মুগ ও খেসারি ডালের ঘাটতি ক্রমান্বয়ে কমবে।

**তেল:** উৎপাদনের পর্যাপ্ত উপাত্ত না থাকায় সয়াবিনের শুধু চাহিদা বিশ্লেষণ করা হয়েছে। তেল ফসলের মধ্যে সরিষা ও বাদামের চাহিদা ও যোগান বিশ্লেষণ করা হয়েছে। ২০২১ সালে সরিষার চাহিদা ও যোগানের ভারসাম্য অবস্থা (১.৫ লক্ষ টন) পরিলক্ষিত হয়। গবেষণার ফলাফল অনুসারে মানুষের খাদ্য হিসেবে ২০৩০ ও ২০৫০ সালে সরিষার চাহিদা যথাক্রমে ২.১ ও ৩.৯ লক্ষ টনের বিপরীতে যোগান দাঁড়াবে যথাক্রমে ১.৮ ও ২.৩ লক্ষ টন। অর্থাৎ ২০৩০ ও ২০৫০ সালে সরিষার যোগান ঘাটতি যথাক্রমে ০.৩ ও ১.৭ লক্ষ টন হতে পারে। তবে উক্ত সময়ে বাদামের চাহিদা স্থিতিশীল থাকার কারণে উদ্বৃত্ত যোগান থাকতে পারে যথাক্রমে ০.৩ ও ০.৬ লক্ষ টন।

**মসলা:** প্রক্ষেপণে দেখা যায়, নির্বাচিত মসলা ফসলের (পেঁয়াজ, রসুন, মরিচ, হলুদ, আদা ও ধনিয়া) মধ্যে সকল প্রকার মসলার চাহিদা ২০৩০ ও ২০৫০ সালে উল্ল্যেখযোগ্য পরিমাণে বৃদ্ধি পাবে। তবে যোগান ক্রমশ বাড়লেও ২০৩০ ও ২০৪০ সাল পর্যন্ত সকল প্রকার মসলার যোগানের ঘাটতি পরিলক্ষিত হবে। এদের মধ্যে ২০৩০ সালে প্রধান মসলা পেঁয়াজের ঘাটতি হবে ৮.৭ লক্ষ টন এবং ২০৪০ সালে ৫.০ লক্ষ টন। তবে পেঁয়াজের ফলন বৃদ্ধি এবং চাষের জমি সম্প্রসারণের কারণে ২০৫০ সালে চাহিদার তুলনায় পেঁয়াজের যোগান বেড়ে যাবে এবং ৩.৩ লক্ষ টন উদ্বৃত্ত থাকতে পারে। মরিচের ক্ষেত্রেও ২০৫০ সালে ১.১ লক্ষ টন উদ্বৃত্ত যোগান থাকতে পারে। গবেষণার ফলাফলে দেখা যায়, নির্বাচিত মসলার মধ্যে রসুনের যোগান ঘাটতি ২০৩০ ও ২০৫০ সালে সবচেয়ে বেশি হতে পারে।

**আলু ও মিষ্টি আলু:** কন্দাল ফসলের মধ্যে মিষ্টি আলুর চাহিদা ২০৩০ ও ২০৫০ সালে প্রায় স্থিতিশীল থাকলেও আলুর চাহিদা বাড়বে। একইভাবে যোগান বৃদ্ধির ধারা অব্যাহত থাকবে। প্রক্ষেপণে দেখা যায়, ২০৩০ ও ২০৫০ সালে যথাক্রমে ১১৬.২ ও ১২৬.৬ লক্ষ টন আলুর চাহিদার বিপরীতে যোগান দাঁড়াবে যথাক্রমে ১১৭.৮ ও ১৪০.৯ লক্ষ টন। অর্থাৎ ২০৩০ সালে ১.৬ লক্ষ টন এবং ২০৫০ সালে ১৪.৩ লক্ষ টন আলুর উদ্বৃত্ত যোগান থাকতে পারে।

**সবজি:** গবেষণায় ১০টি প্রধান সবজির (টমেটো, শিম, বেগুন, শসা, ঢেড়স, করলা, ফুলকপি, বাঁধাকপি, চিচিঙ্গা ও লাউ) শুধু যোগান পৃথক পৃথক প্রক্ষেপণ করা হয়েছে। পাশাপাশি দেশে উৎপাদিত মোট সবজির চাহিদা ও যোগান প্রক্ষেপণ করা হয়েছে। ফলাফলে দেখা যায়, ২০২১ সালে দেশে মোট সবজির চাহিদা ৪১.২ লক্ষ টন থেকে বেড়ে ২০৩০ সালে ৫১.৫ লক্ষ টন হবে। এভাবে ক্রমান্বয়ে বৃদ্ধি পেয়ে ২০৫০ সালে মোট সবজির চাহিদা হবে ৬৫.৫ লক্ষ টন। ২০৩০ থেকে ২০৫০ সময়ের জন্য মোট সবজির ফলন বৃদ্ধি ও চাষের জমি সম্প্রসারণের ফলে উৎপাদন বৃদ্ধি পাবে বলে ধারণা করা হচ্ছে। অপরদিকে, ২০৩০ সালে মোট সবজির যোগান ৫৩.৮ লক্ষ টন হবে এবং ধীরে ধীরে বৃদ্ধি পেয়ে ২০৫০ সালে ৮৯.০ লক্ষ টনে উন্নিত হবে। ফলে ২০৩০ ও ২০৫০ সালে দেশে যথাক্রমে ২.৩ ও ২৩.৫ লক্ষ টন মোট সবজির উদ্বৃত্ত যোগান থাকতে পারে।

**ফল:** প্রক্ষেপণে দেখা যায়, ২০৩০ ও ২০৫০ সময়ের মধ্যে নির্বাচিত ফলের (আম, আনারস, লেবু, কলা, পেঁয়ারা ও তরমুজ) চাহিদা বৃদ্ধির সাথে সাথে যোগানের পরিমাণও ক্রমশ বাড়বে। ফলে উক্ত সময়ে নির্বাচিত সব ফলের উদ্বৃত্ত যোগান থাকবে। এদরে মধ্যে কলা, আম ও পেঁয়ারার উদ্বৃত্ত যোগান ২০৫০ সালে অন্যান্য ফলের তুলনায় বেশি হবে। উক্ত সময়ের মধ্যে প্রযুক্তিগত উন্নয়নে ফলন বৃদ্ধি এবং চাষের জমি সম্প্রসারণের ফলে উৎপাদন বৃদ্ধি পাবে বলে অনুমান করা হয়েছে।

**সুপারিশ:** ২০৩০ এবং ২০৫০ সালরে মধ্যে দেশের কৃষি খাতে উদ্ভুত পরিস্থিতি মোকাবেলা এবং বাণিজ্যিক কৃষির রূপান্তরে নিম্নলিখিত সুপারিশ করা যায়:

- ২০৩০ এবং ২০৪০ দশকের মধ্যে চালের উৎপাদন ঘাটতি দূর করতে উন্নত জাত এবং জলবায়ু সহনশীল প্রযুক্তি উদ্ভাবনের মাধ্যমে উৎপাদনশীলতা বৃদ্ধিকরণ।
- তাপ ও বালাই প্রতিরোধী উচ্চ ফলনশীল গমের জাত (বারি গম ৩৩ ও ডবিওএমআরআই ৩) বাংলাদেশের দক্ষিণ ও উত্তর-পূর্ব অংশে চাষ করা যাবে যেখানে রোপা আমন ধান চাষের পর বিস্তৃর্ণ এলাকা পতিত থাকে।

অধিকন্তু, পার্বত্য চট্টগ্রামে পাহাড়ি উপত্যকা এবং সমতল ভূমিতে গম চাষাবাদ সম্প্রসারণ করা যাবে। সম্প্রসারণ সহায়তা এবং সরকারি প্রণোদনার মাধ্যমে এসমস্ত পতিত জমিতে গমের আবাদ বাড়ানো সম্ভব হবে।

- বিভিন্ন প্রাকৃতিক দুর্যোগ এবং অনিয়ন্ত্রিত বাজার পরিস্থিতিতে চালের যোগান অবিচ্ছিন্ন রাখতে খাদ্য মন্ত্রণালয়ের গুদামগুলোতে ন্যূনতম ১.৫ মিলিয়ন থেকে ২.৫ মিলিয়ন মে. টন চাল মজুদ রাখা।
- উদ্বৃত্ত আলু, ভুট্টা, সবজি ও ফল রপ্তানিকে উৎসাহিত করা এবং এক্ষেত্রে রপ্তানিকারকগণকে প্রণোদনা প্রদান, ভ্যালু চেইন উন্নয়নে বিনিয়োগ কার্যক্রম এবং গুণগত ও নিরাপদ খাদ্য উৎপাদন প্রত্যায়নে সরকারের অধিকতর সহায়তা প্রদান।
- বিবিএস ও ডিএই প্রদত্ত ভুট্টার জমি ও উৎপাদন উপাত্তে হারমোনাইজড করা। তবে নীতি ও পরিকল্পনা প্রণয়নে সহায়ক গবেষণার ক্ষেত্রে বিবিএস এর উপাত্ত ব্যাবহারে অগ্রাধিকার প্রদান করা আবশ্যক।
- ২০৩০ এবং ২০৪০ এর দশকে দেশের কৃষি প্রযুক্তি উন্নয়ন এবং কৃষি সঠিকভাবে রূপান্তর করতে দীর্ঘমেয়াদী পরিকল্পনা গ্রহণ এবং সে লক্ষ্যে গবেষণা, সম্প্রসারণ এবং বাজার ব্যবস্থা উন্নয়নে বিনিয়োগ বৃদ্ধিকরণ।

# Table of Contents

# List of Tables

# List of Figure

## Acronyms

ACF-Autocorrelation Function
ACI-Advance Chemical Industries
AERS-Agricultural Economics and Rural Sociology
ARIMA-Autoregressive Integrated Moving Average
AWD- Alternate Wetting and Drying
BARI-Bangladesh Agricultural Research Institute
BRRI-Bangladesh Rice Research Institute
BARC-Bangladesh Agricultural Research Council
BINA-Bangladesh Institute of Nuclear Agriculture
BAU- Business As Usual
BBS- Bangladesh Bureau of Statistics
BIHS-Bangladesh Integrated Households Survey
BIDS-Bangladesh Institute of Development Studies
BWMRI-Bangladesh Wheat and Maize Research Institute
DAE- Department of Agricultural Extension
FPMU- Food Planning and Monitoring Unit
FGD-Focus Group Discussion
FAO- Food and Agriculture Organization
FAOSTAT-Food and Agricultural Organization Statistics
HIES-Households Income and Expenditure Survey
IPM-Integrated Pest Management
IFPRI-International Food Policy Research Institute
IWMI- International Water Management Institute
KII-Key Informant Interview
MMT-Million Metric Tone
MT-Metric Tone
NARS-National Agricultural Research System
NCSS- Statistical Software
OS- Optimistic Scenario
PS- Pessimistic Scenario
PACF -Partial Autocorrelation Function
USDA-United State Department of Agriculture
Lakh-Hundred Thousand

## Executive Summary

The objectives of the present study was to: (i) estimate supply and demand projections of selected food crops produced in Bangladesh for the period 2030 and 2050, (ii) estimate gaps in food demand and supply of selected food crops in Bangladesh in 2030 and 2050, (iii) carry out sensitivity analysis of food demand and supply of the selected food crops under alternative scenarios, and (iv) suggest recommendations and policy implications.

ARIMA model has been used for projections of demand and supply of selected categories of food crops. They are rice, wheat, maize, pulses, spices, tubers, vegetables and fruits.

Projections with ARIMA (autoregressive integrated moving average) model showed that food consumption in Bangladesh is slowly diversifying. Cereals still provide a major part of the calorie intake, but their share in total calorie supply decreased from 89.6% in 1990 to 83% by 2010 and further decreased to 80.5% in 2021. ARIMA projections showed that it will further decrease to 79.6% by 2030 and 77.5% by 2050.

The share of rice decreased from 80.4% in 1990 to 70.5% in 2021 and will fall to 72.6% in 2030 and further decline to 70.4% in 2050. Absolute consumption slightly decreased 2010 level to 2021 and there after it will remain stable till 2050. The share of wheat slightly increased from 6.6% in 2010 to 6.72% in 2030 and 6.83% in 2050 and absolute consumption will slightly increase. During 2010 to 2030 maize consumption will increase from 6.0 kcal/person/day to 6.5 kcal/person/day and after that it will remain stable. The share of calorie intake from cereals seemed to be reaching a level of saturation. However, as far as rice consumption is concerned, there is no room for significant increases in average consumption even with income growth; in fact, it even started decreasing as in countries with similar consumption and economic growth patterns in Asia.

The contribution to calorie intake from potato, vegetables, and animal products gradually increased during 1990 to 2010 and will continue to increase during 2030 and 2050. The forecasts show that the consumption of animal products (meat, milk, egg and fish) followed similar increasing trend during 1990 to 2030. Beyond 2030 the consumption of animal products will further increase.

**Demand for rice**

Projections of ARIMA model showed that the total direct food demand for rice in 2030 will be 33.9 million metric ton (MMT), which is an 11% increase from the 2021 level. Total crop demand for rice is projected to be 39.1 MMT in 2030 and 42.6 MMT in 2050. Our projection of total demand for rice in 2030 found to be consistent with other studies and data.

**Supply of rice**

Projections showed that under adjusted Business As Usual (BAU) scenario total supply of rice could be 41.04 MMT in 2030 and 52.13 MMT in 2050 against 43.20 MMT and 54.97 MMT, respectively under BAU scenario. According to Pessimistic Scenario (PS) total supply of rice could be 35.47 MMT in 2030 and 40.68 MMT in 2050. Adjusted BAU scenario seems to be more plausible than BAU scenerio. BAU scenario is not feasible in

that with this projected level of production as there will have a rice surplus of around 2.3 MMT in 2021 and 4.2 MMT in 2030. But the reality is that Bangladesh imported about 0.6 MMT rice in 2021. In the next decades Bangladesh will have to face problems of climate change, soil degradation, increased soil salinity, scarcity of irrigation water, etc. The PS scenario reflects rice production under degraded condition. In the long run, new rice technology will be available and will be adopted. However, with the adoption of new rice technology the total production could be most likely in between PS and adjusted BAU scenario.

Based on estimates of adjusted BAU scenario there will have a marginal surplus of rice of 1.95 MMT in 2030. But PS predicts that there could be a deficit of 3.62 MMT in 2030 and a deficit of 1.93 MMT in 2050. According to PS, rice deficit in 2021 was 0.61 MMT which is more plausible than adjusted BAU scenario due to the fact that quantity of rice imported in Bangladesh was 0.6 MMT in 2021.

**Demand for wheat**

The food demand for wheat will be 3.0 MMT in 2030 which is an increase by 0.4 MMT from the 2021 consumption level (13.7% higher). Total demand for wheat is projected to be 6.39 MMT in 2030, and 8.09 MMT in 2050.

**Supply of wheat**

ARIMA model predicted that wheat production in 2030 will be 1.17 MMT and 1.24 MMT in 2050. There could be a deficit of wheat of 5.22 MMT in 2030 and 6.85 MMT in 2050.

**Demand for maize**

The food demand for maize will be 0.14 MMT in 2030 which is 7.7% higher than 2021 level. Total demand for maize is projected to be 8.43 MMT in 2030 and16.99 MMT in 2050.

**Supply of maize**

ARIMA model on the basis of BBS data predicted that maize production will be 6.19 MMT in 2030 and 12.24 MMT in 2050. There will have a deficit of maize of 2.25 MMT in 2030 and 4.75 MMT in 2050 while estimates based on DAE data shows that there will have marginal surplus of 0.88 MMT maize in 2030 and gradually it will rise to 3.09 MMT in 2050. Maize area and yield data of BBS and DAE differs much. It is necessary to harmonize data of these two sources. As a government source of BBS data are to be given priority, they should be used for planning exercise.

**Demand for pulses**

The projected demand for pulses for the period 2030 to 2050 found to be consistent and validated through consultations. The total demand for pulse in 2030 will be 17.9 lakh MT and there will have an increasing trend over the years. In the year 2040 it will rise to 18.9 lakh MT and will further rise to 19.5 lakh MT in 2050. Crop wise estimates showed that annual demand for chickpea, pea, lentil, mungbean, blakhk gram and grass pea in the country will be 1.4 lakh, 3.6 lakh, 7.1 lakh, 2.8 lakh, 1.3 lakh and 2.8 lakh MT, respectively. All pulse crops found to have increasing trend individually over the years and the corresponding consumption demand in 2050 will be 1.6 lakh, 4.0 lakh, 7.8 lakh, 3.1 lakh, 1.6 lakh and 3.1 lakh MT, respectively.

**Supply of pulses**

Projections showed that among the six pulses only lentil, mungbean, grasspea and pea will have increasing trend in 2030 and will continue till 2050. Projections further show that lentil production will increase from 1.77 lakh MT in 2021 to 2.28 lakh MT in 2030 and further rise to 3.7 lakh MT in 2050 due to yield and area increase. Mungbean and grasspea production is predicted to increase to 0.76 lakh and 1.94 lakh MT, respectively in 2030 and further rise to 1.89 lakh and 3.87 lakh MT in 2050 due to yield and area increase.

Chickpea yield will increase from 1.1 ton/ha in 2021 to 1.2 ton/ha in 2030, but its area will decline form 4814 ha in 2021 to 3822 ha in 2030 and as a result, total production of chickpea will be 0.05 lakh MT in 2030 as same as the production level of 2021. Chickpea yield will further increase to 1.3 ton/ha in 2050 but its area will further decrease to 1817 ha and as a result, the total production will fall to 0.02 lakh MT.

Blakhkgram yield will increase from 0.9 ton/ha in 2021 to 1.0 ton/ha in 2030 but its area will decline form 40621 ha in 2021 to 3279 ha in 2030 and as a result total production of blakhkgram will slightly fall from 0.37 lakh MT in 2021 to 0.33 lakh MT in 2030. blakhkgram yield will further increase to 1.1 ton/ha in 2050, but its area will further decrease to 2358 ha in 2050 and as a result total production will fall to 0.26 lakh MT.

Total pulses production will increase from 4.1 lakh MT in 2021 to 5.5 lakh MT in 2030. It will further rise to 19.2 MT in 2050 due to yield increase and area expansion. There will have deficits of supply of all pulses in 2030 amounting 12.88 lakh MT. Deficit of lentil, mungbean and grasspea will decrease over the years. There will have a surplus of all pulses with the amount of 10.24 lakh MT in 2050 due to major contribution of increased productivity of lentil, mungbean and grasspea.

**Demand for oil crops**

Demand for mustard oil will increase from 1.47 lakh in 2021 to 2.1 lakh MT in 2030. It will further rise to 2.9 lakh MT in 2040 and 3.94 lakh MT in 2050. Demand for ground nut oil will be 0.145 lakh MT in 2030 and it will remain almost similar till 2045 and will slightly decline to 0.131 lakh MT in 2050. Demand for soybean oil will increase from 11.9 lakh MT in 2021 to 13.9 lakh MT in 2030 and thereafter it will gradually rise to 16.9 lakh MT in 2050.

**Supply of mustard and ground nut**

The whole (grain) ground nut production will increase from 0.58 lakh MT in 2021 to 0.89 lakh MT in 2030 as a result of yield increase from 1.8 ton/ha in 2021 to 2.1 ton/ha and area expansion form 32.4 thousand ha in 2021 to 42.3 thousand ha in 2030. Ground nut production will gradually rise to 1.42 lakh MT in 2050. Similarly, whole (grain) mustard production will increase from 3.57 lakh MT in 2021 to 4.40 lakh MT in 2030 as a result of yield increase from 1.16 ton/ha in 2021 to 1.2 ton/ha in 2030 and area expansion form 309 thousand ha in 2021 to 343 thousand ha in 2030. Also, mustard production will gradually further rise to 5.6 lakh MT in 2050.

We have converted production of whole ground nut and mustard into oil. It is found that there will have a surplus of ground nut oil of 0.30 lakh MT in 2030 and 0.58 lakh MT in 2050. There will have a deficit of mustard oil of 0.30 lakh MT in 2030 and 1.68 lakh MT in 2050.

**Demand for spices**

The demand for onion will increase from 27.0 lakh MT in 2021 to 34.0 lakh MT in 2030. It will further rise to 40.1 lakh MT in 2040 and 45.5 lakh MT in 2050. Also, demand for garlic will increase from 13.7 lakh MT in 2021 to 17.4 lakh MT in 2030, 20.5 lakh MT in 2040 and 23.2 lakh MT in 2050. Demand for turmeric will be 8.2 lakh MT in 2030 and thereafter it will gradually rise to 10.9 lakh MT in 2050. Demand for dry chili, ginger and coriander will be 4.8, 3.1 and 1.0 lakh MT, respectively in 2030 and there after their demand will gradually rise to 6.4, 4.1 and 1.4 lakh MT in 2050.

**Supply of spices**

The onion production will increase from 18.5 lakh MT in 2021 to 25.4 lakh MT in 2030 and further rise to 48.8 lakh MT in 2050 due to yield increase and area expansion. Turmeric, garlic, ginger, coriander and chili production predicted to increase to 3.8, 6.7, 0.9, 0.2 and 3.4 lakh MT, respectively in 2030 and further rise to 7.3, 12.9, 1.1, 5.0 and 7.5 lakh MT in 2050. Total spices production will increase from 28.1 lakh MT in 2021 to 40.5 lakh MT in 2030. It will further rise to 78.1 lakh MT in 2050 due to yield increase and area expansion

There will have deficits of supply of all spices in 2030 and 2050. Deficit of onion and chili will decrease over the years. There will have surplus of chili production in 2045 and 2050. Total deficit of six spices in 2030 will be 28.08 lakh MT and thereafter it will gradually decrease till 2050. There will have a marginal surplus of onion and chili amounting 3.29 lakh MT and 1.15 lakh MT, respectively in 2050.

**Demand for potato and sweet potato**

The demand for potato will increase from 95.63 lakh MT in 2021 to 116.16 lakh MT in 2030. It will further rise to 122.6, lakh MT in 2040 and 126.59 lakh MT in 2050. Also demand for sweet potato will decrease from 4.12 lakh MT in 2021 to 3.20 lakh MT in 2030 and thereafter rise gradually to 3.38 lakh MT in 2040 and 3.49 lakh MT in 2050.

**Supply of potato and sweet potato**

Potato production is predicted to increase from 98.7 lakh MT in 2021 to 117.8 lakh MT in 2030 as a result of yield increase from 21 ton/ha to 24.2 ton/ha and area expansion from 468.9 thousand ha to 486.8 thousand ha. Its production will further gradually rise 140.9 lakh MT in 2050 due to yield increase to 28.3 ton/ha and area expansion to 535.7 thousand ha.

Sweet potato production is predicted to increase from 3.66 lakh MT in 2021 to 5.43 lakh MT in 2030 as a result of yield increase from 9.66 ton/ha to14.14 ton/ha and area expansion form 26.5 thousand ha to 38.4 thousand ha. Its production will further gradually rise to 15.83 lakh MT in 2050 due to yield increase to 28.3 ton/ha and area expansion to 68.1 thousand ha.

Total potato supply in 2030 will be 117.8 lakh MT and will have a marginal surplus of 1.6 lakh MT. Total potato supply in 2050 is projected to be 140.9 lakh MT and will have a surplus of 14.3 lakh MT.

Total sweet potato supply will be 5.4 lakh MT in 2030 and will have a marginal surplus of 2.2 lakh MT. Total sweet potato supply will be 15.8 lakh MT in 2050 and will have a surplus of 12.3 lakh MT.

**Demand for vegetables**

Total vegetable demand in the country is projected to increase from 41.2 lakh MT in 2021 to 51.5 lakh MT in 2030 with an annual growth rate of 2.8%. This is projected to gradually rise to 65.5 lakh MT in 2050.

**Supply of vegetables**

Supplies of 10 major vegetables have been projected for the period 2030 to 2050. These are tomato, bean, brinjal, cucumber, lady's finger, bitter gourd, cauliflower, cabbage, snake gourd and gourd. These crops cover 68% of total vegetables production of Bangladesh. The selected 10 vegetables are projected to have increasing production due to yield and area expansion. Total production of these crops will increase from 29.8 lakh MT in 2021 to 40.1 lakh MT in 2030 and will gradually rise to 71.0 lakh MT in 2050.

Total vegetable demand in 2030 will be 51.5 lakh MT and supply will be 53.8 lakh MT and will have a marginal surplus of 2.3 lakh MT. Total vegetable supply in 2050 is projected to be 89.0 lakh MT and will have a surplus of 23.5 lakh MT.

**Demand for fruits**

The study selected six major fruits for projections of supply for the period of 2030 to 2050. These fruits are pineapple, lime & lemon, banana, guava, mango and water melon. These crops cover 72% of total fruits production of Bangladesh. Total demand for six major selected fruits in the country is projected to increase from 26.7 lakh MT in 2021 to 32.2 lakh MT in 2030 with an annual growth rate of 2.28%. This is projected to further gradually rise to 43.7 lakh MT in 2050.

**Supply of fruits**

The selected six fruits are projected to have increasing production due to yield and area expansion over the projection period. Total production of these fruits in the country will increase from 29.4 lakh MT in 2021 to 35.5 lakh MT in 2030 and will gradually rise to 51.6 lakh MT in 2050 and will have a marginal surplus of 3.3 lakh MT in 2030 and 7.9 lakh MT in 2050.

**Sensitivity analysis of demand and supply of crops**

Sensitivity analysis was carried out to examine changes in projected crop demand and supply and net effect on surplus or deficit under alternative scenarios for the key crops-rice, vegetables and fruits.

**For demand side:** The study considered three alternative scenarios for comparison of sensitivity of rice, vegetables and fruits demand projections (1) Existing scenario:

Projections with existing rate of calorie intake, (2) Alternative Scenario 1: Crop demand decrease by 5% and (3) Alternative Scenario 2: Crop demand increase by 5%. For rice crop the adjusted BAU and PS scenario seems to be more plausible considering total consumption, food production, import and food balance and gave consistent results. For vegetables and fruits similar consistent results were found.

**For supply side the study considered Alternative scenario 1:** Supply short fall by 8% due to shocks (climate change, disease & pest, market vulnerability) and Alternative scenario 2: Supply short fall by 10% due to shocks. Under the alternative scenarios net supply decreased and gave consistent results.

**Recommendations**

On the basis of the findings of the study following recommendations can be made for transformation and development of Bangladesh agriculture by 2030 and 2050:

1. It is necessary to enhance rice productivity through generating new varieties and climate resilient technology to eliminate rice deficit during 2030s and 2040s.
2. Heat tolerant and disease resistance high yielding wheat varieties (BARI Gom 33 and WMRI Gom 3) can be cultivated in the south and north-east part of the country where vast areas of land remain fallow after cultivation of T. *Aman*. In the south 800 thousand hectare of land remain fallow after T. *Aman*, which could be brought under wheat cultivation. Also, wheat cultivation could be expanded in the mountain valley and plain land of Chattogram Hill Tract. Extension support and government incentives will be required to promote wheat cultivation in the non-conventional fallow lands of the country.
3. Develop a strategic rice grain reserve of minimum 1.5 MMT to maximum 2.5 MMT in public warehouses under Ministry of Food to address vulnerability in rice supply due to various shocks.
4. Need to prepare a long-run plan for technology development and transformation of Bangladesh agriculture in 2030s and 2040s. This will require increased investment in research, extension and market development.
5. It is necessary to harmonize BBS and DAE data specially on maize production. Priority should be given on BBS data over DAE data for policy and planning purposes.
6. Bangladesh can promote export of surplus potato, vegetables and fruits. Government supports will be needed in the form of providing incentives to the exporters, investment in value chain development programs and food quality and safety certification.

Recommendations received from four Regional Validation Workshops and FGDs for transformation of Bangladesh Agricultureare summarized as Annex 4 and 5.

# 1. Introduction

## 1.1 Overview of Bangladesh agriculture and rational of the study

Agriculture is become the driving forces of the economy of Bangladesh. The government is working tirelessly to build sustainable, safe and profitable agricultural systems to ensure food security. The government has been making all out efforts for the overall development of the agriculture sector in the light of Vision 2041, 8th Five Year Plan (2020-25), National Agricultural Policy 2018, Sustainable Development Goals, Deltaplan-2100 and other planning documents. At present, the government has adopted short, medium and long term action plans to meet the future needs of the growing population, based on the agriculture sector's achievements in various emergencies, including the impact of COVID-19.The total production target of food grains in FY 2021-22 is 465.83 lakh metrictonnes (MT), which was 466.35 lakh MT in FY 2020-21. In the revised budget of FY 2021-22, the target for domestic food grain procurement is 19.50 lakh MT. As of February 2022, the country has imported 10.59 lakh MT of food grains under government management. However, a total of 27.69 lakh MT (3.04 lakh MT of rice and 24.65 lakh MT of wheat) was imported in the private sector (MoF, 2022). Despite declining arable land, meeting the food and nutrition needs of the growing population, climate change, and the impact of the COVID-19, crop production continues to grow. At this time, Bangladesh has risen from the fourth plakhe to the third plakhe in rice production in the world, as a result of which the foundation of food security in the country has been strengthened.

During the recent decade, the overall Gross Domestic Product (GDP) of Bangladesh has shown a remarkable progressive increasing trend. The average growth rate of GDP during 2011 to 2021 was 6.4%. In 2020, GDP growth rate declined to 3.45% due to Covid-19 pandemic. But beyond 2020, GDP growth rate again revived with an increasing trend. On the other hand, the growth in agricultural GDP slightly declined, from 4.46% in 2011 to 3.17% in 2021 with an average growth 3.30% during 2011 -2021(Figure 1.1).

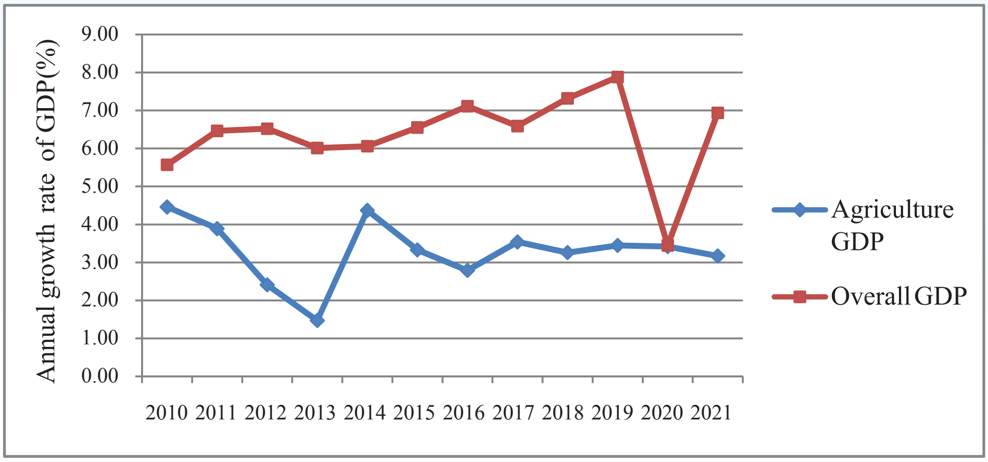



**Figure 1.1 Trend in growth rate in overall GDP and agricultural GDP of Bangladesh during 1971 to 2021**
Source: author’s analysis from BBS data.

There has been a structural change in Bangladesh economy in that share of agriculture to GDP decreased over the years while share of industry and service sector gradually increased over the years. This is desirable and comply sign of development of the economy of Bangladesh. For instance, the share of agriculture, industry and service sectors were 62%, 23.2% and 26.4%, respectively in 1975. But these figures over the years considerably changed and confirmed a structural change in the economy. During 2011-2021, the share of agriculture to GDP declined from 16.81% to 12.07%, while share of industry increased from 25.04% to 36.01% and that of the service sector decreased from 53.03% to 51.92 (BBS, 2021). The economy has moved towards a developing country. It is expected to graduate from less developed country to developing country by 2026.

In 2008, per capita income of the country was only US $ 380. Over the years the per capita income of the country increased as a result of steady growth in GDP with transformation in agriculture, industry and service sectors. In 2021-22 per capita income of Bangladesh rose to US $ 2824. With the latest growth, size of Bangladesh's GDP stands at $465 billion in FY 2021-22 from $416 billion the previous year (BBS, 2021).

The agriculture sector of Bangladesh is playing important role in employment generation and poverty reduction. Bangladesh has a total population of about 169 million people out of which the agricultural sector in 2021 is accounted for almost 41% of the total labour force. During 1981-90, the share of employment in the agriculture sector was 60% of the labour force. The share of the economy as well as the share of employment in the agricultural sector has been decreasing with the expansion of industrial and service sector.

The emerging pattern of growth in poverty reduction in Bangladesh is encouraging. Bangladesh experienced substantial poverty reduction during the last 20 years (2000-2021). During this period, the average annual rate of poverty reduction was 1.4%. During this period GDP per worker both in agriculture and non-agriculture increased substantially and contributed to poverty reduction in Bangladesh. It was found that GDP growth had a higher impact on poverty in Bangladesh than that of all South Asian countries in the region, although Vietnam, China, and Thailand had a higher GDP growth rates than Bangladesh and had a lower reduction rate in poverty (Islam, *et al*, 2017).

The study conducted by Islam et al (2017) revealed that there is a negative relationship between poverty rates and growth in GDP per worker from agriculture and non-agriculture sector in Bangladesh. Such result found to be consistent and confirms the findings of a study of Cervantes-Godoy and Dewbre (2010) conducted in 25 countries of Asia and Africa. Islam et al (2017) carried out a multiple regression analysis in order to quantify the contribution of growth of GDP per worker from agriculture and non-agriculture to poverty reduction in Bangladesh. It was found that an increase in growth rate in agriculture GDP has a larger impact on poverty reduction than that in non-agriculture GDP. The result implied that, other things remaining the same, 1% increase of income of agriculture GDP per worker would reduce poverty by 0.39% while in case of non-agriculture. GDP per worker, 1% increase of income of non-agriculture GDP per worker would reduce poverty by 0.11% in Bangladesh.

The agriculture sector is the center of economy of Bangladesh, it decreasing poverty and ensuring food security. Over the last 30 years, rice production tripled from approximately 10 MMT in the mid-1970s to 37.61MMT in 2021. Such productivity improvement came through the cultivation of high-yielding varieties under irrigation with use of chemical fertilizers and irrigation. It enabled Bangladesh to increase food availability to meet the demands of a rapidly growing population.

Increase in food production and attaining self-sufficiency in Bangladesh requires sustainable growth of the agricultural sector in order to supply adequate food for its increasing population. Fertilizer is considered to be one of the main inputs for increasing crop yields and farm profit. But balanced fertilization is the key to efficient fertilizer use for sustainable high yields. Bangladesh has virtually no possibility of increasing its cultivable land area. Therefore, food production of this country can be increased through expansion of HYVs and balanced use of fertilizer.

There has been a progressive shift in fertilizer policies in Bangladesh. In 1970s fertilizer was popularized with introduction of massive subsidy. Later, Bangladesh gradually moved towards privatization, deregulation, and a reduction of subsidies, which began in the mid-1980s and continued until the mid-1990s. This was partially reversed following the severe fertilizer crisis in 1995. During the global food price crisis in 2007-08 public sector roles were further strengthened towards market intervention and providing subsidy of fertilizers for achieving self-sufficiency and food security.

Expansion of minor irrigation through groundwater using Deep Tube Wells (DTWs) and Shallow Tube Wells (STWs) was the vital component of the GoB's strategy to facilitate irrigation for agricultural development. Agricultural growth in the country has been largely due to the expansion of minor irrigation with private sector investment. There was increasing trend of irrigation growth in Bangladesh from 1982 to 2021.

During 2014-15, BADC increased its capacity to the extent that it could supply a large quantity of quality seeds of HYVs/MVs/Hybrids of four notified crops (rice, wheat, jute, and seed potato), and eight non-notified crops (maize, pulses, oilseeds, spices, and vegetable seeds). In the green revolution period (1970-80s) there was heavy subsidization of seed and the public sector role played in the seed market through BADC. During the 1990s to 2000s the seed market has been liberalized with the New Seed Policy 1993, Seed Amendment Acts 1997 and 2005, and the Seed Rules 1998 and opened market for participation and rise of private enterprises in seed production, import, and distribution. Ensuring supply of quality seeds and controlling marketing of adulterated seeds was emphasized in the Sixth and Seventh Five Year Plan of Bangladesh. Agricultural growth is dependent on a very wide-scale switch to HYV seed. Some of the non-government organizations and the private sector entered into the seed sector with positive impacts on availability of quality seed. Further private-public partnerships for seed, marketing, and extension need to be promoted in the next decades (2030-41) of perspective planning.

Agricultural credit, as an input, plays an important role in driving the agriculture of Bangladesh towards a sustainable level. Food security, employment generation and poverty alleviation are closely linked with the development of the agriculture sector. To strengthen the agricultural and rural credit program, Bangladesh Bank formulated its Agricultural and Rural Credit Policy and Program. The objective of this policy is to ensure easy access to the agricultural and rural credit facilities by the farmers from the scheduled banks of the country. There was an increasing trend in disbursement of agricultural credit during 2005-2021.

The Six, Seven and Eight Five Year Plans of Bangladesh prioritized the importance of research and extension for generation and dissemination of technology to boost agricultural production through promoting intensification, diversification and resilience to climate change. The NARS institutes developed large number of HYV crop varieties of rice, vegetables, spices and fruits. Some of these are salinity and stress tolerant rice, wheat and maize varieties, short duration rice variety, HYV potatoes, vegetables and spices etc. Also BARI developed some important HYV fruit varieties like mango, Malta, guava, lemon, etc. Varietal improvement and improvement of production practices are high priority of NARS research program. Technologies developed by the NARS institutes were disseminated successfully to the farmers through the extension department and NGOs.

Bangladesh has a comparative advantage of production for rice, pulse, potato, onion, maize, vegetables, chili and garlic. So, there is good scope for crop diversification. The analysis of comparative advantage carried out suggests that the menu of crops that Bangladesh can produce efficiently either for import substitution or for export is quite large (Islam et al, 2017).

The importance of high-value crops is increasing in Bangladesh; the share of these products was 40% and 49% of the food consumption basket in rural and urban areas in 2020, respectively. Given high income elasticities, this share is expected to further increase in the future. At present a number of fresh and processed agro-commodities are exported from. Bangladesh. The government is supporting export promotion of agri-commodities. As a result there is increasing trend in export of fresh, frozen and processed food from Bangladesh in the last decade.

Current climate change issues are considerably affecting food security of the millions of people of Bangladesh. It is now one of the most vulnerable countries of climate risks in the world. In Bangladesh, damage caused by natural disasters is one of the main sources of crisis for poor households. Every year, natural calamities such as floods, cyclones, erosion, and droughts cause extensive damage to crops, homes, household and community assets, which can lead to illness or death and a decrease in livelihood opportunities for the poor. Disasters hamper physical access to food, destroy crops, disrupt markets and affect household food security.

However, agriculture being an important engine of growth of the economy, there is no other alternative but to develop the agriculture sector for the alleviation of poverty by attaining accelerated economic growth. Since achievement of food security, and generation of employment opportunities of the huge population of the country are directly linked to the development of agriculture, there have been continued efforts by the Government for the overall development of this sector.

Rice dominates Bangladesh agriculture, with almost 75% of the total cropped area under rice cultivation. Rice production has shown a steady increase in Bangladesh and has even shown signs of acceleration in growth in recent years. Availability of staple food has been increased largely and Bangladesh has become self-sufficient in rice staple food. Since liberation (1971) food production has been tripled in 2020 while population has been increased by 2.6 times.

With an expanding population, planning for future food production and demand is crucial to meeting the food security challenges in Bangladesh. To facilitate this planning, projections of future supply and demand for food are important. Another important issue need to consider in connection with the food supply is that agricultural land is decreasing due to industrialization, urbanization and other factors. Despite the fact that agricultural growth has been higher than the rate of population growth concerns has been raised whether the land mass of Bangladesh is actually capable of supporting its expanding population by 2030 and 2050. Agriculture sector is dynamic, changing with demand of people, availability of technology and change of management practices. This study is an attempt to carry out such future projections with a view to assessing the likely gap between supply and demand. It will be useful for the researchers and the policy makers for development of new crop variety, generation of new technology and actionable policy in the context of 2030 and 2050 scenarios.

## 2. Objectives of the study

- To estimate supply and demand projections of selected food crops produced in Bangladesh in 2030 and 2050;
- To estimate gaps in food demand and supply of selected food crops in 2030 and 2050;
- To carry out sensitivity analysis of food demand and supply of the selected food crops under alternative scenarios; and
- To suggest recommendations and policy implications.

## 3. Methodology

- We have first developed and validated models of supply and demand using the available data;
- Then projected supply and demand of selected crops for the years 2030 and 2050 under various scenarios.

### 3.1 Selected crops

**Table 1. Name of the selected crops for the study**

| Crop type | No. of selected crop | Name of crops |
|---|---|---|
| Cereals | 3 | Rice, Wheat and Maize |
| Tubers | 2 | Potato and Sweet potato |
| Oil seeds | 2 | Mustard and Ground nut |
| Pulses | 6 | Lentil, Chickpea, Mungbean, Blackgram, Grass pea and Pea |
| Vegetables | 10 | Tomato, Country Bean, Brinjal, Cucumber, Lady's finger, Bitter gourd, Cauliflower, Cabbage, Snake gourd and Gourd |
| Spices | 6 | Onion, Garlic, Coriander, Ginger, Turmeric and Chili |
| Fruits | 6 | Mango, Banana, Pineapple, Watermelon, Guava and Lime & lemon |
| Total | 35 | |

### 3.2 Research activities during inception phase

- Literature review: Review of relevant studies, and documents;
- Fine tuning of methodology;
- Preparation of work plan;
- Organizing Inception Workshop and incorporation of feedback.

#### 3.2.1 Literature review

Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) model found to widely used popular model for forecasting of demand and supply of crops. Some important studies used ARIMA model are Islam and Talukdar, (2016 and 2017), Ganesh-Kumar, *et al*, (2012), Amarasinghe, et al (2014)'. Islam and Talukdar's projections in 2015 showed that Bangladesh will have marginal surplus productions of rice by 2030. This result as found to be consistent and plausible. As Bangladesh recently achieved self-sufficiency in rice and reaching towards marginally surplus situation in 2030. Their forecasts of ARIMA models in 2015 showed that supply of rice will be 38.7 MMT in 2030. This projection of rice production in 2030 is closely similar to that of Ganesh-Kumar et al. (2012) of IFPRI which was 38.8 MMT.

Could the future growth of supply of food of a country match with its increased demand for food as a result of population pressure and rising income? A number of studies attempted to answer this and projected demand for and supply of key food items in various countries and assessed gap (Grafton *et al.*, 2015; Ahmad and Kiresur, 2016; Nilesh *et al.*, 2014; Kumar *et al.*, 2016; Valin *et al.*, 2014; Zhou and Staatz, 2016; Ray *et al.*, 2013).

Mishra et al (2021) projected supply of pulse in India using ARIMA model. The model predicted that India will have a pulse production of 31 million tons in 2029. For stochastic prediction estimation; yearly data were used for the period from 1961 to 2019. On the basis of the performance of several goodness of model fit criteria, the most suitable ARIMA model is selected to predict pulse production in India.

Halliyavar, *et al* (2020) used the ARIMA model for projections of supply of tomato, onion and potato in India. ARIMA model has been utilized in the work to come up with the best model for predicting the amount of production based on the past data. The work provides the best AR, MA and ARIMA model and also the prediction for 15 years based on the previous available data.

The study of Sankar (2022) analyzed and determined the design of a stochastic forecasting model for Finger Millet production inTamil Nadu during the years from 1966 to 2017 using ARIMA model. Millet production in Tamil Nadu is projected to decline from 32.13 thousand tons in 2017 to 24.83 thousand tons in 2027.

Samalet al (2022) studied the global rice agriculture towards 2050 with an inter-continental perspective. They found that future additional rice demand will mainly come from the population growth in Africa and Asia. The production growth during the past led by growth in yield has helped in meeting rice demand around the globe. Global rice demand is projected to rise from 439 MMT (milled rice) in 2010 to 496 MMT in 2020, to 555 MMT in 2035. This is an overall increase of 26% in the next 25 years, although demand will decline over time as population growth slows and people diversify from rice to other foods. Asian rice consumption is projected to account for 67% of the total increase, rising from 388 MMT in 2010 to 465 MMT in 2035 despite a continuing decline in per capita consumption in China, India and Bangladesh.

### 3.3 Field Work and Data Collection Phase

**Activities done:**

- Collected and prepared database, cleaned data and carried out descriptive analysis and assess data quality for modeling.
- Visited various research institutes, relevant agencies for assessing available technology and gathered relevant data.
- Carried out four Regional Workshops and seven FGDs at different crops growing areas based on intensive cultivation practices.

### 3.4 Model for Forecast of Food Demand and Supply

Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) time-series methodology was used for modeling and forecasting. ARIMA is a popular most widely used model in the world for forecasting purposes because of its very low forecast error & reliability of estimates.

**ARIMA model structure**

Steps used in estimation of ARIMA model is illustrated below:

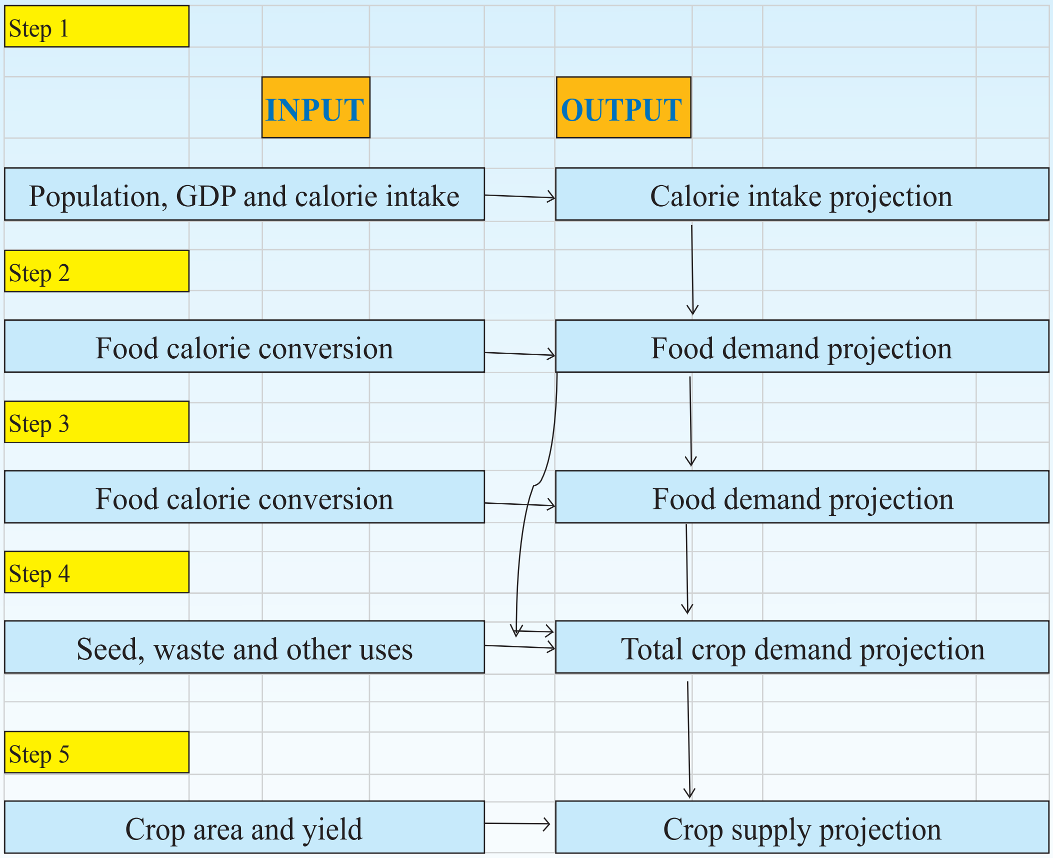



**Figure 1. Framework used for estimating projection of food demand and supply**

**Step 1. Predicts the calorie intake of different crop commodities:** The ARIMA time series model (Box and Jenkins 1976) was used to forecast the per capita gross domestic product (GDP) and calorie intake to 2030 and 2050. The ARIMA (p, d, q) model has p and q autoregressive and moving average terms of the stationary time series of order d; it takes the form:

$$(Y_t - \alpha_1 Y_{t-1} - \alpha_2 Y_{t-2} - \ldots - \alpha_p Y_{t-p}) = \beta_0 + (u_t - \beta_1 u_{t-1} - \beta_2 u_{t-2} - \ldots - \beta_q u_{t-q}) \quad (1)$$

where: Yt is the dth difference of the original time series, and u is a random noise. Differencing of the original variable gives a stationary time series.

In the Step1 the ARIMA models forecasts the calorie demand of selected crops. The total calorie demand is the product of per capita calorie demand and population projections. The population projection of Bangladesh Bureau of Statistics, Planning Commission Ministry of Planing Government of the People's Republic of Bangladesh was used in this study.

**Step 2. Estimates the food demand:** It is the product of calorie supply from food and the food to calorie conversion ratio. The food to calorie conversion ratio (grams/kcal) is the quantity of food required to provide one kcal of nutritional supply. For rice, it is about 0.28 grams/kcal. Calorie content of selected crops was taken from Institute of Nutrition and Food Science, Dhaka University, Bangladesh.

**Step 3. Estimates the feed demand:** It is the product of calorie supply from animal products and the feed to calorie conversion ratio. The feed to calorie conversion ratio of a crop is theratio of the total quantity of crops/products used as feed to the calorie supply from animal products. The feed demand of cereals increases with increasing supply of animal products (Bradford 1999; Bhalla and Hazell 1997).

**Step 4. Estimatesthe total crop demand:** It is the sum of the demand for food, feed, seed, and other uses and waste. The trend of the ratio of all uses (seed+other uses+waste) to total domestic supply indicates the patterns of seed, waste and other uses.

**Step 5. Estimates the food supply:** The ARIMA models predict the area and yield of selected crops. The models projected the rice supply separately for the three main seasons: *Aus*, *Aman* and *Boro*.

**Sensitivity analysis**

Sensitivity analysis was carried out to predict alternative scenarios of food demand and supply projections with the following assumptions:

**Demand side:**

1. Assume 5% decrease of rice demand from 2021 level
2. Assume 5% increase of rice demand from 2021 level

**Supply side:**

1. Supply short fall by 8% due to climate and market shocks
2. Supply short fall by 10% due to climate and market shocks

**BOX and JENKINS ARIMA Method**

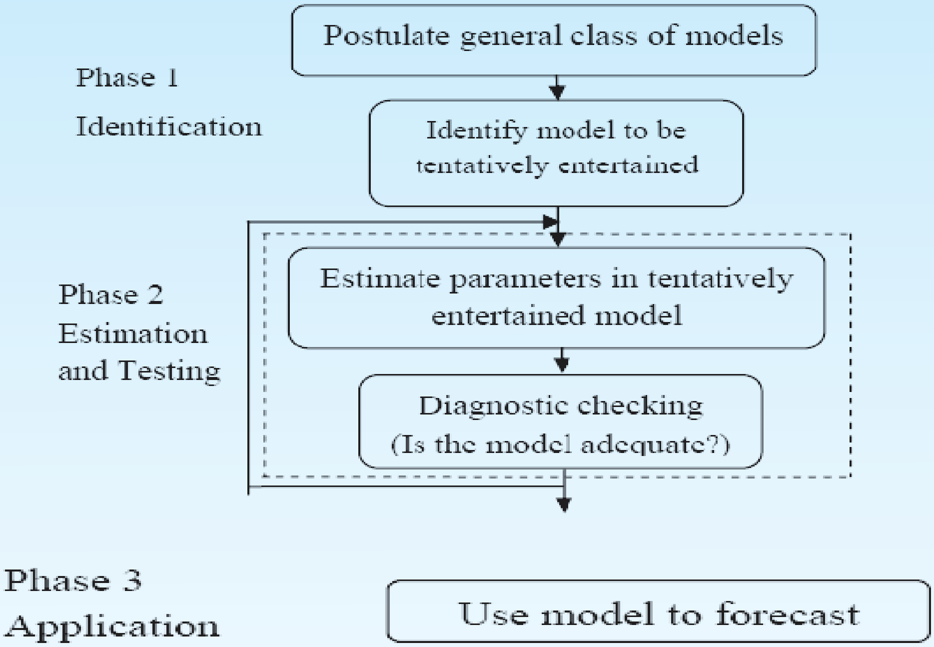



**Figure 2. Illustration of ARIMA Method**

**Identification of ARIMA (P, D, Q) Model**

The NCSS Forecasting software was used for identifying the most parsimonious ARIMA model. An ARIMA analysis uses stationary time series, i.e., those series without trends. At first the time series data is made stationery through differencing. Then the order of the ARIMA called p and q is determined generating and plotting ACF and PACF curves as shown is the graph (Figure 3).

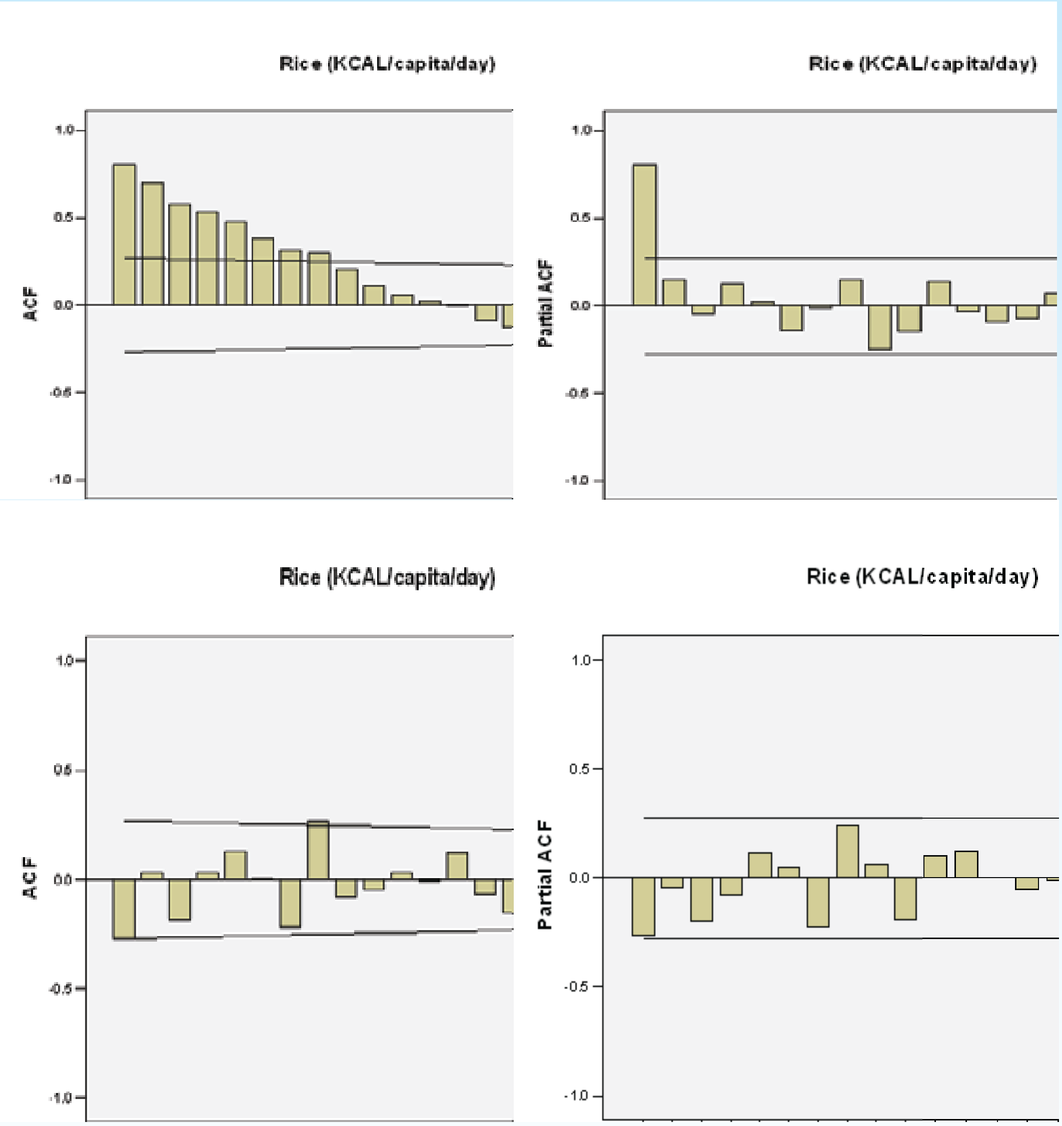



**Figure 3. Identification of p and q**

### 3.5. Sources of data

3.5.1. Mainly secondary data from BBS, DAE, FAOSTAT, NARS Institutes and reports, journals and relevant studies were used for the present study.

The time series data of calorie intakes for ARIMA modeling have been taken from the Food Balance Sheets of the FAOSTAT database (FAO 2013a). These include per capita calorie supply of cereals and rice, wheat, maize, pulses, potato, vegetables and fruits. The food, feed and waste statistics are taken from the commodity balances of the FAOSTAT database (FAO 2013c). These include total food, feed, seed, waste and other uses of the above crops.

The time series data from 1971 to 2021 for ARIMA modeling of the crops areas, production and yields have been taken from BBS. But for estimation of maize forecast model, we have used both BBS and DAE data.

**3.5.2. Primary data from field visits: Workshops, FGDs and KIIs**

Primary data were collected through regional workshops, FGDs, KIIs and consultations with scientists, extension experts, farmers and various stakeholders.

**Limitations**

Inconsistent time series data in some cases may create problem for model validation

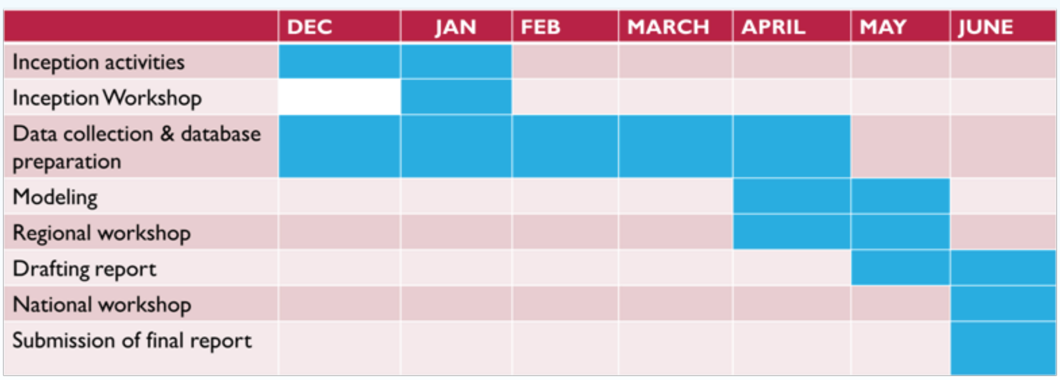
**Treatments:**

- Use statistical tools to clean data and generate missing information
- Use cross section data to supplement
- Use research results and data from of NARS for cross checking
- Try alternative models

**3.6 Work plan**

The study started from mid-December, 2021 and ended by June 30, 2022. Details of work plan by month is illustrated in Figure 4

**Figure 4. Gant chart of work plan**



## 4. Results and discussion

### 4.1 Crop demand projections based on ARIMA model

#### 4.1.1. Estimation of valid ARIMA models for projections of calorie intake of crops

We have used NCSS version 12 software for estimation of ARIMA models and forecasts. The estimated coefficients of the ARIMA models of selected crops have been presented in Table 2 and Table 3. Most of the estimates were found to be significant as indicated by standard errors of the estimates, t-values and all the models was found to be adequate as judged by Portmanteau Test statistics.

**Table 2. Parameter estimates of ARIMA model of calorie intake of cereals, pulses and oil crops**

| Crops | Model | Parameter | Standard error | t-value | Portmanteau Test value | Portmanteau Test decision |
|---|---|---|---|---|---|---|
| Rice | ARIMA (0,1,1) | 0.320** | 0.125 | 2.63 | 32.08 | Adequate model |
| Wheat | ARIMA (1,2,0) | -0.660** | 0.099 | -6.62 | 48.03 | Adequate model |
| Maize | ARIMA (0,1,1) | 0.401 ** | 0.121 | 3.31 | 36.67 | Adequate model |
| Peas | ARIMA (0,1,1) | 0.670 | 0.097 | 6.8963 | 20.49 | Adequate model |
| Other Pulses | ARIMA (0,1,1) | 0.484** | 0.116 | 4.12 | 22.32 | Adequate model |
| Mustard | ARIMA (0,1,1) | 0.598** | 0.103 | 5.828 | 34.82 | Adequate model |
| Soybean | ARIMA (0,1,1) | 0.555** | 0.110 | 5.05 | 34.57 | Adequate model |
| Ground nut | ARIMA (0,1,1) | -0.183 | 0.130 | -1.408 | 37.85 | Adequate model |
| All oil crops | ARIMA (1,1,1) | 0.636 ** | 0.104 | 6.13 | 26.46 | Adequate model |
| | | 0.982 ** | 0.015 | 67.17 | | |

Source: Author's estimation from ARIMA model,Note: ** $p < 0.01$, * $p < 0.05$

We have validated the forecast models by comparing our forecasts results in 2021 with actual data of 2021 level and found that ARIMA models do not have any significant forecast errors.

**Table 3. Parameter estimates of ARIMA model of calorie intake of potato, sweet potato, vegetables, fruits, onion and other spices**

| Crops | Model | Parameter | Standard error | t-value | Portmanteau Test value | Portmanteau Test decision |
|---|---|---|---|---|---|---|
| Potato | ARIMA (0,1,2) | 0.258* | 0.138 | 1.8722 | 93.11 | Adequate model |
| | | -0.303** | 0.139 | -2.1663 | | |
| Sweet potato | ARIMA (0,1,1) | -0.164 | 0.131 | -1.2527 | 24.35 | Adequate model |
| Tomato | ARIMA (0,1,2) | -0.235* | 0.130 | -1.809 | 35.0 | Adequate model |
| | | -0.225* | 0.129 | -1.7335 | | |
| Country Bean | ARIMA (1,1,1) | -0.963** | 0.0868 | -11.099 | 34.92 | Adequate model |
| | | -0.897** | 0.137 | -6.528 | | |
| Other Vegetables | ARIMA (0,1,1) | -0.236* | 0.132 | -1.78 | 68.58 | Adequate model |
| Pineapple | ARIMA (0,1,1) | 0.009 | 0.132 | 0.0663 | 0.68 | Adequate model |
| Banana | ARIMA (0,1,2) | -0.015 | 0.121 | -0.12 | 45.19 | Adequate model |
| | | -0.408* | 0.118 | -3.452 | | |
| Lime & lemon | ARIMA (1,1,0) | -0.154 | 0.131 | -1.1800 | 24.16 | Adequate model |
| Other fruits | ARIMA (0,1,2) | -0.249* | 0.135 | -1.98 | 46.32 | Adequate model |
| | | -0.360* | 0.128 | -2.82 | | |
| Onion | ARIMA (1,1,1) | 0.893** | 0.412 | 2.168 | 43.0 | Adequate model |
| | | 0.842* | 0.476 | 1.770 | | |
| Other spices | ARIMA (0,1,2) | 0.190 | 0.119 | 0.119 | 47.63 | Adequate model |
| | | -0.439** | 0.120 | -3.67 | | |

Source: Author's estimation from ARIMA model, Note: ** $p < 0.01$, * $p < 0.05$

### 4.1.2 Composition of calorie intake

It is found that food consumption pattern in Bangladeshi diet is slowly diversifying over the years. Cereals still provide a major part of the calorie intake, but their share in total calorie supply has decreased from 89.6% in 1990 to 83% by 2010 and further decreased to 80.5% in 2021. ARIMA projections showed that it will further decrease to 79.6% in 2030 and 77.5% in 2050 (Figure 5). The contribution to calorie intake from potato, vegetables and animal products gradually increased during 1990 to 2021 and will continue to increase during 2030 to 2050. However, the absolute intake of these increased from 83 kcal/person/day to 290 kcal/person/dayduring 1990-2021 and will further rise to 310 kcal/person/day in 2030 and will be 354 kcal/person/day in 2050.

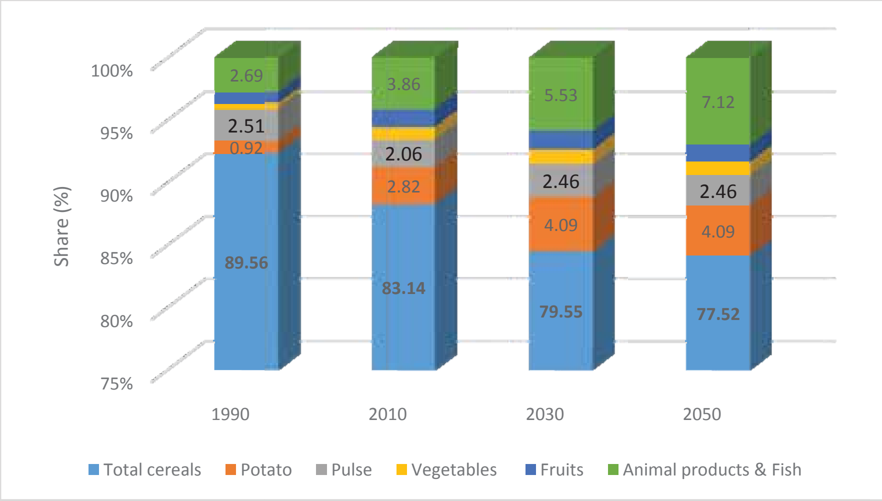



**Figure 5. Share of major food items in total calorie intake per capita**
**Source: Author's estimation**

The share of rice will decrease from 80.4% to 70.5% during 1990 -2021 and will fall to 72.6% in 2030 and further to 70.4% in 2050 and absolute consumption slightly decreased from 2010 level to 2021 and there after it will remain stable till 2050 (Figure 6). The share of wheat will slightly increase from 6.6% in 2010 to 6.72% in 2030 and 6.83% in 2050 and absolute consumption will slightly increase (Figure 6). Maize consumption will increase from 6.0 kcal/person/day to 6.5 kcal/person/dayduring 2010 to 2030 and after that it will remain stable. The share of calorie intake from cereals seems to be reaching a level of saturation. However, as far as rice consumption is concerned, there is no room for significant increases in average consumption even with income growth; in fact, it even started decreasing as in countries with similar consumption and economic growth patterns in Asia (Amarasinghe *et al*. 2014).

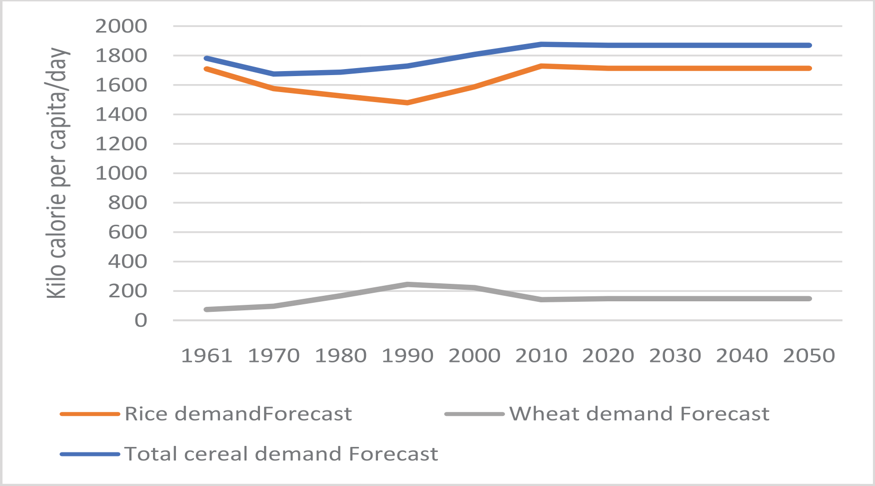



**Figure 6. Projections of per capita calorie intake from cereals**

The share of potato in total calorie intake increased from 0.76% in 1990 to 2.82% in 2010 and it will further increase to 4.12% in 2030 and after that it will remain stable (Figure 5). Absolute consumption of potato would increase from15 kcal/person/day in 1990 to 86 kcal/person/day in 2010 and will further rise to 101.5 kcal/person/day in 2030 after that it will remain stable. The share of calorie intake from potato seems to be reaching a level of saturation beyond 2030.

The share of vegetable in total calorie intake increased from 0.46% in 1990 to 0.98% in 2010 and it will further increase to 1.45% in 2030 and after that it will remain stable (Figure 5). Absolute consumption of vegetable would increase from 9 kcal/person/day in 1990 to 35.5 kcal/person/day in 2030 and after that it would remain stable. Similar to potato, the share of calorie intake from vegetable found to be reaching a level of saturation beyond 2030.

The share of fruits in total calorie intake increased from 0.81% in 1990 to 1.42% in 2010 and would further slightly increase to 1.53% in 2030 and after that it will remain stable (Figure 5). Absolute consumption of fruits would increase from 16 kcal/person/day in 1990 to 37.5 kcal/person/day in 2030 and after that it would remain stable. Similar to potato and vegetable, the share of calorie intake from fruits seems to be reaching a level of saturation beyond 2030.

The ARIMA forecasts show that the consumption of animal products (meat, milk, egg and fish) and non-cereal crops/products (potato, vegetables and fruits) followed similar increasing trend during 1990 to 2030 (Figure 5). Beyond 2030 the consumption of animal products will further increase (Figure 7).

The share of animal products in total calorie intake increased from 2.68% in 1990 to 3.86% in 2010 and will further increase to 5.53% in 2030 and to 7.12% in 2050 (Figure 5). Absolute consumption of animal products increased from 53 kcal/person/day in 1990 to 87 kcal/person/day in 2010 and will further increase to 135.4 kcal/person/day in 2030 and to 179.6 kcal/person/day in 2050 (Figure7).

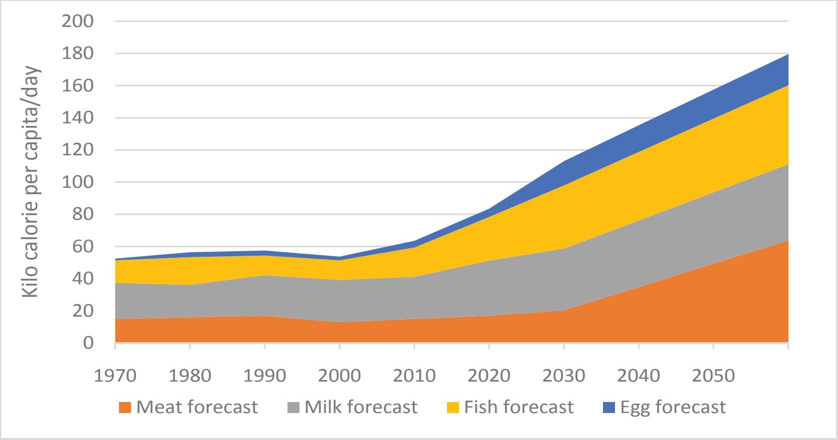



**Figure. 7. Projection of per capita calorie intake from animal products**

**Source: Author's estimation, Per capita calorie intake up to 2013: FAOSTAT and forecasts up to 2050 are authors' estimates.**

### 4.1.3 Demand for cereals

Rice, wheat and maize are the staple cereal food of Bangladesh. The composition of demand of cereals consists of direct for food, feed, seeds and wastage. Table 4 presents projections of food demand for cereal.

Our estimates of ARIMA models showed that daily per capita per day calorie demand for rice is 1777 kcal and the estimate of rice consumption of per person year is 180 kg. This is consistent with other estimates. According to FAO estimates, per capita rice consumption in the country is 181.3kg per year in 2021. The average per capita rice consumption in Bangladesh was second highest in Asia from 2016 to 2019 and it is the highest in Asia by 2020-21, according to a new report published "The Food Outlook" by the Food and Agriculture Organization (FAO, 2022).

In order to validate rice consumption estimates we have reviewed relevant studies and data. We have compared the results with HIES of BBS in 2016, (HIES, 2016) and IFPRI's one large survey conducted in 2011 known as Bangladesh Integrated Household Survey (BIHS) and a survey conducted by BIDS in 2012 (Yunus *et el.* 2019). According to the results of HIES 2016 the per capita consumption of rice declined sharply from 459 grams in 2000 to 440 grams in 2005 and further to 416 grams in 2010; since then to 367 grams in 2016. These estimates imply that the per capita rice consumption has declined by about 1% per annum between 2000 and 2010; and by more than 2% per annum`in the next six years. However, the estimates have been argued to be biased downward due to the failure to account for the changes in consumption behavior. For example, even though the BBS considers several items consumed by the households, the coverage of food grains and items made thereof appears to be rather parsimonious: it considers only 12 items including sweetmeat. Besides, BBS' coverage of food items made of rice and wheat consumed outside home does not seem to be comprehensive. Consequently, the parsimonious inclusion of items made of food grains at home and less than adequate emphasis on consumption of items made of food grains outside home may introduce an inherent downward bias in the estimates of per capita consumption.

The survey results of BIDS showed that per capita consumption of rice decreases over the years both in rural and urban areas, abit marginally. The per capita consumption of rice projected to decline from 469 grams in 2012 to 459 grams in 2016. This translates to annual decline in per capita rice consumption by about half a percentage point during 2012-2016 (Hossain and Yunus 2016). The BIHS estimates of IFPRI implied a decline in per capita daily rice consumption from 467 grams to 426 grams during the same period.

The HIES 2016 estimate of 386 grams of per capita rice consumption appears to be an underestimate and not plausible, as it leads to about 6 MMT of surplus, if compared with the food balance. One possible cross check for this situation is the price hike following the flash flood in the north eastern part of Bangladesh in April 2017 that ensured the loss of about one MMT of rice production. If HIES estimates were right—that is, there was a surplus of over 6 MMT-this was not happened, and the country would not have to import such a big volume of rice. The estimates of the BIHS 2016 and that from 2018 validation survey generate positive net balance. The BIHS 2015 and IFPRI validation survey 2018 generate net balances of 2.4 and 3.5 MMT, respectively. These are clearly plausible estimates, as households always hold precautionary stocks. Our projection of total demand for rice in 2030 based on ARIMA model is 39.1 which is consistent with the results of BIHS survey of IFPRI and survey of BIDS and also close to the projection of Amarasinghe *et al* (2014). Amarasinghe projected that total demand for rice in 2030 will be 37.8 MMT. Our projection of ARIMA model shows that total demand for rice in 2050 will be 42.6 MMT.

**Table 4. Projections of demand for cereals during 2030 to 2050**

| Year and demand | Quantity in MMT | | | |
|---|---|---|---|---|
| | Rice | Wheat | Maize | Total cereal |
| **DirectFood demand** | | | | |
| **2021** | 30.5 | 2.9 | 0.12 | 33.52 |
| **2030** | 33.9 | 3.3 | 0.13 | 37.34 |
| **2035** | 34.9 | 3.5 | 0.14 | 38.54 |
| **2040** | 35.8 | 3.6 | 0.14 | 39.54 |
| **2045** | 36.5 | 3.7 | 0.15 | 40.35 |
| **2050** | 36.9 | 3.8 | 0.15 | 40.85 |
| **Feed demand** | | | | |
| **2021** | 1.9 | 1.00 | 5.44 | 8.34 |
| **2030** | 2.1 | 1.21 | 7.4 | 10.71 |
| **2035** | 2.2 | 1.31 | 8.38 | 11.89 |
| **2040** | 2.2 | 1.41 | 10.71 | 14.32 |
| **2045** | 2.3 | 1.51 | 12.15 | 15.96 |
| **2050** | 2.3 | 1.60 | 15.39 | 19.29 |
| **Seed+other uses+wastage** | | | | |
| **2021** | 2.8 | 1.50 | 0.94 | 4.14 |
| **2030** | 3.1 | 1.86 | 0.9 | 4.58 |
| **2035** | 3.2 | 2.05 | 1.15 | 4.75 |
| **2040** | 3.3 | 2.20 | 1.24 | 5.04 |
| **2045** | 3.3 | 2.45 | 1.34 | 5.14 |
| **2050** | 3.4 | 2.70 | 1.45 | 5.35 |
| **Total crop demand** | | | | |
| **2021** | 35.2 | 5.4 | 6.5 | 47.1 |
| **2030** | 39.1 | 6.39 | 8.43 | 53.92 |
| **2035** | 40.2 | 6.82 | 9.67 | 56.69 |
| **2040** | 41.3 | 7.21 | 12.09 | 60.6 |
| **2045** | 42.1 | 7.66 | 13.64 | 63.4 |
| **2050** | 42.6 | 8.09 | 16.99 | 67.68 |

Source: Author's estimation from ARIMA model

Based on estimates of ARIMA model total food demand of rice in 2021 was 30.5 MMT and including feed, seed, other uses and wastage it was 35.2 MMT. This is also found to be consistent with the estimates of USDA and FAO. According to the USDA, milled rice production is expected to rise by 1.3% to 36.3 MMT in 2022-23 due to increased harvesting, (USDA, 2022) With the prospect of a bumper *Boro* harvest during the current harvesting season,

**Direct food demand for cereals:** The total direct food demands for rice, wheat and maize have been estimated for the years 2030, 2035, 2040, 2045 and 2050. There found to have an increasing trend in total consumption of these cereals (Table 4). The total direct food demand for rice for consumption in 2030 will be 33.9 MMT, which is 11% increase from the 2021 level. The food demand for wheat will be 3.3 MMT in 2030 which is an increase by 0.4 MMT from the 2021 consumption level (13.7% higher). On the other hand, the food demand for maize will be 0.13 MMT in 2030 which is 8.3% higher than 2021 level. Overall, the forecasted total cereal demand for food in 2030 will be 37.34 MMT which is an increase of 3.82 MMT between 2021 and 2030.

The total direct food demand for rice for consumption in 2050 will be 36.9 MMT, which is a 8.8% increase from the 2030 level. The food demand for wheat in 2050 will be 3.8 MMT is an increase by 0.5 MMT from the 2030 consumption level (15% higher). On the other hand, the food demand for maize will be 0.15 MMT in 2050 which is 15% higher than 2030 level. Overall, the forecasted total cereal demand for food in 2050 will be 40.85 MMT which is an increase of 3.51 MMT (or 9.4%) between 2030 and 2050.

**Total crop demand**

Total crop demand for rice was 35.2 MMT in 2021. Total crop demand for rice is projected to be 39.1 MMT in 2030 and 42.6 MMT in 2050.

Total crop demand for wheat and maize were 5.4 MMT and 6.5 MMT, respectively in 2021. Total quantity of wheat and maize imported in 2021 were 7.2 MMT and 2.4 MMT, respectively while production of wheat and maize were 1.03 MMT and 4.21 MMT, respectively according to BBS data. But according to DAE data, maize production was 5.64 MMT. There remain a year ending stock of wheat and maize in Bangladesh every year ranging from 0.5 MMT to 2.0 MMT. Demand for wheat has been trending upward over the last decade due to increasing domestic consumption and exports of wheat-based goods. According to EPB export of wheat-based products from Bangladesh in 2021 around 250 million US dollar (USDA, 2022). Total crop demand for wheat and maize are projected to be 6.39 MMT and 8.43 MMT in 2030 and 8.09 MMT and 16.99 MMT in 2050, respectively (Table 4). Demand for maize has been trending upward over the last decade due to increased growth in livestock and fisheries production and increased industrial uses in Bangladesh.

The total demand for rice will increase by 3.9 MMT between 2021 and 2030, and another 3.5 MMT between 2030 and 2050. The demand for wheat will increase by 0.99 MMT between 2021 and 2030, and another 1.7 MMT during 2030 to 2050. Demand for maize will increase by 1.93 MMT during 2021 to 2030, and a further 8.56 MMT by 2050.

### 4.1.4 Demand for pulses

Table 5 shows the projections of demand for pulses for the period 2030 to 2050. The results are found to be consistent as compared and validated with the consumption demand of 2021. It appeared through consultations with experts, businessmen and importers that farmers produce 1.75 lakh MT of lentils annually and the country's yearly requirement is around 6-7 lakh MT. Lentil import was 5.21 lakh MT in 2020. Our estimates showed that annual demand for lentil in Bangladesh in 2021 was 6.4 lakh MT. Also, the results of demand for chickpea, pea, mungbean, blackgram, grasspea are consistent. The total demand for pulse in 2030 will be 17.9 lakh MT and there will have an increasing trend over the years. In the year 2040 it will rise to 18.9 lakh MT and will further rise to 19.5 lakh MT in 2050. Crop wise estimates showed that annual demand for chickpea, pea, lentil, mungbean, blackgram and grass pea in 2030 in the country will be 1.4 lakh, 3.6 lakh, 7.1 lakh, 2.8 lakh, 1.3 lakh and 2.8 lakh MT, respectively. All these crops found to have increasing trend individually over the years and the corresponding consumption demand in 2050 would be 1.6 lakh, 4.0 lakh, 7.8 lakh, 3.1 lakh, 1.6 lakh and 3.1 lakh MTs, respectively.

**Table 5. Projections of demand for pulses during 2030 to 2050**

| Year | Demand (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Chickpea | Pea | Lentil | Mungbean | Blackgram | Grasspea | All pulse |
| **2021** | 1.3 | 3.3 | 6.4 | 2.6 | 1.3 | 2.6 | 16.1 |
| **2030** | 1.4 | 3.6 | 7.1 | 2.8 | 1.3 | 2.8 | 17.9 |
| **2035** | 1.5 | 3.8 | 7.3 | 2.9 | 1.5 | 2.9 | 18.4 |
| **2040** | 1.5 | 3.8 | 7.5 | 3 | 1.5 | 3 | 18.9 |
| **2045** | 1.5 | 3.9 | 7.7 | 3.1 | 1.5 | 3.1 | 19.3 |
| **2050** | 1.6 | 4 | 7.8 | 3.1 | 1.6 | 3.1 | 19.5 |

Source: Author's estimation from ARIMA models, Note 1 lakh = 0.1 million

### 4.1.5 Demand for oil crops

Per capita consumption of edible oil is 20-22 grams per day. Most households prefer soybean oil for home cooking purposes, but such oil is often blended with palm oil. In 2021, total edible oil consumed in the country constitutes palm oil 51%, soybean oil 43%, mustard oil 5% and ground nut 1% (Figure 8). As the food processing sector grows, domestic consumption of soybean and palm oil is also expected to grow.

It is projected that demand for mustard oil will increase from 1.48 lakh MT in 2021 to 2.1 lakh MT in 2030. It will further rise to 2.94 lakh MT in 2040 and 3.94 lakh MT in 2050 (Table 6).

Demand for ground nut oil will be 0.14 lakh MT in 2030 and it will remain almost similar till 2045 and will slightly decline to 0.13 lakh MT in 2050. Demand for soybean oil will increase from 11.95 lakh MT in 2021 to 13.93 lakh MT in 2030 and thereafter it will gradually rise to 17 lakh MT in 2050.

Local soybean production contributes approximately 5% of total annual soybean demand in Bangladesh. Domestically produced soybean is used predominantly in the feed industry while edible oil is imported both in crude form and as beans that are crushed locally. According to USDA estimates, Bangladesh's soybean imports for 2021-2022 stand at 26 lakh MT and soybean oil imports at 7 lakh MT. There are about 80 soybean oil refineries in Bangladesh that import crude soybean oil and refine it for the domestic market.

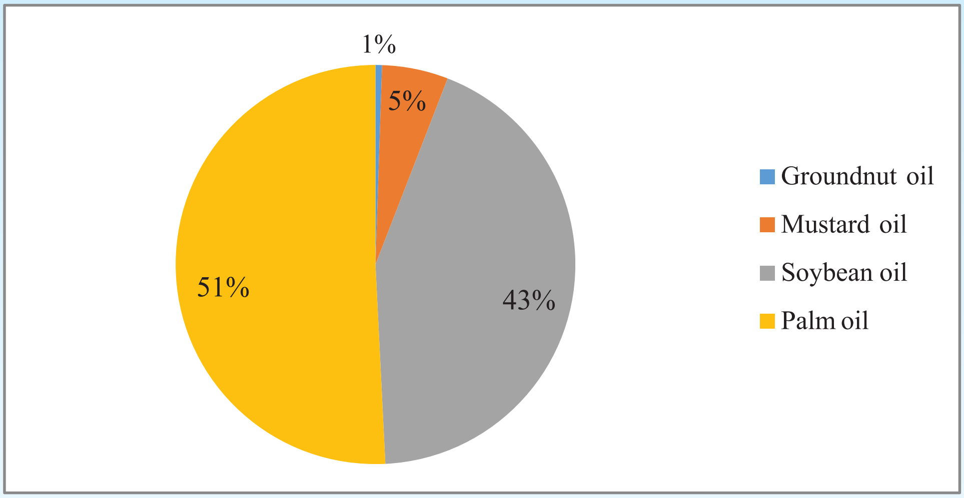



**Figure 8. Consumption pattern of edible oil in Bangladesh in 2021**

**Table 6. Projections of demand for edible oil during 2030 to 2050**

| Year | Demand of edible oil (Quantity in lakh MT) | | |
|---|---|---|---|
| | Groundnut | Mustard | Soybean |
| **2021** | 0.14 | 1.48 | 11.95 |
| **2030** | 0.14 | 2.1 | 13.93 |
| **2035** | 0.15 | 2.48 | 14.77 |
| **2040** | 0.14 | 2.94 | 15.59 |
| **2045** | 0.14 | 3.46 | 16.34 |
| **2050** | 0.13 | 3.94 | 17.00 |

Source: Author's estimation from ARIMA model

### 4.1.6 Demand for spices

Total consumption demand for six spices in Bangladesh in 2021 was 53.9 lakh MT of which onion was 50%, garlic 25%, turmeric 12%, dry chili 7%, ginger 5% and coriander 1% (Figure 9). Projections of ARIMA model showed that demand for onion will increase from 27 lakh MT in 2021to 34.1 lakh MT in 2030. It will further rise to 40.1 lakh MT in 2040 and 45.5 lakh MT in 2050. Also demand for garlic will increase from 13.7 lakh MT in 2021 to 17.4 lakh MT in 2030, 20.5 lakh MT in 2040 and 23.2 lakh MT in 2050. Demand for turmeric will be 8.2 lakh MT in 2030 and there after it will gradually rise to 10.9 lakh MT in 2050 (Table 7). Demand for dry chili, ginger and coriander will be 4.8, 3.1 and 1.0 lakh MT in 2030, respectively and there after their demand will gradually rise to 6.4 lakh, 4.1 lakh and 1.4 lakh MT in 2050.

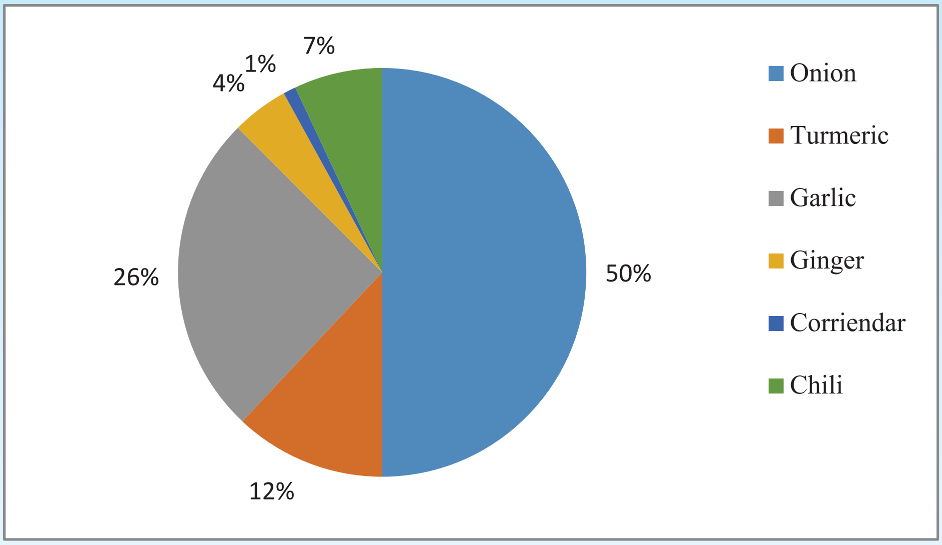



**Figure 9. Consumption pattern of major spices in Bangladesh**

**Table 7. Projections of demand for essential major spices during 2030 to 2050**

| Year | Demand for spices (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Onion | Turmeric | Garlic | Ginger | Coriander | Chili | All |
| **2021** | 27.0 | 6.5 | 13.7 | 2.4 | 0.5 | 3.8 | 53.9 |
| **2030** | 34.1 | 8.2 | 17.4 | 3.1 | 1.0 | 4.8 | 68.6 |
| **2035** | 37.1 | 8.9 | 18.9 | 3.3 | 1.1 | 5.2 | 74.6 |
| **2040** | 40.1 | 9.6 | 20.5 | 3.6 | 1.2 | 5.6 | 80.7 |
| **2045** | 43.0 | 10.3 | 22.0 | 3.9 | 1.3 | 6.0 | 86.5 |
| **2050** | 45.5 | 10.9 | 23.2 | 4.1 | 1.4 | 6.4 | 91.4 |

Source: Author's estimation from ARIMA model

### 4.1.7 Demand for potato and sweet potato

Table 8 shows that demand for potato will increase from 95.63 lakh MT in 2021 to 116.16 lakh MT in 2030. It will further rise to 125 lakh MT in 2040 and 126.59 lakh MT in 2050. Also demand for sweet potato will decrease from 4.12 lakh MT in 2021 to 3.20 lakh MT in 2030 and there after gradually rise to 3.38 lakh MT in 2040 and 3.49 lakh MT in 2050.

**Table 8. Projections of demand for potato and sweet potato during 2030 to 2050**

| Year | Demand (Quantity in lakh MT) | |
|---|---|---|
| | Potato | Sweet potato |
| **2021** | 95.63 | 4.12 |
| **2030** | 116.16 | 3.20 |
| **2035** | 119.55 | 3.30 |
| **2040** | 122.60 | 3.38 |
| **2045** | 125.00 | 3.45 |
| **2050** | 126.59 | 3.49 |

Source: Authors estimation from ARIMN model

### 4.1.8 Demand for vegetables

It is revealed that per capita per year vegetables consumption demand of Bangladesh in 2021 was 24.62 kg and it will increase to 28.58 kg in 2030, It will further gradually rise to 35.39 kg in 2040 and 43.41 kg in 2050. Total vegetable demand in the country is projected to increase from 41.2 lakh MT in 2021 to 51.5 lakh MT in 2030 with an annual growth rate of 2.8% (Figure 10). This is projected to further gradually rise is 65.5 lakh MT in 2050.

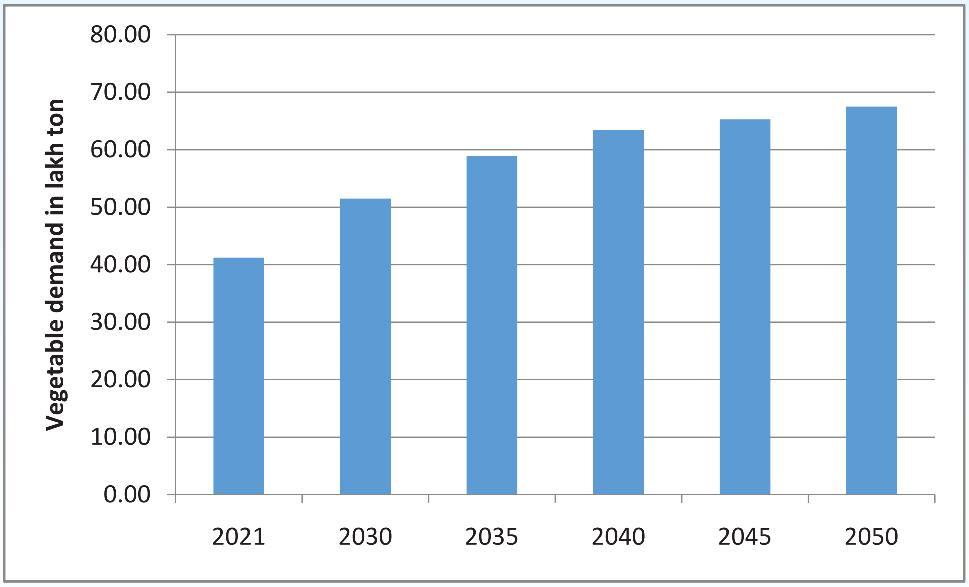



**Figure 10. Projections of demand for vegetables during 2030 to 2050**

### 4.1.9 Demand for fruits

Bangladesh is blessed with a variety of fruits due to tropical and subtropical climate. Figure 11 illustrates production patterns of fruits in Bangladesh. It is revealed that among the fruit crops grown in Bangladesh, mango, jackfruit and banana could be ranked first, second and third, respectively in terms of production coverage/share (Figure 11). Table 9 presents projections of consumption demand for selected major six fruits in Bangladesh. Total demand for six major selected fruits in the country is projected to increase from 26.7 lakh MT in 2021 to 32.2 lakh MT in 2030 with an annual growth rate of 2.28%. This is projected to further gradually rise to 43.7 lakh MT in 2050.

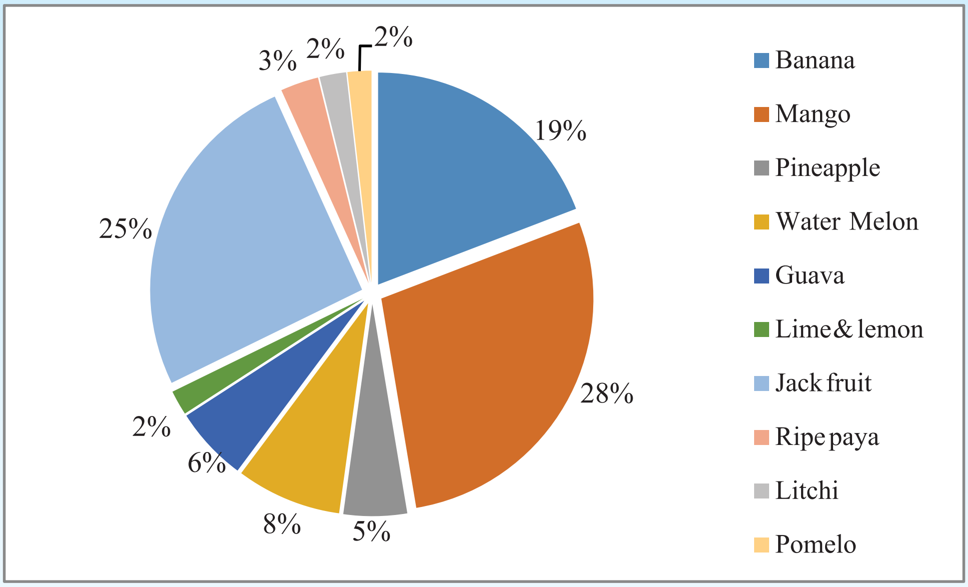



**Figure 11. Share of different fruits in total production of Bangladesh**

**Table 9. Projections of demand for major fruits during 2030 to 2050**

| Year | Demand (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pineapple | Lime & lemon | Banana | Guava | Mango | Water melon | All |
| **2021** | 1.3 | 1.0 | 8.3 | 2.2 | 10.9 | 3.0 | 26.7 |
| **2030** | 1.5 | 1.4 | 10.3 | 2.8 | 12.6 | 3.6 | 32.2 |
| **2035** | 1.6 | 1.5 | 11.2 | 3.1 | 13.5 | 4.0 | 35 |
| **2040** | 1.7 | 1.7 | 12.2 | 3.5 | 14.4 | 4.4 | 37.9 |
| **2045** | 1.8 | 1.9 | 13.1 | 3.8 | 15.3 | 4.9 | 40.8 |
| **2050** | 1.9 | 2.1 | 14.1 | 4.2 | 16.1 | 5.3 | 43.7 |

Source: Author's estimation from ARIMA model

## 4.2 Projections of crop area and yield

### 4.2.1. Projections of crop areas

The estimated coefficients of the ARIMA models of areas of different food crops have been presented in Table 10 and 11. All the models were found to be valid with significant parameters as indicated by standard errors of the estimates, t-values and Portmanteau test results.

**Table 10. Parameter estimates of ARIMA models of areas of rice, wheat, maize, pulses, oil and spices crop**

| Crops | Model | Parameter | Standard error | t-value | Portmanteau Test value | Portmanteau Test decision |
|---|---|---|---|---|---|---|
| *Aman* Rice | ARIMA (0,1,2) | 0.484** | 0.126 | 3.815 | 42.26 | Adequate model |
| | | 0.488** | 0.126 | 3.854 | | |
| *Boro* Rice | ARIMA (0,1,1) | -0.151 | 0.142 | -1.063 | 51.76 | Adequate model |
| *Aus* Rice | ARIMA (0,1,2) | 0.003 | 0.137 | -0.023 | 39.58 | Adequate model |
| | | -0.319** | 0.138 | -2.294 | | |
| Wheat | ARIMA (1,2,0) | -0.446** | 0.116 | -3.832 | 35.55 | Adequate model |
| Maize | ARIMA (1,2,0) | -0.547 ** | 0.121 | -4.50 7 | 30.59 | Adequate model |
| Peas | ARIMA (1,2,0) | -0.391** | 0.131 | -2.975 | 27.07 | Adequate model |
| Chickpea | ARIMA (1,2,0) | -0.470** | 0.125 | -3.7345 | 37.40 | Adequate model |
| Lentil | ARIMA (1,2,0) | -0.486** | 0.124 | -3.895 | 27.82 | Adequate model |
| Mung bean | ARIMA (1,2,0) | -0.494** | 0.124 | -3.981 | 29.92 | Adequate model |
| Black gram | ARIMA (0,2,1) | 0.975** | 0.017 | 54.436 | 26.21 | Adequate model |
| Grass pea | ARIMA (1,2,0) | -0.426** | 0.129 | -3.295 | 14.76 | Adequate model |
| All Pulses | ARIMA (0,1,1) | 0.918** | 0.054 | 16.971 | 14.05 | Adequate model |
| Mustard | ARIMA (1,1,1) | -0.809 ** | 0.234 | -3.45 5 | 29.09 | Adequate model |
| | | -0.90 5** | 0.1759142 | -5.143 | | |
| Ground nut | ARIMA (0,2,1) | 0.968 ** | 0.015 | 62.115 | 46.40 | Adequate model |
| Onion | ARIMA (0,1,1) | -0.602** | 0.114 | -5.252 | 24.20 | Adequate model |
| Garlic | ARIMA (1,1,2) | 0.655** | 0.193 | 3.389 | 16.60 | Adequate model |
| | | 0.793** | 0.192 | 4.137 | | |
| | | -0.485** | 0.133 | -3.6483 | | |
| Ginger | ARIMA (1,1,1) | 0.647** | 0.113 | 5.711 | 32.65 | Adequate model |
| | | 0.961** | 0.026 | 35.621 | | |
| Chili | ARIMA (1,2,0) | -0.505** | 0.123 | -4.0981 | 20.54 | Adequate model |
| Coriander | ARIMA (1,1,2) | 0.973** | 0.059 | 16.542 | 57.36 | Adequate model |
| | | 1.193** | 0.151 | 7.866 | | |
| | | -0.320 | 0.144 | -2.219 | | |
| Turmeric | ARIMA (0,1,1) | 0.432 | 0.128 | 3.349 | 11.65 | Adequate model |

Source: Author's estimation, Note: ** $p < 0.01$, * $p < 0.05$

**Table 11. Parameter estimates of ARIMA models of areas of potatoes, vegetables and fruits crops**

| Crops | Model | Parameter | Standard error | t-value | Portmanteau Test value | Portmanteau Test decision |
|---|---|---|---|---|---|---|
| Potato | ARIMA (1,2,0) | -0.525** | 0.121 | -4.322 | 50.20 | Adequate model |
| Sweet potato | ARIMA (1,2,0) | -0.314 * | 0.13 1 | -2.408 | 49.19 | Adequate model |
| Tomato | ARIMA (1,2,0) | -0.605** | 0.112 | -5.362 | 49.51 | Adequate model |
| Country Bean | ARIMA (1,2,0) | -1.057** | 0.149 | -7.075 | 30.82 | Adequate model |
| Brinjal | ARIMA (1,2,0) | -0.509** | 0.122 | -4.178 | 15.00 | Adequate model |
| Cucumber | ARIMA (1,2,0) | -0.689** | 0.105 | -6.510 | 51.84 | Adequate model |
| Lady's finger | ARIMA (1,2,0) | -0.480** | 0.135 | -3.553 | 50.43 | Adequate model |
| Bitter gourd | ARIMA (1,2,0) | -0.598* | 0.122 | -4.887 | 55.94 | Adequate model |
| Cauliflower | ARIMA (1,2,0) | -0.615** | 0.113 | -5.421 | 50.92 | Adequate model |
| Cabbage | ARIMA (1,2,0) | -0.670** | 0.132 | -5.0783 | 59.28 | Adequate model |
| Snake gourd | ARIMA (1,2,0) | -0.477* | 0.140 | -3.393 | 49.37 | Adequate model |
| Gourd | ARIMA (1,2,0) | -0.499** | 0.121 | -4.117 | 57.09 | Adequate model |
| All vegetables | ARIMA (1,2,0) | -0.527** | 0.120 | -4.370 | 42.66 | Adequate model |
| Pineapple | ARIMA (0,1,1) | -0.340* | 0.133 | -2.544 | 41.15 | Adequate model |
| Banana | ARIMA (0,2,1) | 0.642** | 0.102 | 6.293 | 44.84 | Adequate model |
| Lime & lemon | ARIMA (0,1,1) | 0.097 | 0.140 | 0.694 | 8.61 | Adequate model |
| Guava | ARIMA (1,1,0) | 0.028 | 0.141 | 0.201 | 8.09 | Adequate model |
| Mango | ARIMA (1,2,1) | -0.378* | 0.164 | -2.301 | 16.60 | Adequate model |
| | | 0.650* | 0.142 | 4.582 | | |
| Water melon | ARIMA (0,2,1) | 0.943* | 0.022 | 42.524 | 42.52 | Adequate model |

Source: Author's estimation, Note: ** $p < 0.01$, * $p < 0.05$

### 4.2.2. Projection of areas of cereal crops

Rice is the major cereal crop of Bangladesh, covered nearly 80% of the gross cropped area (GCA) of Bangladesh in 2021. *Aus* rice area decreased from 3000.0 thousand ha to 1100 thousand ha during the period 1972 to 2015, Thereafter it slightly increased to 1300 thousand ton in 2021 (Figure 7). ARIMA model of *Aus* rice predicts that *Aus* rice area will further slightly increase to 1350 thousand ha in 2030 and thereafter it will stabilize at 1350 thousand ha still 2050. *Aman* area in 1972 was 5400 thousand ha and in 2021 it was 5600 thousand ha. Forecast of ARIMA model shows that *Aman* area will reach to 5680 thousand in 2030 and thereafter it will stabilize at 5500 thousand ha still 2050. *Boro* rice area in Bangladesh significantly increased from 800 thousand ha to 4780 thousand ha during 1972 to 2021. ARIMA model predicts that *Boro* rice area will slightly increase to 4790 thousand ha in 2030 and thereafter it will stabilize at 4790 thousand ha in 2050.

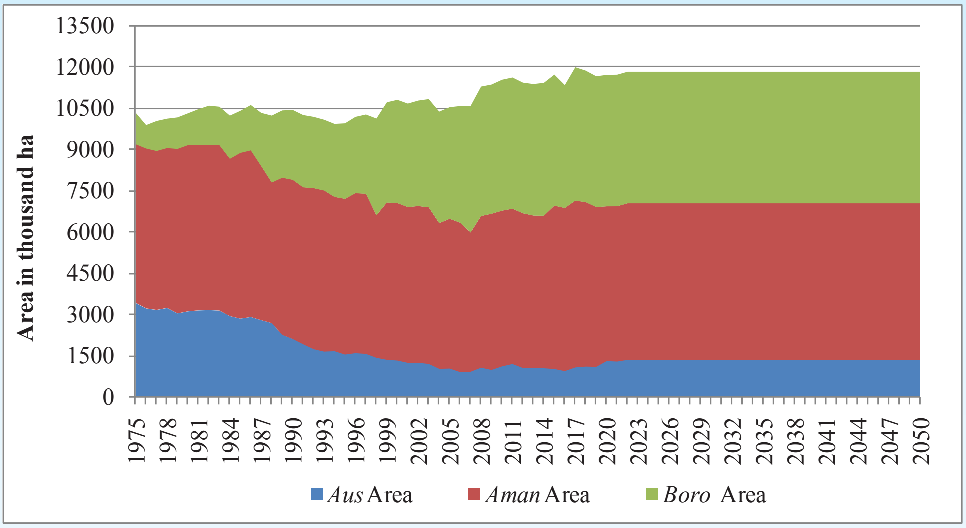



**Figure 12. Projections of rice areas of Bangladesh**

Wheat and maize are minor cereal crops in Bangladesh. ARIMA model predicted that wheat area will slightly decrease to 315 thousand ha in 2030 from 332 thousand ha in 2021 and it will further slightly decrease to 281 thousand ha by 2050 (Figure 13). Maize area in the past increased significantly from 2800 ha in 1972 to 480 thousand ha in 2021. The model also predicts that maize area will increase to 614 thousand ha in 2030 and will rise to 906 thousand ha in 2050.

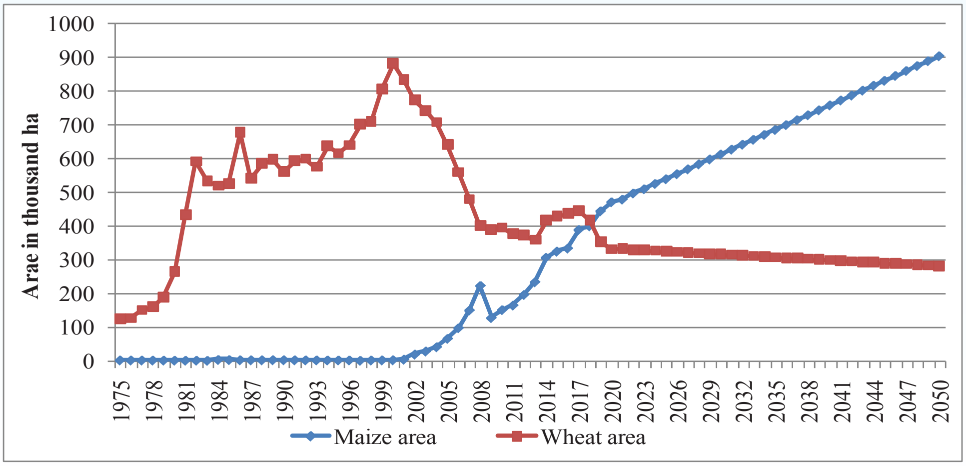



**Figure 13. Projections of areas of maize and wheat of Bangladesh**

### 4.2.3. Projection of areas of pulse crops

During the period from 1971 to 1985, pulses area of Bangladesh increased from 0.68 million ha to the peak of 1.53 million ha. After 1985, pulses area gradually declined and it was lowest in 2010 at 0.72 million ha. There after it slightly increased to 0.69 million ha in 2021. ARIMA model predicts that pulses area will increase to 0.80 million ha in 2030 and will rise to 1.00 million ha in 2050 (Figure 14).

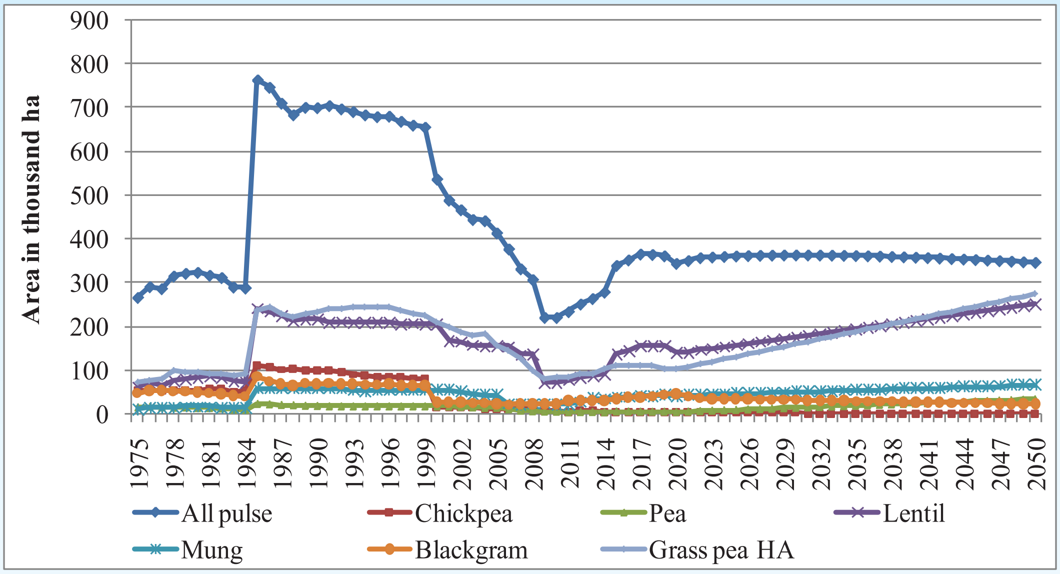



**Figure 14. Projections of areas of all pulses of Bangladesh**

### 4.2.4. Projection of areas of spices crops

During the period from 1971 to 2021, spices area of Bangladesh increased from 159 thousand ha to 420 thousand ha. During 1971- 2021, onion area of Bangladesh increased from 33 thousand ha to 185 thousand ha. During the same period garlic area of Bangladesh increased from 14 thousand ha to 74 thousand ha, ginger area increased from 5 thousand ha to 10 thousand ha, coriander area increased from 5 thousand ha to 20 thousand ha, turmeric from 12 thousand ha to 33 thousand ha and chili from 88 thousand ha to 97 thousand ha. ARIMA model predicts that all these spices crops areas will have increasing trend (Figure 15). Total spices area will increase to 482 thousand ha in 2030 and will rise to 627 thousand ha in 2050.

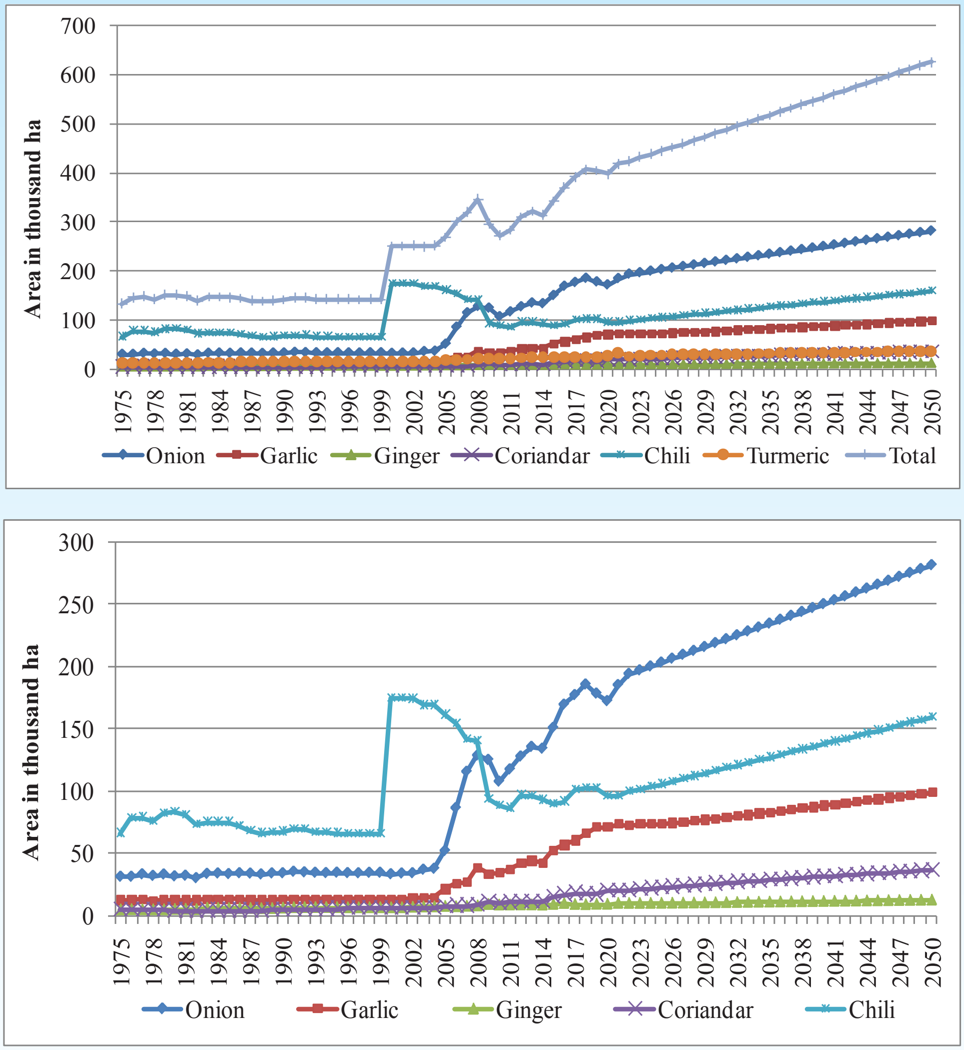



**Figure 15. Projections of areas of all spices crops of Bangladesh**

### 4.2.5. Projection of areas of groundnut and mustard crops

During 1971- 2021, groundnut area of Bangladesh increased from 32 thousand ha to 35 thousand ha. During the same period mustard area of Bangladesh increased from 217 thousand ha to 309 thousand ha. ARIMA model predicted that all these crops area will have increasing trend (Figure 16) Total ground nut area will increase to 42 thousand ha in 2030 and will rise to 61 thousand ha in 2050 and mustard area will increase to 343 thousand ha in 2030 and will rise to 377 thousand ha in 2050.

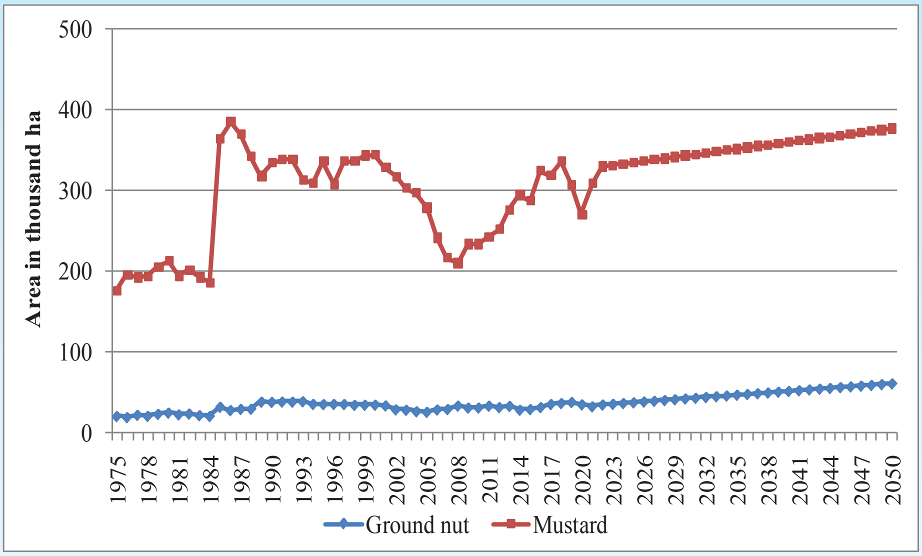



**Figure 16. Projections of areas of all ground nut and mustard in Bangladesh**

### 4.2.6. Projection of areas of potato and sweet potato crops

During the period 1971 to 2021, potato area of Bangladesh increased gradually from 86 thousand ha to 462 thousand ha. During same period sweet potato area decreased from 73 thousand ha in 1971 to 35 thousand ha in 2021. Forecasts results showed that potato area will increase to 487 thousand ha in 2030 and will further rise to 536 thousand ha in 2050. Also sweet potato area will increase to 38 thousand ha in 2030 and will further rise to 68 thousand ha in 2050 (Figure 17).

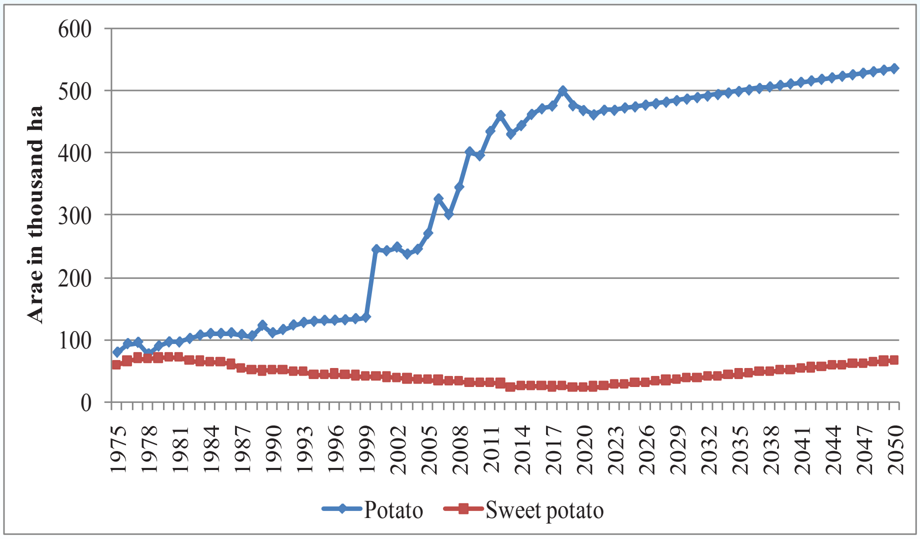



**Figure 17. Projections of areas of potato and sweet potato in Bangladesh**

### 4.2.7. Projection of areas of vegetables crop

During the period 1971 to 2021, total vegetable area of Bangladesh increased gradually from 322 thousand ha to 1102 thousand ha. Forecasts shows that vegetable area will increase to 1365 thousand ha in 2030 and will further rise to 1804 thousand ha in 2050 (Figure 18a). The areas of 10 selected vegetable crops will have increasing trends during 2030 to 2050 (Figure 18b).

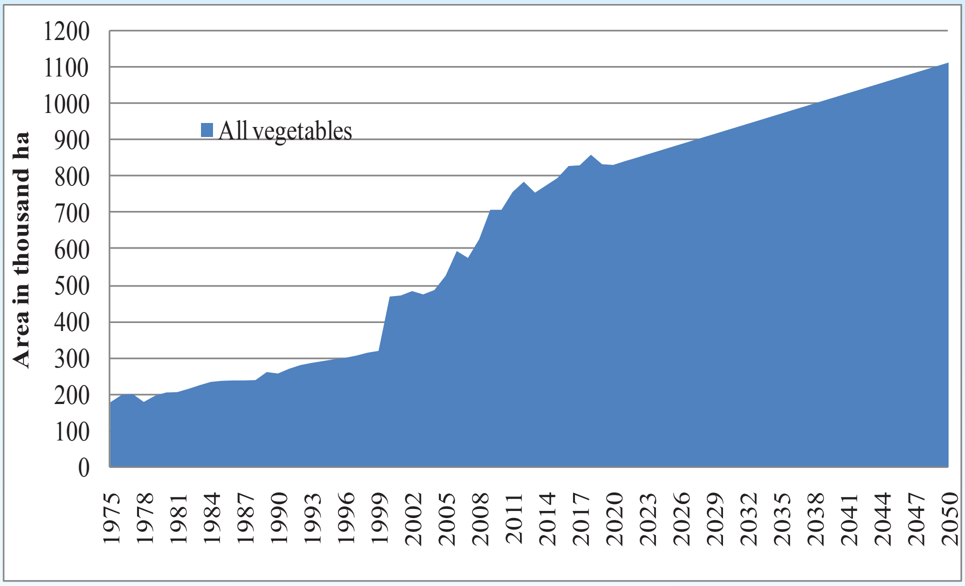



**Figure 18a. Projections of total vegetable areas of Bangladesh**

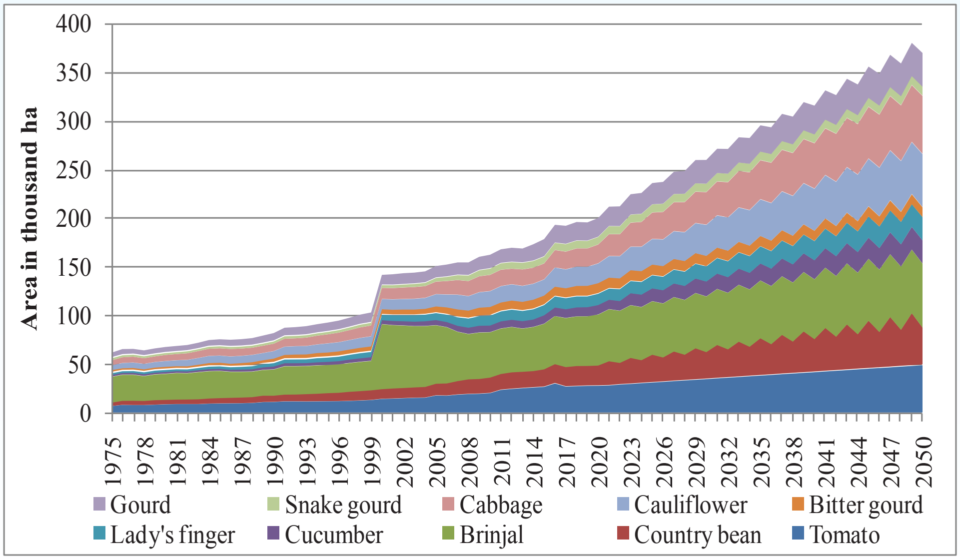



**Figure 18b. Projections of areas of selected vegetables in Bangladesh**

### 4.2.8. Projection of areas of fruit crops

Total fruits area of the country will increase from 4.02 lakh ha in 2021 to 7.5 lakh ha in 2030 and will further rise to 9.5 lakh ha in 2050. Total areas of six selected fruits increased form 105 thousand ha to 203 thousand ha in 2021. All these fruits have increasing trend in areas during 2030 to 2050 (Figure 19) and total fruits area of six selected crops will increase from 203 thousand ha in 2021 to 340 thousand ha in 2030 and further rise to 647 thousand ha in 2050.

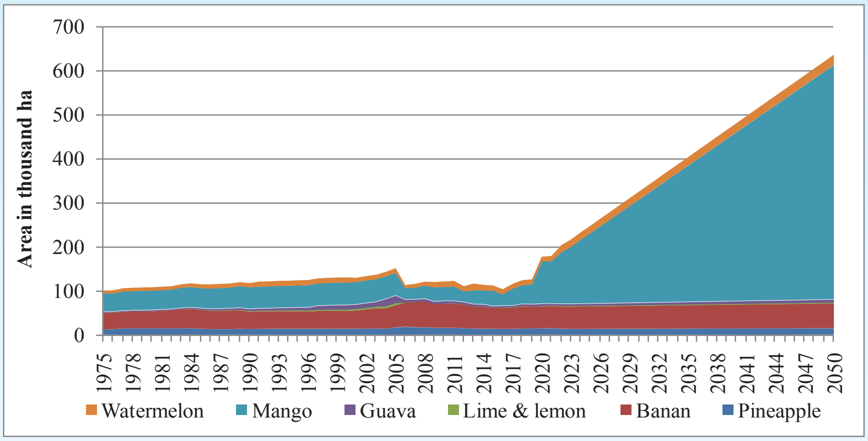



**Figure 19. Projections of areas of fruits in Bangladesh**

### 4.2.9 Projections of crop yield

The estimated coefficients of the ARIMA models of yields of different crops have been presented in Table 12 and 13. All the models found to be valid with significant parameters as indicated by standard errors of the estimates and t-values and Portmanteau test results.

The projections of crops yield below assumed that factors that contributed to growth in the past, such as advances in technology and high-yielding crop varieties, will continue to be developed and contribute to yield increases.

**Table 12. Parameter estimates of ARIMA models of yields of rice, wheat, maize, pulses, oil and spices crop**

| Crops | Model | Parameter | Standard error | t-value | Portmanteau Test value | Portmanteau Test decision |
|---|---|---|---|---|---|---|
| ***Aman* Rice** | ARIMA (0,1,1) | 1.014** | 0.007 | 139.062 | 48.70 | Adequate model |
| ***Boro* Rice** | ARIMA (0,1,1) | 1.011** | 0.004 | 213.596 | 51.76 | Adequate model |
| ***Aus*Rice** | ARIMA (1, 0,0) | 1.021** | 0.007 | 131.458 | 49.63 | Adequate model |
| **All rice** | ARIMA (1,0,0) | 0.89 4** | 0.060 | 14.876 | 51.79 | Adequate model |
| **Wheat** | ARIMA (1,1,0) | 0.215** | 0.127 | 1.685 | 31.82 | Adequate model |

| Crops | Model | Parameter | Standard error | t-value | Portmanteau Test value | Portmanteau Test decision |
|---|---|---|---|---|---|---|
| **Maize** | ARIMA (1,1,0) | 0.292** | 0.136 | 2.147 | 18.60 | Adequate model |
| **Peas** | ARIMA (1,1,0) | -0.487** | 0.161 | -3.021 | 61.04 | Adequate model |
| **Chickpea** | ARIMA (1,1,0) | -0.526** | 0.131 | -4.012 | 57.37 | Adequate model |
| **Lentil** | ARIMA (1,2,0) | -0.274** | 0.137 | -1.999 | 29.55 | Adequate model |
| **Mung bean** | ARIMA (1,2,0) | -0.599** | 0.117 | -5.108 | 48.22 | Adequate model |
| **Black gram** | ARIMA (1,1,0) | -0.281** | 0.165 | -1.708 | 56.72 | Adequate model |
| **Grass pea** | ARIMA (1,2,0) | -0.677 ** | 0.106 | -6.361 | 57.64 | Adequate model |
| **All Pulses** | ARIMA (1,2,0) | 0.618** | 0.113 | -5.45 4 | 53.10 | Adequate model |
| **Mustard** | ARIMA (0,1,1) | 0.293** | 0.135 | 2.156 | 46.12 | Adequate model |
| **Ground nut** | ARIMA (0,1,1) | 0.612** | 0.108 | 5.636 | 47.76 | Adequate model |
| **Onion** | ARIMA (0,2,1) | 0.902** | 0.0546 | 16.439 | 34.69 | Adequate model |
| **Garlic** | ARIMA (1,2,0) | -0.577** | 0.117 | 4.921 | 35.98 | Adequate model |
| **Ginger** | ARIMA (1,1,0) | 0.359** | 0.134 | 2.667 | 38.41 | Adequate model |
| **Chili** | ARIMA (0,2,1) | 0.903** | 0.079 | 11.294 | 34.04 | Adequate model |
| **Coriander** | ARIMA (0,1,1) | 0.291** | 0.135 | 2.142 | 26.39 | Adequate model |
| **Turmeric** | ARIMA (0,2,1) | 0.97 9** | 0.014 | 67.521 | 42.04 | Adequate model |

Source: Author's estimation, Note: ** $p < 0.01$, * $p < 0.05$

### 4.2.10. Projections of yields of rice crops

The ARIMA model predicted that yield of all rice will increase by 1.7% annually between 2021 and 2030 and will reach to 3.7 ton/ha in 2030. It will further increase by 1.4% annually between 2030 and 2050 reaching to 4.7 ton/ha by 2050 (Figure 20).

The yield of *Aman* rice will increase by 2.2% annually during 2021 to 2030 and will reach from 2.5 ton/ha to 3.0 ton/ha in 2030. It will further increase by 1.5 % annually during 2030 to 2050, will reach to 3.9 ton/ha in 2050.

The yield of *Boro* rice will increase by 2.2% annually during 2021 to 2030 and will reach from 4.2 ton/ha to 4.7 ton/ha in 2030. It will further increase by 1.5 % annually during 2030 to 2050, will reach to 5.9 ton/ha in 2050 (Figure 21).

The yield of *Aus* rice will increase by 2.1% annually during 2021 to 2030 and will reach from 2.6 ton/ha to 3.1 ton/ha in 2030. It will further increase by 2.7 % annually during 2030 to 2050, will reach to 4.8 ton/ha by 2050.

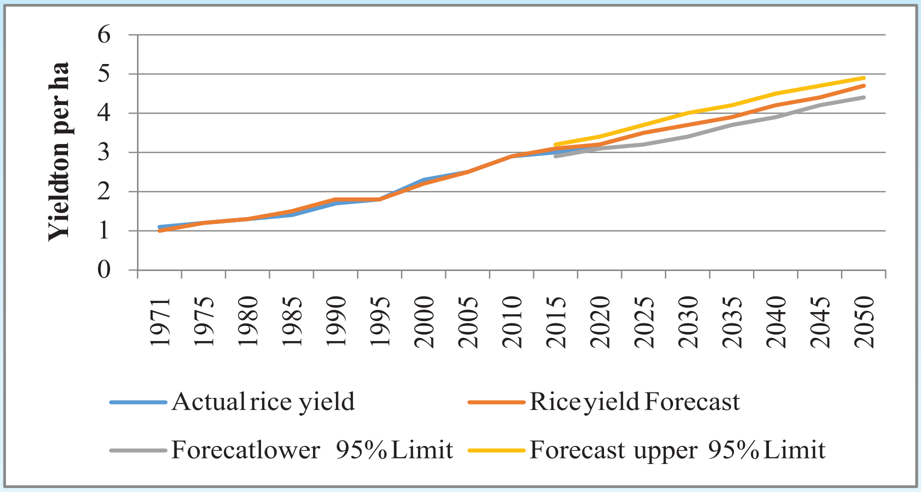



**Figure 20. Projections of rice yield during 2030 to 2050**

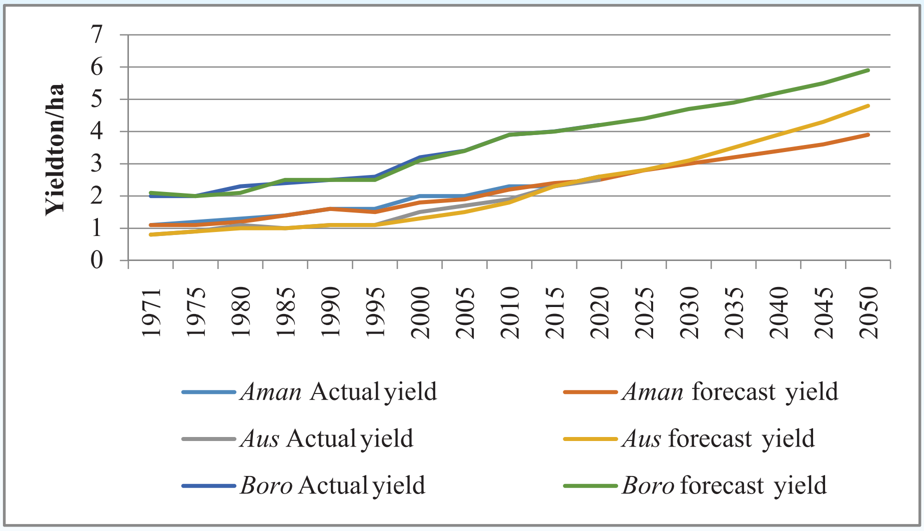



**Figure 21. Projections of yields of *Aman*, *Boro* and *Aus* rice during 2030 to 2050**

### 4.2.11. Projections of yields of wheat and maize crops

The yield of wheat will increase by 4.3% annually between 2021 and 2030 and will reach from 2.3 ton/ha to 3.2 ton/ha in 2030. It will further increase by 1.25% annually between 2030 and 2050 and will reach to 4.0 ton/ha by 2050.

The yield of maize will increase by 2.8% annually between 2021 and 2030 and will reach from 8.08 ton/ha to 10.08 ton/ha in 2030. It will further increase by 1% annually between 2030 and 2050 and will reach to 13.52 ton/ha by 2050 (Figure 22).

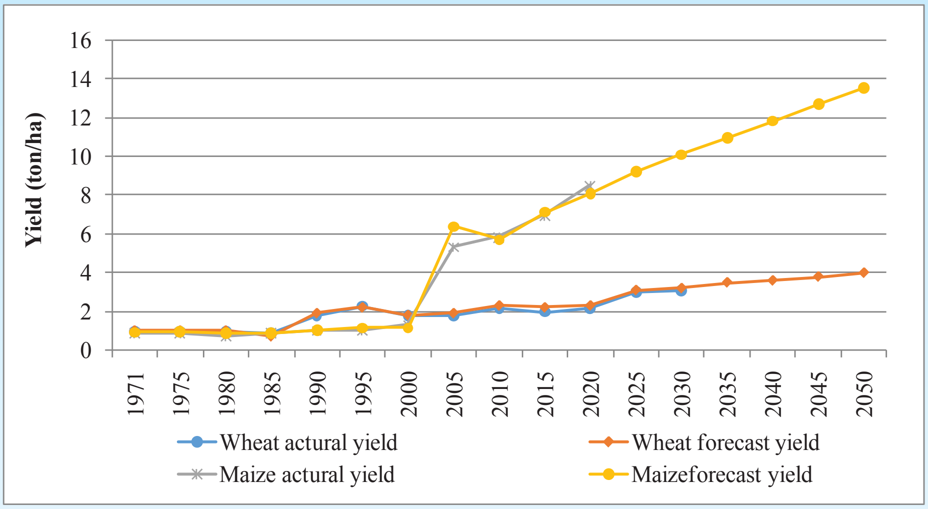



**Figure 22. Projections of wheat and maize yield during 2030 to 2050**

### 4.2.12. Projections of yields of pulse crops

The average yield of all pulses will increase by 3% annually between 2021 and 2030 and will reach from 1.1 ton/ha to 1.4 ton/ha in 2030. It will further increase by 1 % annually between 2030 and 2050 and will reach to 1.7 ton/ha by 205. All the selected seven pulse crops will have increasing trend in yields during 2030 to 2050. The projected yield of pea, chick pea, lentil, mungbean, blackgram and grass pea will be 1.1, 1.2, 1.3. 1.5. 1.0 and 1.2 ton/ha, respectively, in 2030. Also, all these yields will further rise to 1.3. 1.3, 1.5, 2.8, 1.1 and 1.4 ton /ha, respectively in 2050 (Figure 23).

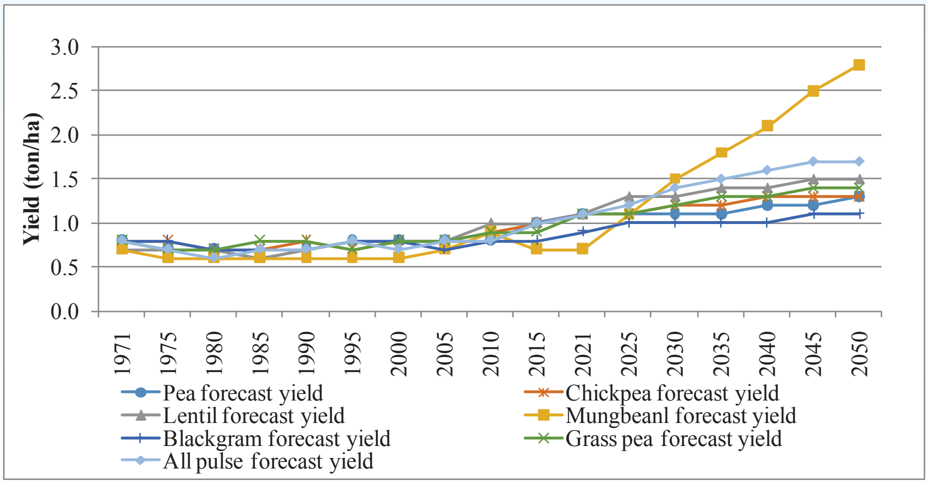



**Figure 23. Projections of yieldof pulse crops during 2030 to 2050**

### 4.2.13. Projections of yields of oil crops

It is predicted that average yield of groundnut will increase by 2.6% annually between 2021 and 2030 and will reach from 1.78 ton/ha to 2.1 ton/ha in 2030. It will further increase by 1 % annually between 2030 and 2050 will reach to 2.34 ton/ha by 2050.

The average yield of mustard will increase by 1% annually between 2021 and 2030 and will reach from 1.14 ton/ha to 1.22 ton/ha in 2030. It will further increase by 1.14 % annually between 2030 and 2050 and will reach to 1.50 ton/ha by 2050 (Figure 24).

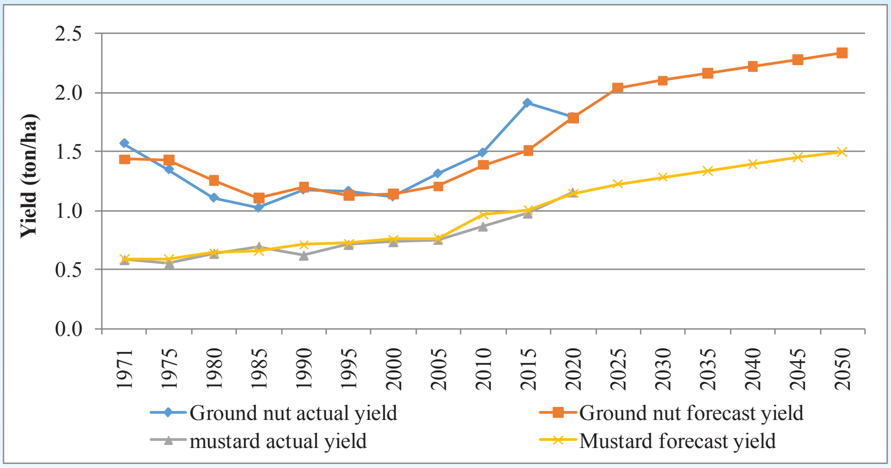



**Figure 24. Projections of ground nut and mustard crops yield during 2030 to 2050**

### 4.2.14. Projections of yields of spice crop

The average yield of all spices will increase by 2.75% annually between 2021 and 2030 and will reach from 5.95 ton/ha to 7.42 ton/ha in 2030. It will further increase by 2.3 % annually between 2030 and 2050 and will reach to 10.82 ton/ha by 2050. It is predicted that all the selected six spices crops will have increasing trend in yields during 2030 to 2050. The predicted yields of onion, garlic, ginger, chili, coriander and turmeric will be 11.6, 8.6, 8.0, 2.9, 1.1, 12.3 and 7.42 ton/ha, respectively, in 2030. Also, all these yields will further rise to 17.3, 13, 8.7, 4.7, 1.3, and 19.9 ton/ha respectively in 2050 (Figure 25).

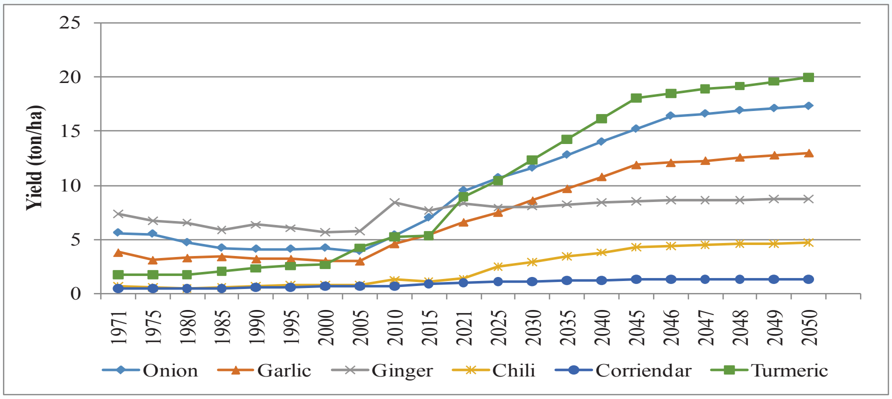



**Figure 25. Projections of spices crops yield during 2030 to 2050**

### 4.2.15 Projections of yields of tuber crops

The average yield of potato will increase by 1.1% annually between 2021 and 2030 and will reach from 21.0 ton/ha to 23.0 ton/ha in 2030. It will further increase by 1.1 % annually between 2030 and 2050 and will reach to 27.9 ton/ha by 2050.

The average yield of sweet potato will increase by 1.5% annually between 2021 and 2030 and will reach from 9.60 ton/ha to 14.40 ton/ha in 2030. It will further increase by 3.1 % annually between 2030 and 2050 and will reach to 23.24 ton/ha by 2050 (Figure 26).

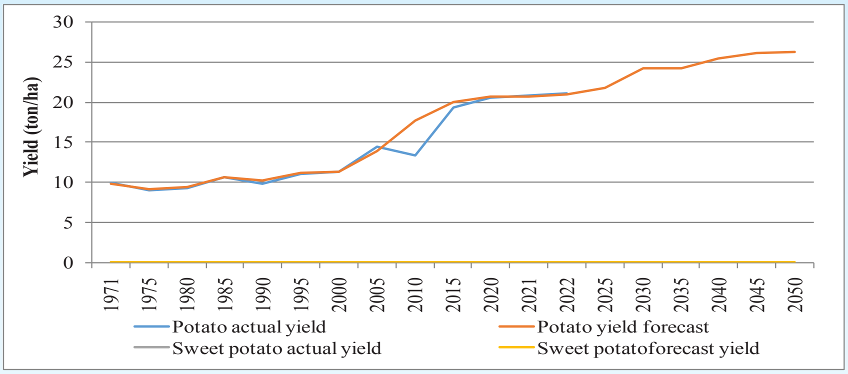



**Figure 26. Projections of potato and sweet potato crops yield during 2030 to 2050**

### 4.2.16. Projections of yields of vegetable crops

The average yield of all vegetables will increase by 1% annually between 2021 and 2030 and will reach from 15.3 ton/ha to 16.4 ton/ha in 2030. It will further increase by 1% annually between 2030 and 2050 and will reach to 19.4 ton/ha by 2050.

All the selected ten vegetables will have increasing trend in yields during 2030 to 2050 (Figure 27). The predicted yields of tomato, bean, brinjal, cucumber, lady's finger, bitter gourd, cauliflower, cabbage, snake gourd and gourd will be 17.8, 9.0, 22.1, 16.3, 6.3, 6.9, 14.9, 18.4, 9.1 and 12.9 ton/ha, respectively in 2030. Also, all these yields will further rise to 22.3, 12.9, 23.4, 33.9, 6.7, 10.5, 16.5, 22.0, 17.4 and 14.6 ton/ha respectively in 2050.

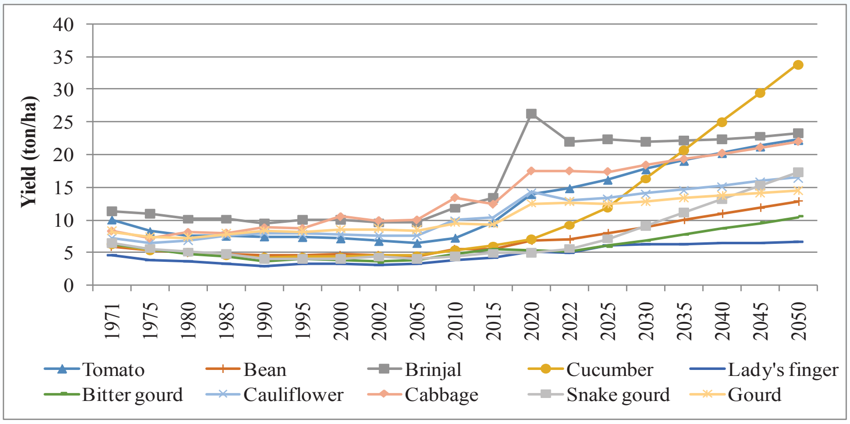



**Figure 27. Projections of vegetable crops yield during 2030 to 2050**

#### 4.2.17. Projections of yields of fruit crops

The average yield of the six fruits will increase by 1.8 % annually between 2021 and 2030 and will reach from 29.05 ton/ha to 33.75 ton/ha in 2030. It will further increase by 1.62 % annually between 2030 and 2050 and will reach to 44.7 ton/ha by 2050.

All the selected six fruits will have increasing trend in yields during 2030 to 2050. The predicted yields of pineapple, banana, lime & lemon, guava, mango and water melon will be 15.9, 20.8, 48.1, 62.7, 33.6 and 21.4 ton/ha, respectively in 2030. Also all these yields will further rise to 18.3, 31.0, 66.7, 84.0, 44.9 and 23.3 ton/ha, respectively in 2050 (Figure 28).

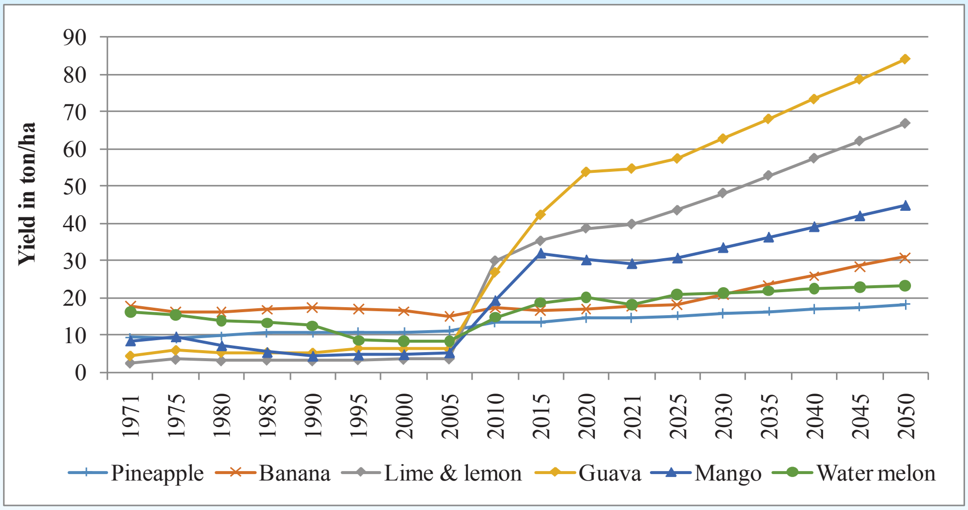



**Figure 28. Projections of yield of fruits during 2030 to 2050**

### 4.3. Projections of supply of crops

#### 4.3.1 Projections of supply of rice

In order to validate rice supply estimates, we have reviewed relevant studies and compared the results.

There might have a bias in rice production estimates of DAE and BBS as evident from expert consultations in the field. We allowed a crop cut error adjustment of 5% production deviation in the adjusted BAU forecast to make it more plausible forecast. We have considered different alternative scenarios for comparison of projections of supply of key crop- rice:

- **BAU scenario:** Projections of ARIMA model with business-as-usual case,
- **Adjusted BAU scenario:** Crop cut bias
- **Pessimistic scenario (PS):** Projections of ARIMA model at lower limit with 95% confidence level to reflect effect of natural calamities and degraded condition like flood, drought and insect/pest, soil degradation, etc.

The results of above three alternative scenarios are presented in Table 13. Projections based on ARIMA model shows that under adjusted BAUscenario total supply of rice could be 41.04 million metric ton (MMT) in 2030 and 52.13 MMT in 2050 against 43.20 MMT and 54.97 MMT, respectively under BAU scenario. According to pessimistic scenario total supply of rice could be 35.47 MMT in 2030 and 40.68 MMT in 2050. Table 14 presents projections of *Aus*, *Aman* and *Boro* rice under different scenarios.

Under BAU scenario total rice production could be higher than adjusted BAU scenarios. Adjusted BAU scenario seems to be more plausible than BAU scenarios. BAU scenario is not feasible in that with this projected level of production as there will have a rice surplus of around 2.3 million ton in 2021 and 4.2 million in 2030. But the reality is that Bangladesh had food deficit and imported about 0.6 MMT rice in 2021. In the next decades Bangladesh will have to face problems of climate change, soil degradation, increased soil salinity, scarcity of irrigation water, etc. The PS scenario reflects rice production under degraded condition. In the long-term new rice technology will be available and will be adopted. However, with the adoption of new rice technology the total production could be most likely in between PS and adjusted BAU scenario.

**Table 13. Projections of production (supply) of rice during 2030 to 2050 (Quantity in MMT)**

| **Year** | **Supply** | | | |
|---|---|---|---|---|
| | BBS/DAE actual | BAU | BAU withcrop cut adjustment | Pessimistic |
| **2021** | 37.33 | 37.54 | 35.66 | 34.59 |
| **2030** | | 43.20 | 41.04 | 35.47 |
| **2035** | | 45.43 | 43.16 | 36.52 |
| **2040** | | 48.28 | 45.86 | 38.18 |
| **2045** | | 51.12 | 48.56 | 39.49 |
| **2050** | | 54.87 | 52.13 | 40.68 |

Source: Author's estimation from ARIMA model

**Table 14. Projections of production (supply) of *Aus*, *Aman* and *Boro* riceduring 2030 to 2050 (Quantity in MMT)**

| Year | BAU with adjustment | | | | Pessimistic | | | |
|---|---|---|---|---|---|---|---|---|
| | *Aus* | *Aman* | *Boro* | Total rice | *Aus* | *Aman* | *Boro* | Total rice |
| **2021** | 3.22 | 13.33 | 19.11 | 35.66 | 3.00 | 12.91 | 18.68 | 34.59 |
| **2030** | 3.46 | 16.18 | 21.40 | 41.04 | 3.24 | 13.06 | 19.17 | 35.47 |
| **2035** | 3.59 | 17.26 | 22.31 | 43.16 | 3.24 | 13.63 | 19.65 | 36.52 |
| **2040** | 3.85 | 18.34 | 23.68 | 45.86 | 3.37 | 14.19 | 20.61 | 38.18 |
| **2045** | 4.10 | 19.42 | 25.04 | 48.56 | 3.64 | 14.76 | 21.09 | 39.49 |
| **2050** | 4.23 | 21.04 | 26.86 | 52.13 | 3.78 | 15.33 | 21.57 | 40.68 |

This projection of rice production in 2030 is compared with the projection of Ganesh *et al.*, (2012) and Amarasinghe *et al.,* (2014.). Also compared rice projection in 2050 with Kabir *et el.,* (2015) study "Rice Vision for Bangladesh: 2050 and Beyond". Ganesh projected that rice production in 2030 will be 38.8 MMT under BAU scenario. Projection of

Amarasinghe showed that production of rice in 2030 will be 49 MMT under BAU scenario (Table 15). However, a contentious point in the projection of Amarasinghe *et. al.* is the area expansion, mainly *Boro* rice area which will expand from 4.10 million ha in 2010 to 5.7 million ha by 2030. With increasing pressure on land due to urbanization and development and the consequent decreasing availability of land, it is not plusiible to assume that a horizontal expansion of area is possible. Amarasinghe's projection also showed that with the forecasts of yield growth, self-sufficiency of rice is possible even without this area expansion. His estimation showed that even under the pessimistic scenario of lower growth in yield, i.e. along the 75% Lower Limit of Confidence interval (PS scenario), the total rice production of 39 MMT tons would be more than sufficient to meet the total demand by 2030. But our projections showed that expansion of rice area would not be feasible in the long run, beyond 2020 rice area will stabilize (at *Aus* 1.0 million ha, *Aman* 5.6 million ha and *Boro* 4.7 million ha) and remain so up to 2050. This seems more plausible result under the context of increasing population pressure and urbanization on land resources and gradual decline of cultivable land over time in Bangladesh. Moreover, land will shift from rice to high value non-rice crops and as a result area of non-rice crop will expand.

Kabir, *et al.*, 2015 analyzed genetic characteristics of BRRI modern rice varieties contributing to yield. Results showed that improving genetic yield potential of rice by 0.044 ton/ha per year, it is possible to secure 2.7 MMT of surplus with a total production of 48 MMT in 2050. If this is to happen, the current national average clean rice yield of 3.17 ton/ ha will have to be elevated to 4.82 ton/ha in 2050. Our ARIMA model also predicted that yield of rice in 2050 will be 4.8 ton/ha and hence our yield model is validated. Adjusted BAU scenario of our ARIMA model predicted that total production in 2050 could be 52.13 MMT. However, limitations of the Kabir *et. el.*, 2015 study is that it did not use national population statistics approved by the Planning Commission, rather it used an arbitrary population growth curve. Secondly, it analyzed soil health scenario of the country only from the result of an experiment conducted at BRRI Head quarter. Thirdly, it used some assumptions on availability of rice lands, reduction of yield gap and adoption path of crop variety which require further validation and confirmation because rice production in the future will have to face natural calamities and degraded condition like flood, drought and insect/pest, soil degradation, Finally, it did not use any statistical forecasting model for analyzing time series data having auto correlation problem.

**Table 15. Comparison of present projections of supply of rice with the projections of others (Quantity in MMT)**

| Projection for the year | Present projections in 2022 | | | Ganesh's projections in 2013 | | | Amarasinghe's projections in 2014 | |
|---|---|---|---|---|---|---|---|---|
| | BAU | Adjusted BAU | PS | OS | BAU | PS | BAU | PS |
| **2030** | 43.20 | 41.04 | 35.47 | 39.0 | 38.8 | 38.8 | 49 | 39 |
| **2050** | 54.87 | 52.13 | 40.68 | - | - | - | - | - |

Source: Author's estimation from ARIMA model, Ganesh et al, (2013) and Amarasinghe et al(2014)

Notes: Data source used by Ganesh is BBS. Data source used by Amarasinghe is Rice Knowledge Bank of BRRI, OS: Optimistic Scenario

### 4.3.2 Projections of surplus and deficit of rice supply

Projections of surplus and deficit of supply of rice by 2030 and 2050 is presented in Table 16. It is already discussed above that BAU scenario is not plausible. Based on estimates of adjusted BAU scenario there will have a marginal surplus of rice of 1.95 MMT in 2030 and it will gradually raise to 4.60 MMT in 2040 and further to 9.53 MMT in 2050. But PS predicted that there could be a deficit of 3.62 MMT in 2030, 3.08 MMT in 2040 and a deficit of 1.93 MMT in 2050. According to pessimistic scenario rice deficit in 2021 was 0.61 MMT due to flood which is more plausible than adjusted BAU scenario due to the fact that quantity of rice imported in Bangladesh was 0.6 MMT in 2021.

**Table 16. Projections of surplus and deficit of supply of rice by 2030 and 2050 (Quantity in MMT)**

| Year | Demand | Supply | | | Surplus (+)/deficit (-) | | |
|---|---|---|---|---|---|---|---|
| | | BAU | Adjusted BAU | Pessimistic | BAU | Adjusted BAU | Pessimistic |
| **2021** | 35.20 | 37.54 | 35.66 | 34.59 | 2.34 | 0.46 | -0.61 |
| **2030** | 39.09 | 43.20 | 41.04 | 35.47 | 4.11 | 1.95 | -3.62 |
| **2035** | 40.23 | 45.43 | 43.16 | 36.52 | 5.20 | 2.93 | -3.72 |
| **2040** | 41.26 | 48.28 | 45.86 | 38.18 | 7.02 | 4.60 | -3.08 |
| **2045** | 42.07 | 51.12 | 48.56 | 39.49 | 9.05 | 6.49 | -2.57 |
| **2050** | 42.60 | 54.87 | 52.13 | 40.68 | 12.27 | 9.53 | -1.93 |

Source: Author's estimation from ARIMA model

### 4.3.3 Projections of supply of wheat and maize

It is known from FPMU that wheat data of BBS and DAE have been harmonized. So, we have used BBS data for projection of supply of wheat. We have two alternative projections of maize supply using BBS and DAE data. The results are presented in Table 18.

Wheat production in 2021 was 1.03 MMT. Bangladesh Food Situation Report 2021 of FPMU also used BBS data to analyze food supply scenario of Bangladesh and supported this wheat production estimate. While USDA estimated wheat production in Bangladesh was 1.8 MMT but their source of data is unknown. ARIMA model predicted that wheat production in 2030 will be 1.17 MMT in 2030 and 1.24 MMT in 2050. Compared to 2021 level, wheat production will increase by 0.14 MMT in 2030 from 2021 level and increase by 0.07 MMT in 2050 from 2030 level as a result of slight expansion of yield while area will decline from 332 thousand ha in 2021 to 316 thousand ha in 2030 and further to 281 thousand ha of area in 2050.

Investigation has been made on the potentials of wheat production in the country. It is revealed from the analysis of data received from Bangladesh Wheat and Maize Research Institutes (BWMRI) that there are good prospects to enhance wheat production in the country. After liberation wheat production in the country gradually increased from 119 thousand ha in 1972 and gradually reached to the peak 889 thousand ha in 2000. Thereafter, wheat area has been declining due to its competition with other crops, mainly rice and other winter crops. BWMRI developed a number of heat tolerant and disease resistance high yielding wheat varieties (BARI Gam 33 and BWMRI Gam 3) which can be cultivated in the south and north-east part of the country where vast areas of land remain fallow after cultivation of T. *Aman*. In the south 800 thousand ha of land which remains fallow after T. *Aman* could be brought under wheat cultivation. Wheat cultivation could be expanded in the mountain valley and plain land of Chattogram Hill Tract. Extension support and government incentives will be required to promote wheat cultivation in the non-conventional fallow lands of the country. With the expansion of wheat cultivation in conventional land in the south an additional quantity of 2.64 MMT of wheat could be produced.

Projection on the basis of BBS data showed that maize production in 2030 will be 6.19 MMT in 2030 and 20.08 MMT in 2050. Compared to 2021 level, maize production will increase by 1.98 MMT in 2030 due to increase of yield from 8.2 ton/ha to 10.0 ton/ha and area expansion from 480 thousand ha to 614 thousand ha. Maize production will gradually rise to 12.24 MMT in 2050 due to area and yield expansion.

Projection on the basis of DAE data showed that maize production in 2030 will be 9.31 MMT in 2030 and 12.24 MMT in 2050. Compared to 2021 level, maize production will increase by 3.66 MMT in 2030 due to increase of yield from 10 ton/ha to 11.7 ton/ha and area expansion from 564 thousand ha to 796 thousand ha. Maize production will gradually rise to 20.08 MMT in 2050 due to area and yield expansion.

In order to validate maize production projections results we have compared the actual data of 2021with the projected results of 2021. We found that ARIMA model generated results which are more close to the actual production data of 2021. We have also reviewed relevant studies and data.

We found that significant gap exists in the maize area and yield data of BBS and DAE. As a result, maize production data of DAE found to be higher than that of BBS for the period 2012-2021. For instance, according to BBS data maize production in 2021 was 4.21 MMT while DAE data shows that it was 5.64 MMT. While USDA estimates of maize production in 2021 was 4.70 MMT which is close to BBS result. But source of data used by USDA to arrive at this estimate of 4.70 million is unknown. Maize area and yield data of BBS and DAE differs much. It is necessary to harmonize data of these two sources. As a government source of data, BBS should be given priority and should be used for planning exercise (Table 17).

**Table 17. Projections of production (supply) of wheat and maize by 2030 and 2050**

| Year | Supply (Quantity in MMT) | | |
|---|---|---|---|
| | Maize | | Wheat (BBS data) |
| | BBS data | DAE data | |
| **2021** | 4.21 | 5.64 | 1.03 |
| **2030** | 6.19 | 9.31 | 1.17 |
| **2035** | 7.51 | 11.69 | 1.17 |
| **2040** | 8.96 | 14.22 | 1.19 |
| **2045** | 10.54 | 17.09 | 1.22 |
| **2050** | 12.24 | 20.08 | 1.24 |

Source: Author’s estimation from ARIMA model

### 4.3.4 Projections of surplus and deficit of wheat and maize supply

Projections of surplus and deficit of supply of wheat and maize by 2030 and 2050 is presented in Table 18.

Demand for wheat in 2021 was 5.40 MMT while production was 1.03 MMT thus had a deficit of 4.37 MMT. According to Food Situation Report 2021 quantity of wheat imported in 2021 was 5.53 MMT. Bangladesh exports substantial volumes of wheat-based products. According to the Export Promotion Bureau of Bangladesh (EPB), the export value of wheat-based products in Bangladesh during 2021-22 was around US$250 million, an increase of about 130% from 2016-17. There always remains a carryover stock in public and private warehouses after meeting the actual grain demand. Thus the estimate seems to be plausible and robust. ARIMA model predicted that wheat production in 2030 will be 1.17 MMT and 1.24 MMT in 2050. There could be a deficit of wheat of 5.22 MMT in 2030 and 6.85 MMT in 2050.

Demand for maize in 2021 was 6.50 MMT while production was 4.21 MMT according to BBS data and thus had a deficit of 2.29 MMT. In 2021, quantity of maize imported was 2.46 MMT. These estimates of maize demand, supply and deficit is plausible and valid. While estimates based on DAE data shows that there was a maize deficit of 0.86 MMT in 2021.

Maize demand in the country will gradually increase over the years due to increased production of livestock and fishes and industrial uses. Maize demand in 2030 will be 8.43 MMT and will gradually rise to 16.99 MMT in 2050.

According to estimates based on BBS data there will have a maize deficit of 2.25 MMT in 2030 and gradually it will rise to 4.75 MMT in 2050 while estimates based on DAE data shows that there will have marginal surplus of 0.88 MMT of maize in 2030 and gradually it will rise to 3.09 MMT in 2050. Thus, projection based on BBS data seemingly plausible.

**Table 18. Projections of surplus and deficit of supply of maize and wheat by 2030 and 2050**

| **Year** | **Quantity in MMT** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Demand | | Supply | | | Surplus(+)/deficit (-) | | |
| | Maize | Wheat | Maize | | Wheat | Maize | | Wheat |
| | | | BBS | DAE | | BBS | DAE | |
| **2021** | 6.50 | 5.40 | 4.21 | 5.64 | 1.03 | -2.29 | -0.86 | -4.37 |
| **2030** | 8.43 | 6.39 | 6.19 | 9.31 | 1.17 | -2.25 | 0.88 | -5.22 |
| **2035** | 9.67 | 6.82 | 7.51 | 11.69 | 1.17 | -2.16 | 2.02 | -5.66 |
| **2040** | 12.09 | 7.21 | 8.96 | 14.22 | 1.19 | -3.13 | 2.13 | -6.01 |
| **2045** | 13.64 | 7.66 | 10.54 | 17.09 | 1.22 | -3.10 | 3.45 | -6.45 |
| **2050** | 16.99 | 8.09 | 12.24 | 20.08 | 1.24 | -4.75 | 3.09 | -6.85 |

Source: Author's estimation from ARIMA model

### 4.3.5 Projections of supply of mustard and ground nut

The ground nut production will increase from 0.58 lakh MT in 2021 to 0.89 lakh MT in 2030 as a result of yield increase from 1.8 ton/ha to 2.1 ton/ha and area expansion form 32.4 thousand ha to 42.3 thousand ha (Table 19). Similarly, mustard production will increase from 3.57 lakh MT in 2021 to 4.40 lakh MT in 2030 as a result of yield increase from 1.16 ton/ha to 1.2 ton/ha and area expansion form 309 thousand ha to 343 thousand in 2030. Ground nut production will gradually further rise to 1.43 lakh MT in 2050 due to area expansion to 61 thousand ha and yield expansion to 2.34 ton/ha. Also, mustard production will gradually rise to 5.65 lakh MT in 2050 due to area expansion to 377 thousand ha and yield expansion to 1.5 ton/ha.

**Table 19. Projections of production (supply) of ground nut and mustard by 2030 and 2050**

| Year | Supply of ground nut and mustard (Quantity in lakh MT) | |
|---|---|---|
| | Ground nut | Mustard |
| **2021** | 0.58 | 3.57 |
| **2030** | 0.89 | 4.40 |
| **2035** | 1.02 | 4.71 |
| **2040** | 1.15 | 5.02 |
| **2045** | 1.29 | 5.35 |
| **2050** | 1.43 | 5.65 |

Source: Author's estimation from ARIMA model

### 4.3.6 Projections of surplus and deficit of ground nut and mustard supply

We have converted production of whole ground nut and mustard into oil. Projections of surplus and deficit of supply of ground nut oil and mustard oil for the period 2030 to 2050 is presented in Table 20. There will have a surplus of ground nut oil of 0.30 lakh MT in 2030 and 0.58 lakh MT in 2050. There will have a deficit of mustard oil of 0.30 lakh MT in 2030 and 1.68 lakh MT in 2050.

**Table 20. Projections of surplus and deficit of ground nut oil and mustard oil by 2030 and 2050**

| Year | Demand of oil (Quantity in lakh MT) | | Supply of oil (Quantity in lakh MT) | | Surplus (+)/deficit(-) (Quantity in lakh MT) | |
|---|---|---|---|---|---|---|
| | Groundnut | Mustard | Ground nut | Mustard | Ground nut oil | Mustard oil |
| **2021** | 0.14 | 1.48 | 0.29 | 1.43 | 0.15 | -0.05 |
| **2030** | 0.14 | 2.06 | 0.45 | 1.76 | 0.30 | -0.30 |
| **2035** | 0.15 | 2.48 | 0.51 | 1.88 | 0.36 | -0.60 |
| **2040** | 0.14 | 2.97 | 0.57 | 2.01 | 0.43 | -0.96 |
| **2045** | 0.14 | 3.46 | 0.64 | 2.14 | 0.50 | -1.32 |
| **2050** | 0.13 | 3.94 | 0.71 | 2.26 | 0.58 | -1.68 |

Source: Author's estimation from ARIMA model

### 4.3.7 Projections of supply of major spices

The onion production will increase from 18.5 lakh MT in 2021 to 25.4 lakh MT in 2030 as a result of yield increase from 9.5 ton/ha 11.6 ton/ha and area expansion form 1.94 lakh ha to 2.81 lakh ha (Table 21). It will further rise to 48.8 lakh MT in 2050 due to yield increase and area expansion.

Similar to the trend of onion, there is increasing trend in production of other spice crops from the period of 2021 to 2050 due to yield increase and area expansion (Table 22)

Garlic production will increase from 4.9 lakh MT in 2021 to 6.7 lakh MT in 2030 as a result of yield increase from 6.6 ton/ha to8.6 ton/ha and area expansion form 73684 ha to 78144 ha. It will further rise to 12.9 lakh MT in 2050 due to yield increase and area expansion (Table 21).

Also, there will have increased supply of garlics ginger, conriendar and chilli during 2021-2050, due to area and yield expansion.

**Table 21. Projections of production (supply) of spices from 2030 to 2050**

| Year | Supply of spices (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Onion | Turmeric | Garlic | Ginger | Coriander | Dry chili | All |
| **2021** | 18.5 | 2.4 | 4.9 | 0.9 | 0.2 | 1.4 | 28.1 |
| **2030** | 25.4 | 3.8 | 6.7 | 0.9 | 0.3 | 3.4 | 40.5 |
| **2035** | 30.1 | 4.6 | 8.1 | 0.9 | 0.3 | 4.3 | 48.3 |
| **2040** | 35.1 | 5.5 | 9.6 | 1.0 | 0.4 | 5.3 | 56.7 |
| **2045** | 40.5 | 6.4 | 11.2 | 1.0 | 0.4 | 6.4 | 65.9 |
| **2050** | 48.8 | 7.3 | 12.9 | 1.1 | 0.5 | 7.5 | 78.1 |

Source: Author's estimation from ARIMA model

### 4.3.8 Projections of surplus and deficit of spices supply

Projections of deficit of supply of spices for the period 2030 to 2050 is presented in Table 22. There will have deficits of supply of total spices in 2030 and 2050. Total deficit of six spices in 2030 will be 28.08 lakh MT and thereafter it will gradually decrease to 13.27 lakh MT till 2050. Deficit of onion and chili will decrease over the years. There will have surplus of only chili production in 2045and 2050. Also, there will have a surplus of onion in 2050. A marginal surplus of onion and chili amounting 3.29 lakh MT and 1.15 lakh MT, respectively are forecasted in 2050.

**Table 22. Projections of surplus and deficit of supply of spices by 2030 and 2050**

| Year | Spices (Quantity in lakh MT): Surplus (+)/Deficit (-) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Onion | Turmeric | Garlic | Ginger | Coriander | Chili | Total |
| **2021** | -8.49 | -4.12 | -8.88 | -1.57 | -0.34 | -2.42 | -25.82 |
| **2030** | -8.68 | -4.39 | -10.67 | -2.21 | -0.74 | -1.39 | -28.08 |
| **2035** | -7.06 | -4.32 | -10.85 | -2.41 | -0.77 | -0.86 | -26.27 |
| **2040** | -5.07 | -4.18 | -10.90 | -2.62 | -0.83 | -0.36 | -23.97 |
| **2045** | -2.59 | -3.96 | -10.77 | -2.83 | -0.85 | 0.39 | -20.61 |
| **2050** | 3.29 | -3.57 | -10.28 | -2.97 | -0.89 | 1.15 | -13.27 |

Source: Author's estimation from ARIMA model

### 4.3.9 Projections of supply of pulses

Projections based on ARIMA model showed that among the six pulses only lentil, mungbean, grasspea and pea will have increasing trend in 2030 and will continue till 2050 (Table 23). Lentil production will increase from 1.77 lakh MT in 2021 to 2.28 lakh MT in 2030 as a result of yield increase from 1.1 ton/ha to 1.3 ton/ha and area expansion form 1.14 lakh ha to 1.76 lakh ha. It will further gradually rise to 3.76 lakh MT in 2050 due to yield increase to 1.6 ton/ha and area expansion to 2.5 lakh ha.

Mungbean production will increase from 0.41 lakh MT in 2021 to 0.76 lakh MT in 2030 as a result of yield increase from 0.7 ton/ha to 1.5 ton/ha and area expansion form 44 thousand ha to 51 thousand ha. It will further gradually rise to 1lakh MT in 2050 due to yield increase to 2.8 ton/ha and area expansion to 67 thousand ha.

Grasspea production will increase from 1.3 lakh MT in 2021 to 1.94 lakh MT in 2030 as a result of yield increase from 1.1 ton/ha to 1.2 ton/ha and area expansion form 1.10 lakh ha to 1.62 lakh ha. It will further gradually rise to 3.87 lakh MT in 2050 due to yield increase to 1.4 ton/ha and area expansion to 2.77 lakh ha.

Pea production will increase from 0.08 lakh MT in 2021 to 0.17 lakh MT in 2030 as a result of area expansion form 7 thousand ha to 15.5 thousand ha. It will further gradually rise to 0.44 lakh MT in 2050 due to yield increase from 1.1 ton/ha in 2030 to 1.3 ton/ha m 2050 and area expansion to 33 thousand ha.

Chickpea yield will increase from 1.1 ton/ha in 2021 to 1.2 ton/ha in 2030 but its area will decline form 4.8 thousand ha in 2021 to 3.8 thousand ha in 2030 and as result total production of chick pea will be 0.05 lakh MT in 2030 which is same as the production level of 2021 (Table 23). Chickpea yield will further increase to 1.3 ton/ha in 2050 but its area will further decrease to 1.8 thousand ha in 2050 and as a result total production will further fall to 0.02 lakh MT.

Blackgram yield will increase from 0.9 ton/ha in 2021 to 1.0 ton/ha in 2030 but its area will decline form 4 thousand ha in 2021 to 3.3 thousand ha in 2030 and as a result total production of blackgram will slightly fall from 0.37 lakh MT in 2021 to 0.33 lakh MT in 2030 (Table 23). Blackgram yield will further increase to 1.1 ton/ha in 2050 but its area will further decrease to 23.6 thousand ha in 2050 and as a result total production will further fall to 0.26 lakh MT.

**Table 23. Projections of production (supply) of pulses from 2030 to 2050**

| Year | Pulse supply (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Chickpea | Pea | Lentil | Mungbean | Blackgram | Grasspea | All pulse |
| **2021** | 0.05 | 0.08 | 1.77 | 0.41 | 0.37 | 1.31 | 3.99 |
| **2030** | 0.05 | 0.17 | 2.28 | 0.76 | 0.33 | 1.94 | 5.54 |
| **2035** | 0.04 | 0.22 | 2.72 | 0.99 | 0.3 | 2.48 | 6.76 |
| **2040** | 0.04 | 0.29 | 2.99 | 1.24 | 0.28 | 2.85 | 7.69 |
| **2045** | 0.03 | 0.35 | 3.48 | 1.58 | 0.28 | 3.47 | 9.2 |
| **2050** | 0.02 | 0.44 | 3.76 | 1.89 | 0.26 | 3.87 | 10.24 |

Source: Author's estimation from ARIMA model

### 4.3.10 Projections of surplus and deficit of pulses supply

Projections of deficit of supply of pulses for the period 2030 to 2050 are presented in Table 24. There will have deficits of supply of all pulses in 2030 amounting 12.88 lakh MTs. Deficit of lentil, mungbean and grasspea will decrease over the years due to major contribution of increased productivity. As a result, total shortage of all pulses will gradually decline over the years. There will have a deficit of all pulses with the amount of 9 lakh MT in 2050.

**Table 24. Projections of surplus and deficit of supply of pulses by 2030 and 2050**

| Year | Surplus (+)/Deficit (-) of pulse (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Chick pea | Pea | Lentil | Mungbean | Blackgram | Grasspea | All pulse |
| **2021** | -1.23 | -3.20 | -4.65 | -2.15 | -0.92 | -1.26 | -12.12 |
| **2030** | -1.38 | -3.47 | -4.84 | -2.09 | -1.10 | -0.91 | -12.36 |
| **2035** | -1.43 | -3.53 | -4.61 | -1.94 | -1.16 | -0.46 | -11.66 |
| **2040** | -1.47 | -3.55 | -4.53 | -1.76 | -1.22 | -0.16 | -11.19 |
| **2045** | -1.50 | -3.58 | -4.19 | -1.48 | -1.25 | 0.41 | -10.06 |
| **2050** | -1.53 | -3.55 | -4.00 | -1.22 | -1.29 | 0.77 | -9.26 |

Source: Author's estimation from ARIMA model

### 4.3.11 Projections of supply of potato and sweet potato

Projections of crop specific supply of selected two tuber crops, potato and sweet potato in 2030 to 2050 are presented in Table 25.

Potato production will increase from 98.70 lakh MT in 2021 to 117.81 lakh MT in 2030 as a result of yield increase from 21 ton/ha to 24.2 ton/ha and area expansion form 468.9 thousand ha to 486.8 thousand ha. Its production will further gradually rise 140.89 lakh MT in 2050 due to yield increase to 28.3 ton/ha and area expansion to 535.7 thousand ha.

Sweet potato production will increase from 3.66 lakh MT in 2021 to 5.43 lakh MT in 2030 as a result of yield increase from 9.66 ton/ha to14.14 ton/ha and area expansion form 26.5 thousand ha to 38.4 thousand ha. Its production will further gradually rise to 15.83 lakh MT in 2050 due to yield increase to 28.3 ton/ha and area expansion to 68.1 thousand ha.

**Table 25. Projections of production (supply) of potato and sweet potato from 2030 to 2050**

| Year | Supply (Quantity in lakh MT) | |
|---|---|---|
| | Potato | Sweet potato |
| **2021** | 98.70 | 3.66 |
| **2030** | 117.81 | 5.43 |
| **2035** | 120.76 | 7.52 |
| **2040** | 130.36 | 9.95 |
| **2045** | 136.63 | 12.73 |
| **2050** | 140.89 | 15.83 |

#### 4.3.12 Projections of surplus and deficit of tuber crops supply

Projections of deficit and surplus of supply of potato and sweet potato for the period 2030 to 2050 are presented in Table 26 and Table 27, respectively. Total potato demand in 2030 will be 116.1 lakh MT and supply will be 117.81 lakh MT and will have a marginal surplus of 2.84 lakh MT. Total potato demand in 2050 is projected to be 126.59 lakh MT and supply will be 140.9 lakh MT and will have a surplus of 14.30 lakh MT (Table 26).

**Table 26. Projections of surplus and deficit of supply of potato by 2030 and 2050**

| Year | Surplus (+)/deficit (-) (Quantity in lakh MT) | | |
|---|---|---|---|
| | Supply | Demand | Surplus |
| **2021** | 98.70 | 95.63 | 3.07 |
| **2030** | 117.81 | 116.16 | 1.65 |
| **2035** | 120.76 | 119.55 | 1.21 |
| **2040** | 130.36 | 122.60 | 7.76 |
| **2045** | 136.63 | 125.00 | 11.63 |
| **2050** | 140.89 | 126.59 | 14.30 |

Total sweet potato demand in 2030 will be 3.2 lakh MT and supply will be 5.43 lakh MT and will have a marginal surplus of 2.23 lakh MT. Total sweet potato demand in 2050 is projected to be 9.28 lakh MT and supply will be 15.83 lakh MT and will have a surplus of 12.34 lakh MT (Table 27).

**Table 27. Projections of surplus and deficit of supply of sweet potato by 2030 and 2050**

| Year | Surplus (+)/deficit (-) (Quantity in lakh MT) | | |
|---|---|---|---|
| | Supply | Demand | Surplus (+)/deficit (-) |
| **2021** | 3.66 | 4.12 | -0.46 |
| **2030** | 5.43 | 3.20 | 2.23 |
| **2035** | 7.52 | 3.30 | 4.22 |
| **2040** | 9.95 | 3.38 | 6.56 |
| **2045** | 12.73 | 3.45 | 9.28 |
| **2050** | 15.83 | 3.49 | 12.34 |

#### 4.3.13 Projections of supply of vegetables

We have selected 10 major vegetables for projections of crop supply for the period 2030 to 2050. These crops are tomato, bean, brinjal, cucumber, lady's finger, bitter gourd, cauliflower, cabbage, snake gourd and gourd. These crops cover 68% of total vegetables production of country and the rest of the crops cover 32% (Figure 29). Projections of supply of selected vegetables during 2030 to 2050 are presented in Table 28.

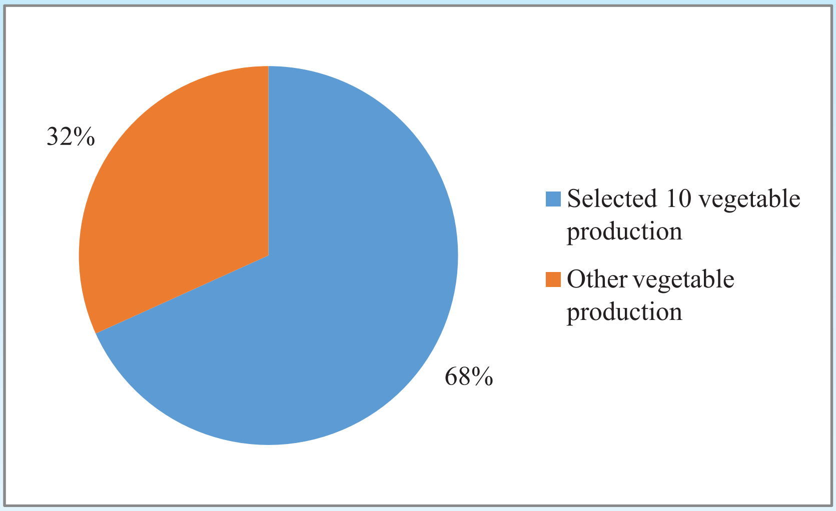



**Figure 29. Extent of coverage selected 10 vegetables in total vegetable production of Bangladesh**

The selected vegetables projected to have increasing production due to yield and area expansion. Total production of these 10 crops will increase from 29.8 lakh MT in 2021 to 40.1 lakh MT in 2030 and will gradually rise to 71 lakh MT in 2050. Total area of these crops will gradually increase from 212 thousand ha in 2021 to 370 thousand ha in 2050 and average yield will increase from 11 tons/ha in 2021 to 18 tons/ha in 2050.

**Table 28. Projections of supply of selected vegetables in 2030 to 2050**

| Year | Supply (Quantity in lakh MT) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tomato | Bean | Brinjal | Cucumber | Lady's finger | Bitter gourd | Cauliflower | Cabbage | Snake gourd | Gourd | Total of 10 |
| **2021** | 4.4 | 1.6 | 11.8 | 0.9 | 0.6 | 0.6 | 3.0 | 3.9 | 0.4 | 2.6 | 29.8 |
| **2030** | 6.3 | 2.5 | 12.6 | 2.5 | 1.0 | 0.7 | 4.5 | 6.1 | 0.8 | 3.2 | 40.1 |
| **2035** | 7.4 | 3.8 | 13.2 | 3.6 | 1.1 | 0.8 | 5.5 | 7.7 | 1.0 | 3.6 | 47.8 |
| **2040** | 8.6 | 3.7 | 13.8 | 4.9 | 1.3 | 0.9 | 6.5 | 9.3 | 1.2 | 4.1 | 54.4 |
| **2045** | 9.8 | 5.8 | 14.6 | 6.4 | 1.4 | 1.0 | 7.7 | 11.1 | 1.4 | 4.6 | 64.0 |
| **2050** | 11.1 | 4.9 | 15.4 | 8.1 | 1.6 | 1.1 | 8.9 | 13.0 | 1.7 | 5.1 | 71.0 |

Source: Author's estimation from ARIMA model

### 4.3.14 Projections of surplus and deficit of vegetables supply

Projections of surplus of supply of vegetables for the period 2030 to 2050 are presented in Table 30. Total vegetable demand in the country in 2030 will be 51.5 lakh MT and total supply will be 53.8 lakh MT and will have a marginal surplus of 2.3 lakh MT. Total vegetable demand in the country in 2050 is projected to be 65.5 lakh MT and supply will be 89 lakh MT and will have a surplus of 23.5 lakh MT. (Table 29 and Figure 30).

**Table 29. Projections of surplus of supply of all vegetables of Bangladesh by 2030 and 2050**

| Year | Quantity in lakh MT | | |
|---|---|---|---|
| | Demand | Supply | Surplus |
| **2021** | 41.2 | 41.7 | 0.5 |
| **2030** | 51.5 | 53.8 | 2.3 |
| **2035** | 58.9 | 62.5 | 3.6 |
| **2040** | 63.4 | 70.3 | 6.9 |
| **2045** | 65.3 | 80.9 | 15.7 |
| **2050** | 65.5 | 89.0 | 23.5 |

Source: Author's estimation from ARIMA model

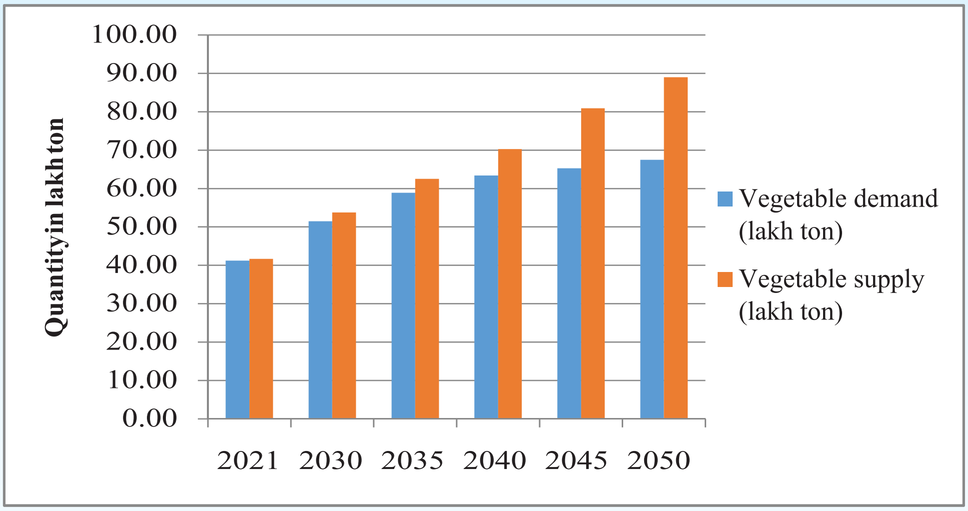



**Figure 30. Projections of demand and supply of vegetables in 2030 to 2050**

### 4.3.15 Projections of supply of fruits

We have selected six major fruits for projections of supply for the period 2030 to 2050. These fruits are pineapple, lime & lemon, banana, guava, mango and water melon. These fruits cover 72% of total fruit production of the country. Projections of crop specific supply of selected fruits in 2030 to 2050 are presented in Table 30.

The selected fruits projected to have increasing production due to yield and area expansion over the period. Total supply of these fruits in the country will increase from 29.4 lakh MT in 2021 to 35.5 lakh MT in 2030 and will gradually rise to 51.6 lakh MT in 2050. Total area of these fruits will gradually increase from 203 thousand ha in 2021 to 647 thousand ha in 2050 and average yield will increase from 29 tons/ha in 2021 to 44 tons/ha in 2050.

**Table 30. Projections of production (supply) of fruits from 2030 to 2050**

| Year | Supply (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pineapple | Lime & lemon | Banana | Guava | Mango | Water melon | All |
| **2021** | 2.1 | 1.2 | 8.7 | 2.4 | 12.1 | 3.0 | 29.4 |
| **2030** | 2.2 | 1.4 | 10.7 | 3.2 | 14.0 | 4.0 | 35.5 |
| **2035** | 2.3 | 1.6 | 12.3 | 3.8 | 14.9 | 4.3 | 39.3 |
| **2040** | 2.5 | 1.8 | 13.8 | 4.5 | 15.8 | 4.7 | 43.2 |
| **2045** | 2.6 | 2.0 | 15.5 | 5.1 | 16.8 | 5.0 | 47.1 |
| **2050** | 2.8 | 2.3 | 17.5 | 5.8 | 17.7 | 5.6 | 51.6 |

Source: Author's estimation from ARIMA model

### 4.3.16 Projections of surplus and deficit of fruits supply

Projections of surplus of supply of fruits for the period 2030 to 2050 are presented in Table 32. Total surplus of six selected fruits in 2030 will be 3.3 lakh MT and it will gradually rise to 7.9 lakh MT in 2050 (Table 31).

**Table 31. Projections of surplus and deficit of supply of fruits by 2030 and 2050**

| Year | Surplus of fruits (Quantity in lakh MT) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pineapple | Lime & lemon | Banana | Guava | Mango | Water melon | All |
| **2021** | 0.8 | 0.2 | 0.4 | 0.1 | 1.2 | 0 | 2.7 |
| **2030** | 0.7 | 0.1 | 0.4 | 0.4 | 1.3 | 0.4 | 3.3 |
| **2035** | 0.7 | 0.1 | 1.1 | 0.7 | 1.4 | 0.4 | 4.3 |
| **2040** | 0.8 | 0.1 | 1.7 | 1.0 | 1.4 | 0.3 | 5.3 |
| **2045** | 0.8 | 0.2 | 2.4 | 1.3 | 1.5 | 0.2 | 6.3 |
| **2050** | 0.9 | 0.2 | 3.4 | 1.6 | 1.6 | 0.3 | 7.9 |

Source: Author's estimation from ARIMA model

## 4.4 Sensitivity Analysis

### 4.4.1 Demand side

We have considered three alternative scenarios for comparison of sensitivity of key crops: rice, vegetables and fruits demand projections:

- Existing scenario: Projections with existing rate of calorie intake
- Alternative Scenario 1: Crop demand decrease by 5%
- Alternative Scenario 2: Crop demand increase by 5%

#### a. Sensitivity analysis of rice crop demand

**Results under Alternative scenario 1 and 2:**

The results of alternative scenario 1 and 2 are presented in Table 32 and Table 33, respectively. Projections show that under alternative scenario 1 total demand for rice will be 37.12 million ton (MMT) in 2030 and 40.47 MMT in 2050. Under PS scenario total deficit of rice could be 1.67 MMT in 2030 and will have a marginal surplus of 2.46 MMT in 2050 against 6.0 MMT and 14.4 MMT, respectively under BAU scenario and 3.9 MMT and 13.9 MMT, respectively under adjusted BAU scenario. The results of adjusted BAU appeared to be more plausible than BAU. The adjusted BAU and PS scenario seems to be more plausible considering total consumption, food production, import and food balance.

The results of alternative scenario 2 showed that rice demand will rise slightly to 41.04 MMT in 2030 and 44.73 MMT in 2050. Again surplus/deficit figure will change under BAU, Adjusted BAU and PS. In this case also the results of adjusted BAU appeared to be more plausible than BAU.

**Table 32 Sensitivity analysis of projections of demand and surplus/deficits of rice under alternative scenario 1 (Quantity in MMT)**

| Year | Demand under Scenario 1 | Existing scenario: Surplus (+)/deficit (-) | | | Alternative scenario 1: Surplus (+)/deficit (-) | | |
|---|---|---|---|---|---|---|---|
| | | BAU | Adjusted BAU | Pessimistic (PS) | BAU | Adjusted BAU | Pessimistic (PS) |
| **2021** | 33.44 | 2.34 | 0.46 | -0.61 | 4.1 | 2.22 | 1.15 |
| **2030** | 37.12 | 4.11 | 1.95 | -3.62 | 6.06 | 3.9 | -1.67 |
| **2035** | 38.22 | 5.2 | 2.93 | -3.72 | 7.21 | 4.94 | -1.70 |
| **2040** | 39.20 | 7.02 | 4.6 | -3.08 | 9.08 | 7.64 | -0.04 |
| **2045** | 39.97 | 9.05 | 6.49 | -2.57 | 11.15 | 10.34 | 1.27 |
| **2050** | 40.47 | 12.27 | 9.53 | -1.93 | 14.4 | 13.91 | 2.46 |

Source: Author's estimation

**Table 33. Sensitivity analysis of projections of demand and surplus/deficits of rice under alternative scenario 2 (Quantity in MMT)**

| Year | Existing Demand | Demand under Alternate scenario 2 | Existing scenario | | | Alternative scenerio 2 | | |
|---|---|---|---|---|---|---|---|---|
| | | | Surplus (+)/deficit (-) | | | Surplus (+)/deficit (-) | | |
| | | | BAU | Adjusted BAU | Pessimistic (PS) | BAU | Adjusted BAU | Pessimistic (PS) |
| **2021** | 35.2 | 36.96 | 2.34 | 0.46 | -0.61 | 0.58 | -1.30 | -2.37 |
| **2030** | 39.09 | 41.04 | 4.11 | 1.95 | -3.62 | 2.16 | 0.00 | -5.57 |
| **2035** | 40.23 | 42.24 | 5.2 | 2.93 | -3.72 | 3.19 | 0.92 | -5.72 |
| **2040** | 41.26 | 43.32 | 7.02 | 4.6 | -3.08 | 4.96 | 2.54 | -5.14 |
| **2045** | 42.07 | 44.17 | 9.05 | 6.49 | -2.57 | 6.95 | 4.39 | -4.68 |
| **2050** | 42.6 | 44.73 | 12.27 | 9.53 | -1.93 | 10.14 | 7.40 | -4.05 |

Source: Author's estimation

**b. Sensitivity analysis of vegetable crop demand**

**Results under Alternative scenario 1 and 2:**

The results of alternative scenario 1 and 2 are presented in Table 34 and Table 35, respectively. Projections showed that under alternative scenario1, total demand of vegetable will be 48.9 lakh MT in 2030 and 62.2 lakh MT in 2050. Total surplus of vegetables will rise to 4.9 lakh MT in 2030 and 26.8 lakh MT in 2050. Under alternative scenario 2, total vegetable demand will slightly increase and surplus will slightly decline. Thus, the results found to be consistent.

**Table 34. Sensitivity analysis of projections of demand and surplus of vegetables under alternative scenario 1**

| Year | Quantity in lakh MT | | | |
|---|---|---|---|---|
| | Existing demand | Demand under Scenario 1 | Base scenario Surplus(+)/Deficit(-) | Alternative Scenario 1 Surplus(+)/Deficit(-) |
| **2021** | 41.2 | 39.1 | 0.5 | 2.6 |
| **2030** | 51.5 | 48.9 | 2.3 | 4.9 |
| **2035** | 58.9 | 56.0 | 3.6 | 6.5 |
| **2040** | 63.4 | 60.2 | 6.8 | 10.1 |
| **2045** | 65.3 | 62.0 | 15.7 | 18.9 |
| **2050** | 65.5 | 62.2 | 15.5 | 26.8 |

Source: Author's estimation

**Table 35 Sensitivity analysis of projections of surplus and deficit of vegetables under alternative scenario 2**

| Year | Quantity in lakh MT | | | |
|---|---|---|---|---|
| | Existing demand | Demand under Scenario 2 | Base scenario Surplus(+)/Deficit(-) | Alternative Scenario 2 Surplus(+)/Deficit(-) |
| **2021** | 41.2 | 43.3 | 0.5 | -1.6 |
| **2030** | 51.5 | 54.1 | 2.3 | -0.3 |
| **2035** | 58.9 | 61.8 | 3.6 | 0.7 |
| **2040** | 63.4 | 66.6 | 6.8 | 3.7 |
| **2045** | 65.3 | 68.6 | 15.7 | 12.3 |
| **2050** | 65.5 | 68.8 | 15.5 | 20.2 |

Source: Author's estimation

### c. Sensitivity analysis of fruits demand

**Results under Alternative scenario 1 and 2:**

The results of alternative scenario 1 and 2 are presented in Table 36. Projections showed that under alternative scenario 1 total demand of fruits will be 30.6 lakh MT in 2030 and 41.5 lakh MT in 2050. Total surplus of fruits will rise to 4.9 lakh MT in 2030 and 10.1 lakh MT in 2050. Under alternative scenario 2 total fruits demand and surplus will slightly increase. Thus, the results found to be consistent.

**Table 36. Sensitivity analysis of projections of demand and surplus of fruits under alternative scenario 1 and 2 (Quantity in lakh MT)**

| Year | Existing scenario | | Alternative scenario 1 | | Alternative scenario 2 | |
|---|---|---|---|---|---|---|
| | Demand of six fruits | Surplus(+)/ Deficit(-) | Demand of six fruits | Surplus(+)/ Deficit(-) | Demand of six fruits | Surplus(+)/ Deficit(-) |
| **2021** | 26.7 | 2.7 | 25.4 | 4.0 | 28.0 | 1.3 |
| **2030** | 32.2 | 3.3 | 30.6 | 4.9 | 33.8 | 1.6 |
| **2035** | 35 | 4.3 | 33.2 | 6.1 | 36.7 | 1.7 |
| **2040** | 37.9 | 5.3 | 36.0 | 7.2 | 39.8 | 1.9 |
| **2045** | 40.8 | 6.3 | 38.8 | 8.3 | 42.9 | 2.0 |
| **2050** | 43.7 | 7.9 | 41.5 | 10.1 | 45.9 | 2.2 |

Source: Author's estimation

### 4.4.2 Supply side

**Alternative scenarios considered:**

We have considered different alternative scenarios for comparison of projections of supply of key crops- rice, vegetables and fruits:

**Alternative scenario 1:** Supply short fall by 8% due to shocks (climate change, disease & pest, market vulnerability, other reasons, etc.)

**Alternative scenario 2:** Supply short fall by 10% due to shocks (climate change, disease & pest, market vulnerability, other reasons, etc.)

**a. Sensitivity analysis of rice supply**

In addition to above 2 alternative scenarios, we have considered three alternative cases for comparison of projections of supply of key crops- rice:

- **BAU case:** Projections of ARIMA model with business-as-usual case
- **Adjusted BAU case:** Projections of ARIMA model with business-as-usual case,with the adjustment of crop cut bias
- **Pessimistic case (PS):** Projections of ARIMA model at lower limit with 95% confidence level,

**Results under Alternative scenario 1:** Supply short fall by 8% due to shocks (climate change, disease & pest, market vulnerability, other reasons, etc.)

The results of alternative scenario 1 of BAU, adjusted BAU and PS are presented in Table 37. Projections showed that under PS scenario total supply of rice could be 32.63 MMT in 2030 and 37.43 MMT in 2050 against 39.74 MMT and 50.48 MMT, respectively under BAU scenario and 37.76 MMT and 47.96 MMT, respectively under adjusted BAU scenario. Under BAU scenario total rice production could be higher than adjusted BAU scenarios. Adjusted BAU scenario seems to be more plausible than optimistic BAU scenario. In the next decades Bangladesh will have to face problems of climate change, soil degradation, increased soil salinity, scarcity of irrigation water, etc. The PS scenario reflects rice production under degraded condition. In the long-term new rice technology will be available and will be adopted. However, with the adoption of new rice technology the total production could be most likely in between PS and adjusted BAU level.

**Table 37. Sensitivity analysis of projections of total supply and surplus/deficits of rice under alternative scenario 1 (Quantity in MMT)**

| Year | Demand | Supply under scenario 1 | | | Surplus (+)/deficit (-) under scenario 1 | | |
|---|---|---|---|---|---|---|---|
| | | BAU | Adjusted BAU | PS | BAU | Adjusted BAU | PS |
| **2021** | 35.2 | 34.54 | 32.81 | 31.82 | -0.66 | -2.39 | -3.38 |
| **2030** | 39.09 | 39.74 | 37.76 | 32.63 | 0.65 | -1.33 | -6.46 |
| **2035** | 40.23 | 41.80 | 39.71 | 33.60 | 1.57 | -0.52 | -6.63 |
| **2040** | 41.26 | 44.42 | 42.19 | 35.13 | 3.16 | 0.93 | -6.13 |
| **2045** | 42.07 | 47.03 | 44.68 | 36.33 | 4.96 | 2.61 | -5.74 |
| **2050** | 42.6 | 50.48 | 47.96 | 37.43 | 7.88 | 5.36 | -5.17 |

Source: Author’s estimation

**Results under Alternative scenario 2:** Supply short fall by 12% due to shocks (climate change, disease & pest, market vulnerability, other reasons, etc.)

Sensitivity analysis in Table 38 shows that under the Alternative scenario 2 total rice production will further slightly decline than Alternative scenario 1 presented in Table 38. Thus, the result found to be consistent.

**Table 38 Sensitivity analysis of projections of total supply and surplus/deficits of rice under alternative scenario 2 (Quantity in MMT)**

| Year | Demand | Supply under scenario 2 | | | Surplus (+)/deficit (-) underscenario 2 | | |
|---|---|---|---|---|---|---|---|
| | | BAU Forecast (OS) | Adjusted BAU forecast | Pessimistic Lower 95% limit | BAU Forecast | Adjusted BAU forecast | Pessimistic lower 95% limit |
| **2021** | 35.2 | 33.04 | 31.38 | 30.44 | -2.16 | -3.82 | -4.76 |
| **2030** | 39.09 | 38.02 | 36.12 | 31.21 | -1.07 | -2.97 | -7.88 |
| **2035** | 40.23 | 39.98 | 37.98 | 32.14 | -0.25 | -2.25 | -8.09 |
| **2040** | 41.26 | 42.49 | 40.36 | 33.60 | 1.23 | -0.90 | -7.66 |
| **2045** | 42.07 | 44.99 | 42.73 | 34.75 | 2.92 | 0.66 | -7.32 |
| **2050** | 42.6 | 48.29 | 45.87 | 35.80 | 5.69 | 3.27 | -6.80 |

Source: Author's estimation

**b. Sensitivity analysis of vegetable supply**

**Results under Alternative scenario 1 and 2:**

The results of alternative scenario 1 and 2 are presented in Table 39. Projections showed that under alternative scenario 1 total supply of vegetable will be 49.5 lakh MT in 2030 and 81.9 lakh MT in 2050. The results seem to be more plausible in that in the coming decades as vegetable supply in the country would face random shocks of climate change, pest & diseases and market fluctuations, etc. The alternative scenario 1 and 2 reflects vegetable supply under such condition. The results of alternative scenario 2 showed that vegetable supply will decline further slightly to 47.3 lakh MT in 2030 and will have deficit of 4.2 lakh MT while total supply will be 78.3 lakh MT in 2050 with a surplus of 12.8 lakh MT. In the long-term new vegetable technology will be available and adopted. However, with the adoption of new technology the total production could generate a surplus. The result is found to be consistent.

**Table 39 Sensitivity analysis of projections of total supply and surplus/deficits of vegetables under alternative scenarios**

| Year | Quantity in lakh MT | | | | | | |
|---|---|---|---|---|---|---|---|
| | Existing scenario | | | Scenario 1 | | Scenario 2 | |
| | Demand | Supply | Surplus | Supply | Surplus (+)/ deficit (-) | Supply | Surplus (+)/ deficit (-) |
| **2021** | 41.2 | 41.7 | 0.5 | 38.4 | -2.8 | 36.7 | -4.5 |
| **2030** | 51.5 | 53.8 | 2.3 | 49.5 | -2 | 47.3 | -4.2 |
| **2035** | 58.9 | 62.5 | 3.6 | 57.5 | -1.4 | 55 | -3.9 |
| **2040** | 63.4 | 70.3 | 6.8 | 64.7 | 1.3 | 61.9 | -1.5 |
| **2045** | 65.3 | 80.9 | 15.7 | 74.4 | 9.1 | 71.2 | 5.9 |
| **2050** | 65.5 | 89 | 15.5 | 81.9 | 16.4 | 78.3 | 12.8 |

Source: Author's estimation

### c. Sensitivity analysis of fruits supply

**Results under Alternative scenario 1 and 2:**

The results of alternative scenario 1 and 2 are presented in Table 40. Projections showed that under alternative scenario 1 total supply of fruits will be 32.7 lakh MT in 2030 and 47.5 lakh MT in 2050. The results seem to be more plausible in that in the coming decades as fruits supply in the country would face random shocks of climate change, pest & diseases and market fluctuations, etc. The alternative scenario 1 and 2 reflects fruits supply under such condition. The results of alternative scenario 2 show that fruits supply will decline slightly to 31.2 lakh MT in 2030 and will have deficit of 1 lakh MT, while total supply will be 45.4 lakh MT in 2050 with a surplus of 1.7 lakh MT. In the long-run new fruits production technology will be available and adopted. However, with the adoption of new technologies the total production could generate a surplus of 1.7 lakh MT. The result is found to be consistent.

**Table 40. Sensitivity analysis of projections of total supply and surplus(+)/deficits(-) of fruits under alternative sceneries (Quantity in lakh MT)**

| Year | Base scenario | | | Alternativescenario 1 | | Alternativescenario 2 | |
|---|---|---|---|---|---|---|---|
| | Demand | Supply of six fruits | Surplus(+)/deficit(-) | Supply | Surplus(+)/deficit(-) | Supply | Surplus(+)/deficit(-) |
| **2021** | 26.7 | 29.4 | 2.7 | 27 | 0.4 | 25.9 | -0.8 |
| **2030** | 32.2 | 35.5 | 3.3 | 32.7 | 0.4 | 31.2 | -1.0 |
| **2035** | 35.0 | 39.3 | 4.3 | 36.2 | 1.2 | 34.6 | -0.4 |
| **2040** | 37.9 | 43.2 | 5.3 | 39.7 | 1.8 | 38.0 | 0.1 |
| **2045** | 40.8 | 47.1 | 6.3 | 43.3 | 2.5 | 41.4 | 0.6 |
| **2050** | 43.7 | 51.6 | 7.9 | 47.5 | 3.8 | 45.4 | 1.7 |

Source: Author's estimation

## 5. Conclusions and Recommendations

### 5.1 Conclusions

We estimated ARIMA models for projecting demand and supply for selected 35 crops in Bangladesh during 2030 to 2050. It was found that ARIMA models gave plausible results. We compared our projections with others and found that our analysis was robust and quite plausible from realistic point of view.

Projections showed that food consumption in Bangladesh would be slowly diversifying. The share of rice in total calorie supply would decrease from 82% in 2010 to 79% in 2030 and further decline to 78.6% in 2050.

Bangladesh will have to face problems of climate change, soil degradation, increased soil salinity, scarcity of irrigation water, etc. The pessimistic scenario (PS) reflects rice production under degraded condition. In the long-run new rice technology will be available and will be adopted. However, with the adoption of new rice technology the total production could be most likely in between PS and adjusted BAU scenario. Based on estimates of adjusted BAU scenario there will have a marginal surplus of rice of 1.95 MMT in 2030 and it will gradually increase over the years till 2050. But PS predicts that there could be a deficit of 3.62 MMT in 2030 and a deficit of 1.93 MMT in 2050. According to PS rice deficit in 2021 was 0.61 MMT which is more plausible than adjusted BAU scenario due to the fact that quantity of rice imported in Bangladesh was about 0.6 MMT in 2021 and Bangladesh will import more rice due to flood in 2022.

ARIMA model on the basis of BBS data predicted that there will have a deficit of maize of 2.25 MMT in 2030 and 4.75 MMT in 2050, while estimates based on DAE data showed that there will have marginal surplus of 0.88 MMT of maize in 2030 and gradually it will rise to 3.09 MMT in 2050. There could be a deficit of wheat of 5.22 MMT in 2030 and 6.85 MMT in 2050.

Bangladesh will have a surplus of ground nut oil of 0.30 lakh MT in 2030 and 0.58 lakh MT in 2050. There will have a deficit of mustard oil of 0.30 lakh MT in 2030 and 1.68 lakh MT in 2050.

Bangladesh will have a deficit of supply of all spices in 2030 and 2050. Deficit of onion and chili will decrease over the years. There will have surplus of chili production in 2045 and 2050. Also, there will have a surplus of onion in 2050. There will have a marginal surplus of onion and chili amounting 3.29 lakh MT and 1.15 lakh MT, respectively in 2050. Total deficit of six spices in 2030 will be 28.1 lakh MT and thereafter it will gradually decrease to 13.27 lakh MT in 2050.

Bangladesh will have a marginal surplus of 2.84 lakh MT potato in 2030 and 14.3 lakh MT in 2050. The country will have a marginal surplus of 2.3 lakh MT vegetable in 2030 and 23.5 lakh MT in 2050. Total surplus of six selected fruits of Bangladesh in 2030 will be 3.3 lakh MT and it will gradually rise to 7.9 lakh MT in 2050.

## 5.2 Recommendations

On the basis of the findings of the study following recommendations can be made for transformation and development of Bangladesh agriculture by 2030 and 2050:

1. It is necessary to enhance rice productivity through generating new varieties and climate resilient technology to eliminate rice deficit during 2030s and 2040s.
2. Heat tolerant and disease resistance high yielding wheat varieties (BARI Gam 33 and BWMRI Gam 3) can be cultivated in the south and north-east parts of the country where vast areas of land remain fallow after cultivation of T. *Aman*. In the south 800 thousand ha of land remain fallow after T. *Aman*, which could be brought under wheat cultivation. Also, wheat cultivation could be expanded in the mountain valley and plain land of Chattogram Hill Tract. Extension support and government incentives will be required to promote wheat cultivation in the non-conventional fallow lands of the country.
3. Develop a strategic rice grain reserve of minimum 1.5 MMT to maximum 2.5 MMT in public warehouses of Ministry of Food to address vulnerability in rice supply due to various shocks.
4. Need to prepare a long-run plan for technology development and transformation of Bangladesh agriculture in 2030s and 2040s. This will require increased investment in research, extension and market development.
5. It is necessary to harmonize BBS and DAE data specially on maize production. Priority should be given on BBS data over DAE data for policy and planning purposes.
6. Bangladesh can promote export of surplus potato, vegetables and fruits. Government supports will be needed in the form of providing incentives to the exporters, investment in value chain development programs and food quality and safety certification.

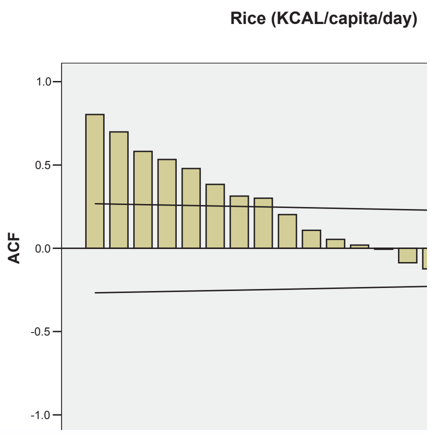
Recommendations received from four Regional Validation Workshops and FGDs for transformation of Bangladesh Agricultureare summarized as follows (For details see Annex 4 and 5):

1. Enhance production and distribution of quality seeds in the country.
2. Improving soil fertility management, promote organic and balanced fertilizers use.
3. Develop irrigation technology.
4. Promote mechanization in agriculture to address labor shortage and reduce production costs.
5. Reduce post-harvest losses.
6. Promote processing of vegetables and fruits.
7. Promote export of vegetables and fruits.
8. Capacity development of experts, farmers and market actors.

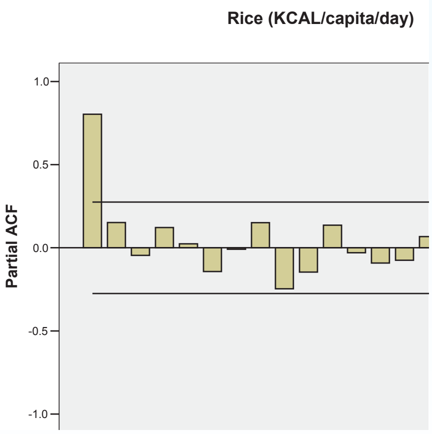
**Annex 1. Procedure of identification and estimation of ARIMA model**

The SPSS 13 Forecasting module is used for identifying the most parsimonious ARIMA model. An ARIMA analysis uses stationary time series, i.e., those series without trends. A non-stationary time series would generally have non-zero autocorrelations (ACF) up to several lags. Number of non-zero partial autocorrelation functions (PACF) indicate the order of differencing required to make a series stationary. The per capita cereal consumption series is non-stationary {Figure 1(a)}, but the first difference series is stationary {Figure 1(b)}.

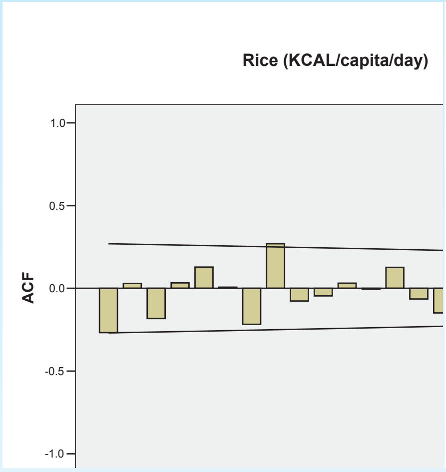
The next step in the analysis is to identify the moving average (MA) and autoregressive (AR) terms in the model. ACF and PACF of a stationary series determine the order of AR or MA or both. Exponentially decaying ACFs indicate an AR process, and non-zero PACFs indicate the order of the AR process. Exponentially decaying PACFs indicate an MA process, and non-zero ACFs show the order of the MA process. Exponentially decaying ACFs and PACFs indicate a mixed AR and MA process. Exponentially decaying PACFs of the first differenced per capita calorie supply (Figure 1(c)) indicates a MA process, and a single non zero ACF coefficient shows that the process isin the order of 1. This shows that de-trended per capita calorie supply of cereals is a MA processin the order of 1, i.e., ARIMA (0,1,1). The next step in the ARIMA model building is parameter estimation. This generally requires either least-squares or non-linear parameter estimation methods. The final step in theestimation process is diagnostic checking, i.e., to test whether the estimated model fits data adequately. This is indicated by statistically nonsignificant ACF and PACF coefficients of the residuals. Figure 2 shows that ACF and PACF of residuals of the ARIMA (0,1,1) model of per capita calorie supply of rice is not significantly different from zero. The ACF and PACF plots are general guidelines for determining the type and order of the ARIMA model.



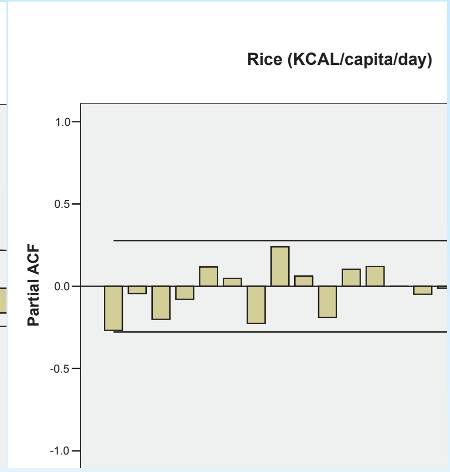

(a) ACF of per capita calorie supply from rice




(b) PACF of per capita calorie supply from rice



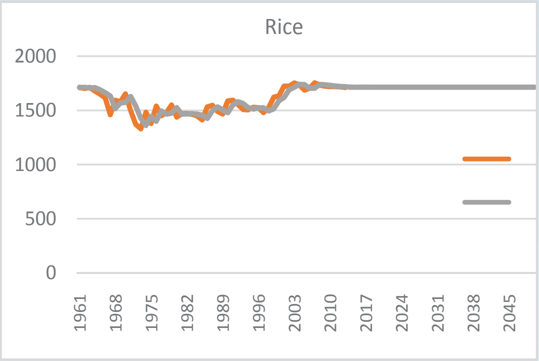

(c) ACF after first difference

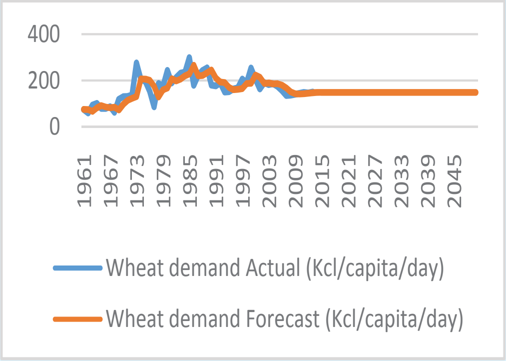


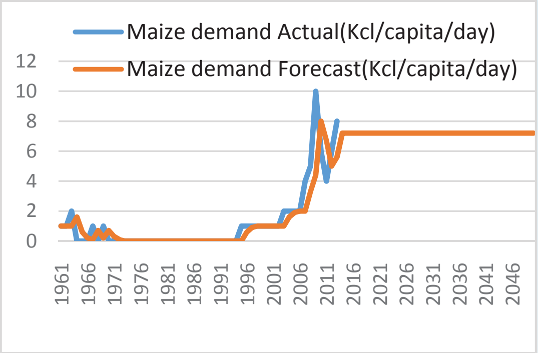

(d) PACF after first difference

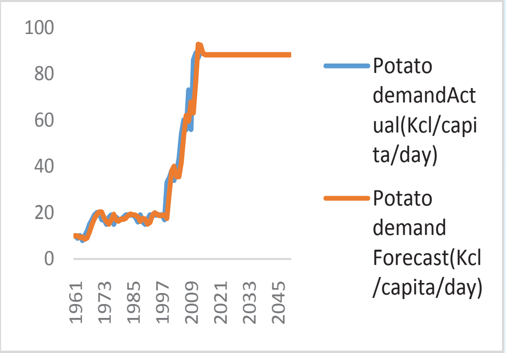
Annex Figure1. (a) ACF, and (b) PACF of per capita calorie supply from cereals; and (c) ACF, and (d) PACF of first difference

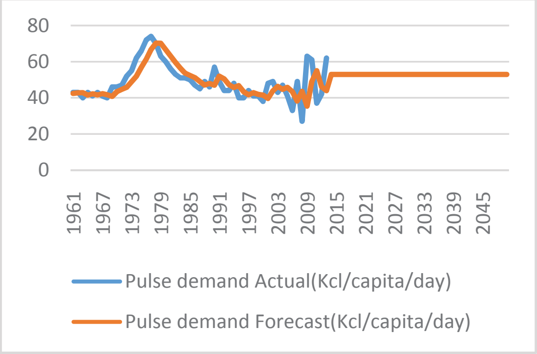
## Annex 2 Forecast of calorie intake per capita per day

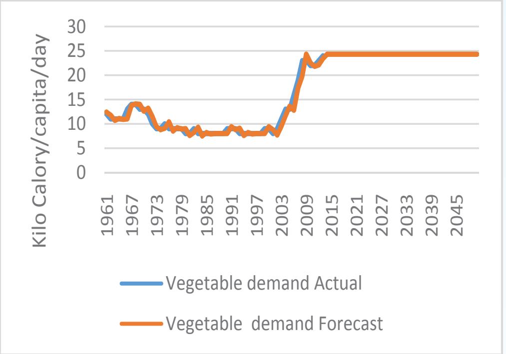


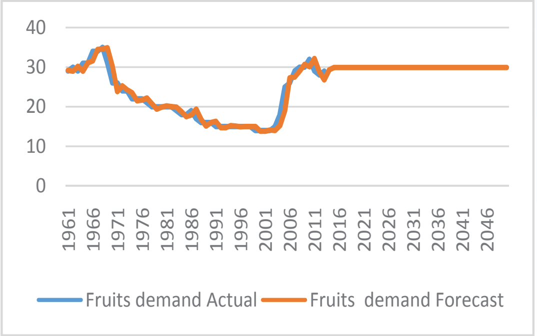



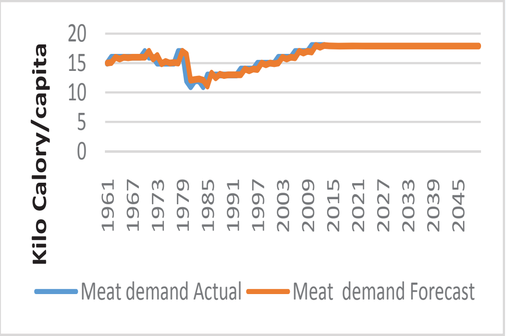



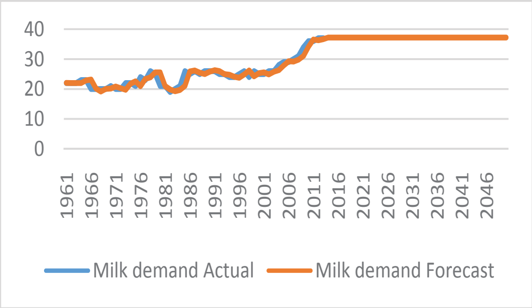

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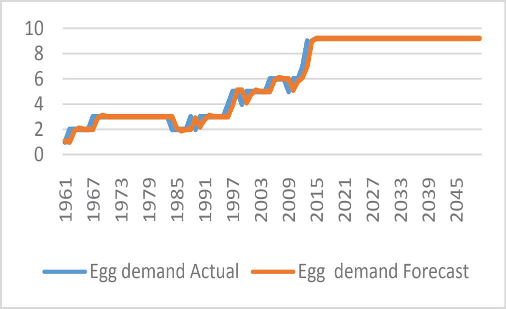
Milk demand Actual
Milk demand Forecast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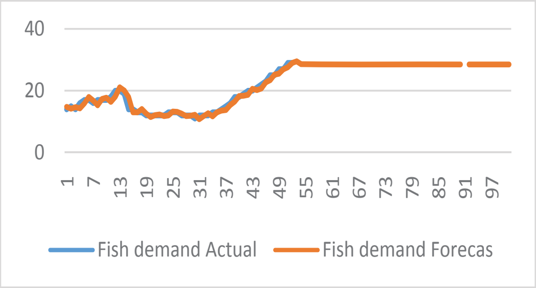
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Fish demand Forecas

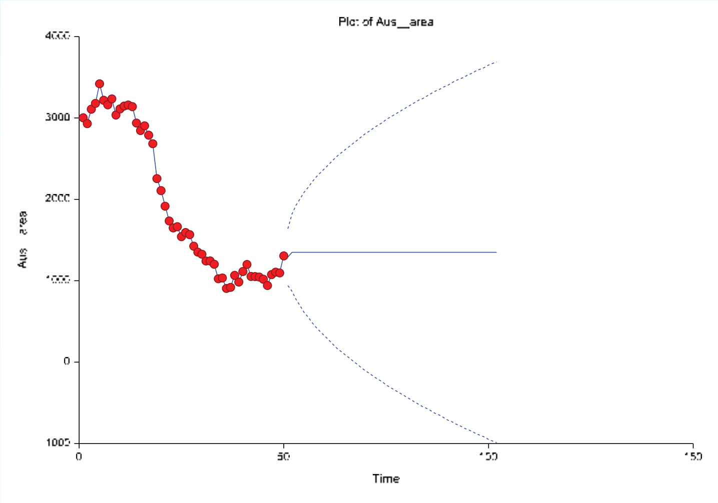
# Annex 3. Results of projections of crops area

## 3.1 Projection of *Aus* area

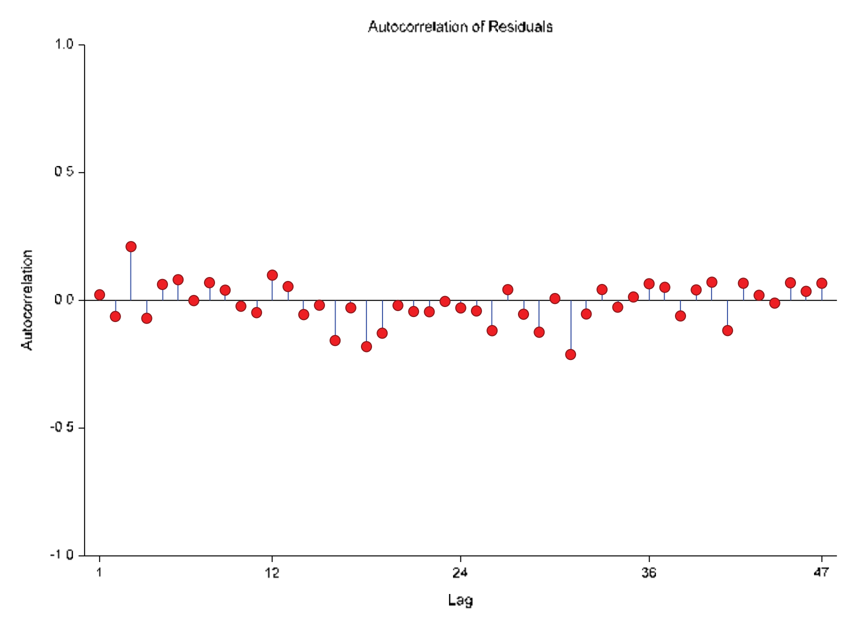
### Model Description Section

| | | |
|---|---|---|
| Series | *Aus*__area | |
| Model | Regular(0,1,2) | Seasonal(No seasonal parameters) |
| Observations | 50 | |
| Missing Values | None | |
| Iterations | 9 | |
| Pseudo R-Squared | 98.143791 | |
| Residual Sum of Squares | 736447.3 | |
| Mean Square Error | 15669.09 | |
| Root Mean Square | 125.1762 | |

### Forecast and Data Plot



## Autocorrelation Plot Section




**Portmanteau Test Section *Aus*__area**

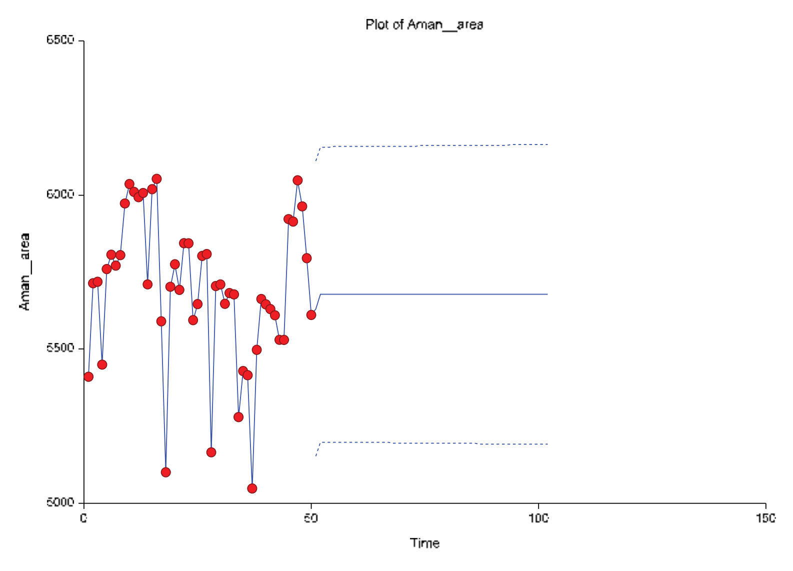
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 45 | 39.58 | 0.700132 | Adequate Model |

## 3.2 Projection of *Aman* area

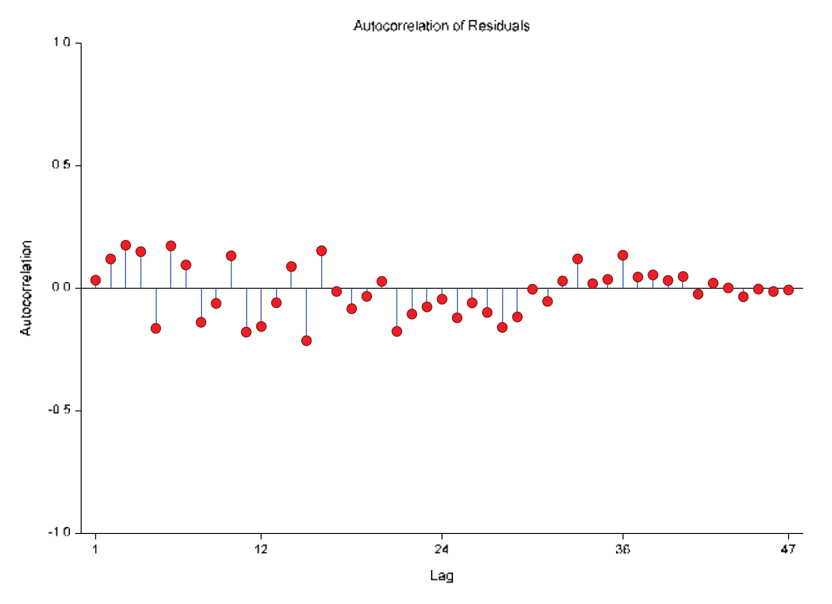
## Model Description Section

| | |
|---|---|
| Series | *Aman*__area |
| Model | Regular(0,1,2)    Seasonal(No seasonal parameters) |
| Observations | 50 |
| Missing Values | None |
| Iterations | 20 |
| Pseudo R-Squared | 20.552901 |
| Residual Sum of Squares | 2211411 |
| Mean Square Error | 47051.29 |
| Root Mean Square | 216.9131 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section *Aman*__area

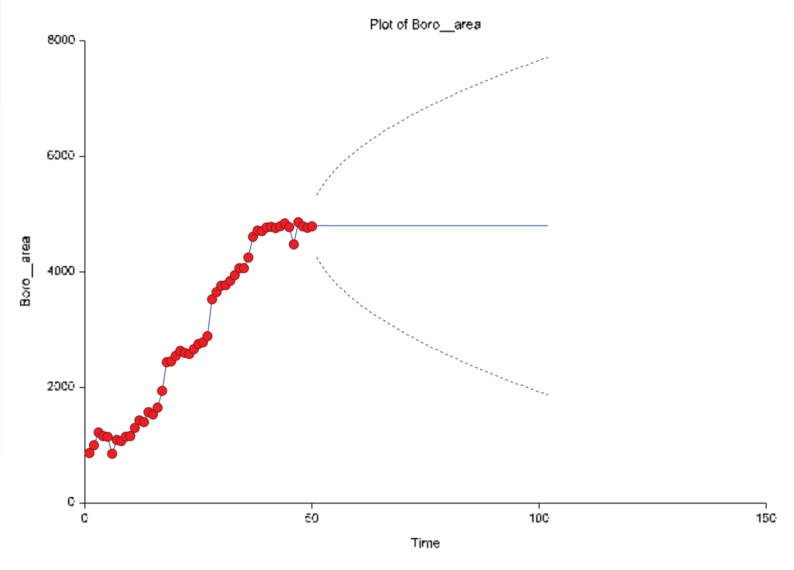
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 45 | 42.26 | 0.588622 | Adequate Model |

### 3.3 Projections of *Boro* area

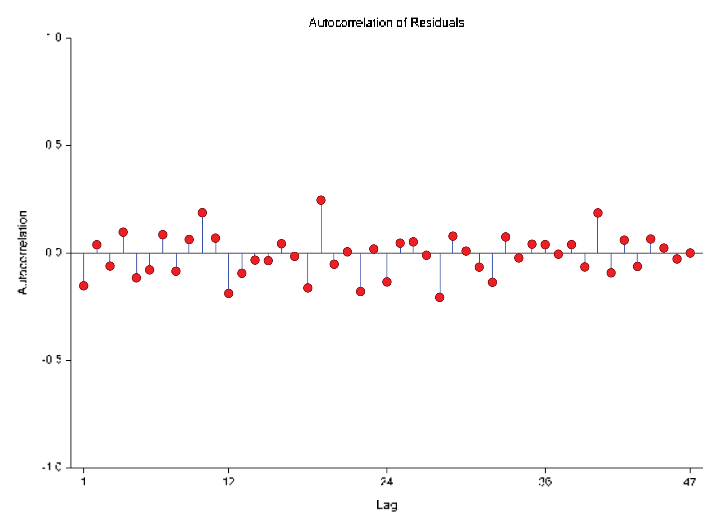
## Model Description Section

| | | |
|---|---|---|
| Series | *Boro*__area | |
| Model | Regular(0,1,1) | Seasonal(No seasonal parameters) |
| Observations | 50 | |
| Missing Values | None | |
| Iterations | 18 | |
| Pseudo R-Squared | 98.530462 | |
| Residual Sum of Squares | 1526410 | |
| Mean Square Error | 31800.21 | |
| Root Mean Square | 178.3261 | |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section *Boro*__area (Continued)

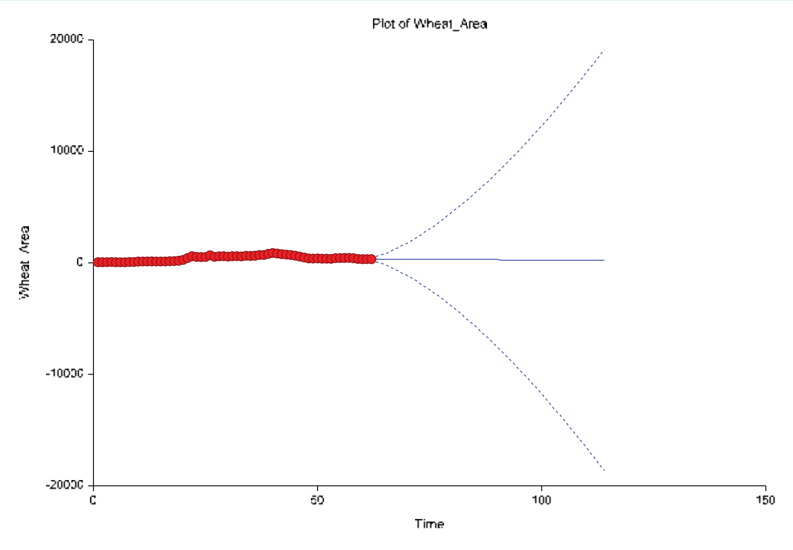
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 51.76 | 0.259086 | Adequate Model |

### 3.4 Projection of wheat area model

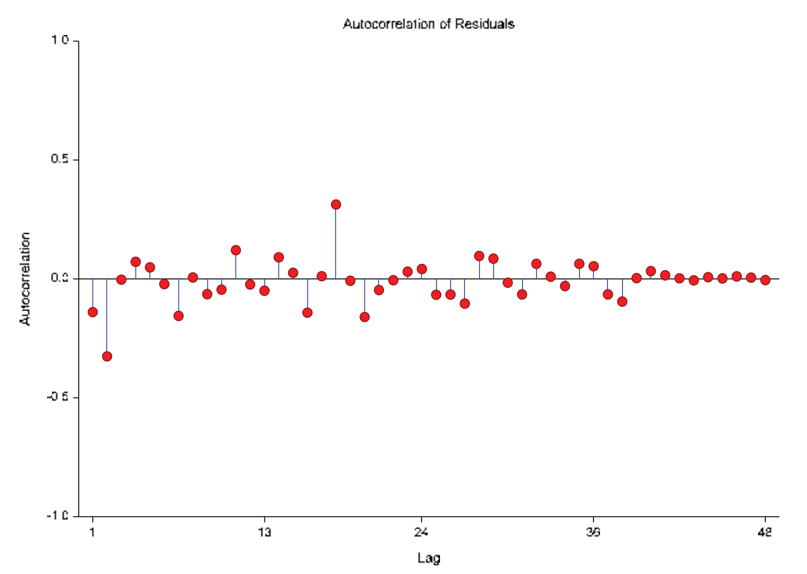
## Model Description Section

| | | |
|---|---|---|
| Series | Wheat_Area | |
| Model | Regular (1,2,0) | Seasonal (No seasonal parameters) |
| | | |
| Observations | 62 | |
| Missing Values | None | |
| Iterations | 3 | |
| Pseudo R-Squared | 93.728407 | |
| Residual Sum of Squares | 221360.1 | |
| Mean Square Error | 3751.866 | |
| Root Mean Square | 61.25248 | |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section Wheat_Area

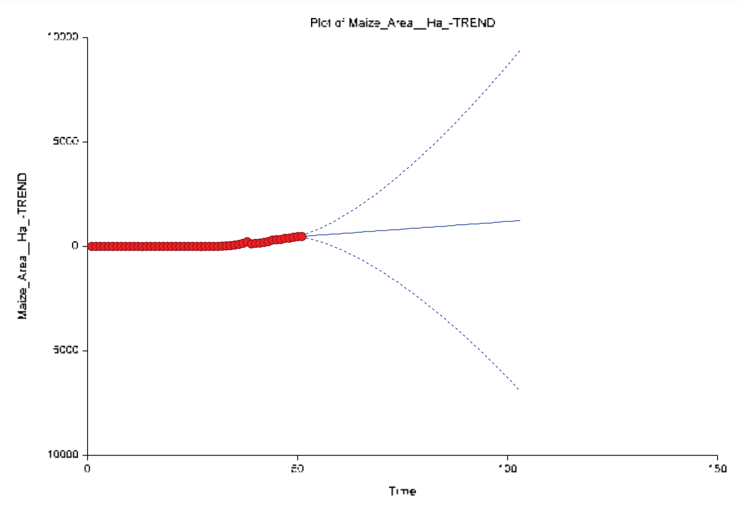
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 35.55 | 0.889261 | Adequate Model |

### 3.5 Projection of maize area

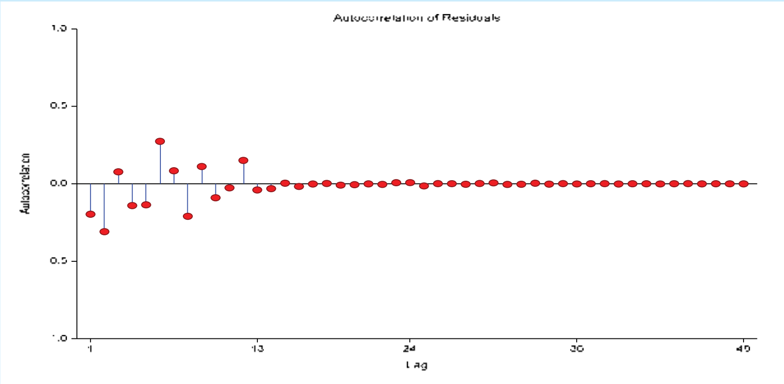
## Model Description Section

| | |
|---|---|
| Series | Maize_Area__Ha_-TREND |
| Model | Regular (1,2,0)    Seasonal (No seasonal parameters) |
| Trend Equation | (-114.3232) +(7.980494) x(date) |
| Observations | 51 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 96.481516 |
| Residual Sum of Squares | 38182.82 |
| Mean Square Error | 795.4755 |
| Root Mean Square | 28.20417 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Maize_Area__Ha_-TREND

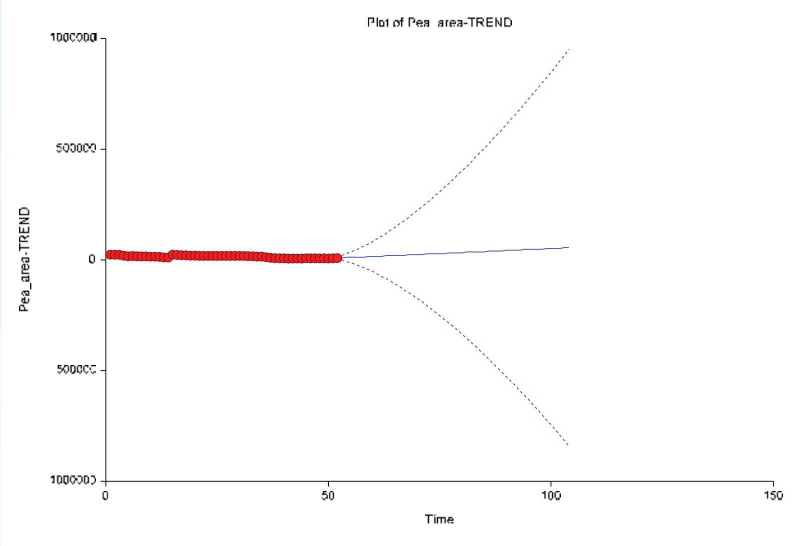
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 20.85 | 0.999661 | Adequate Model |

### 3.6 Projection of area of pea

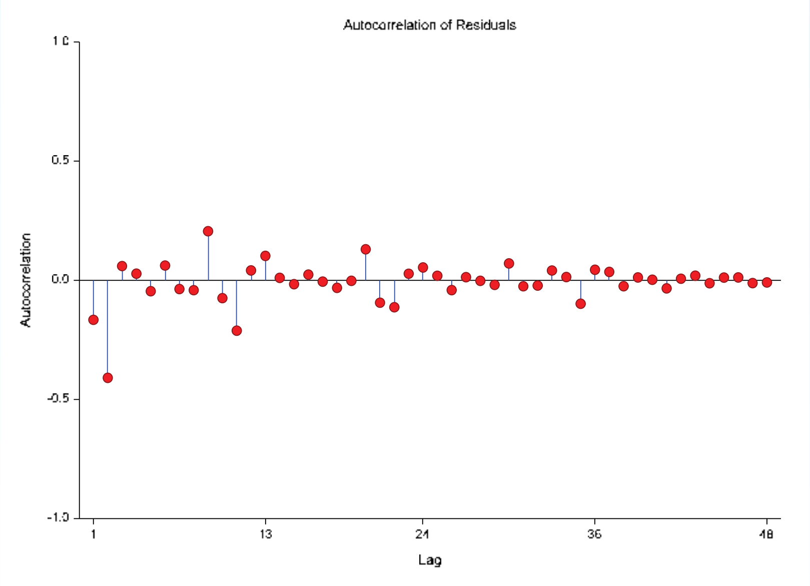
## Model Description Section

| | |
|---|---|
| Series | Pea_area-TREND |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Trend Equation | (22299.65) +(-288.3484) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 76.688554 |
| Residual Sum of Squares | 3.813402E+08 |
| Mean Square Error | 7782452 |
| Root Mean Square | 2789.705 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section Pea_area-TREND

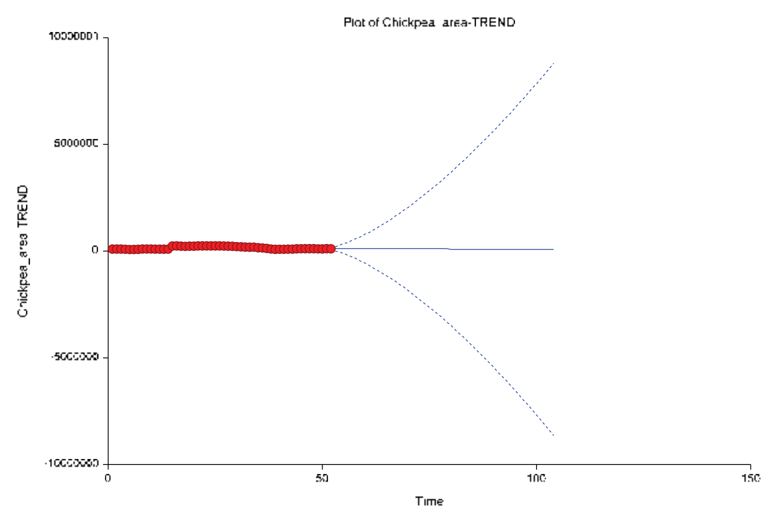
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 27.20 | 0.990820 | Adequate Model |

### 3.7 Projection of area of chickpea

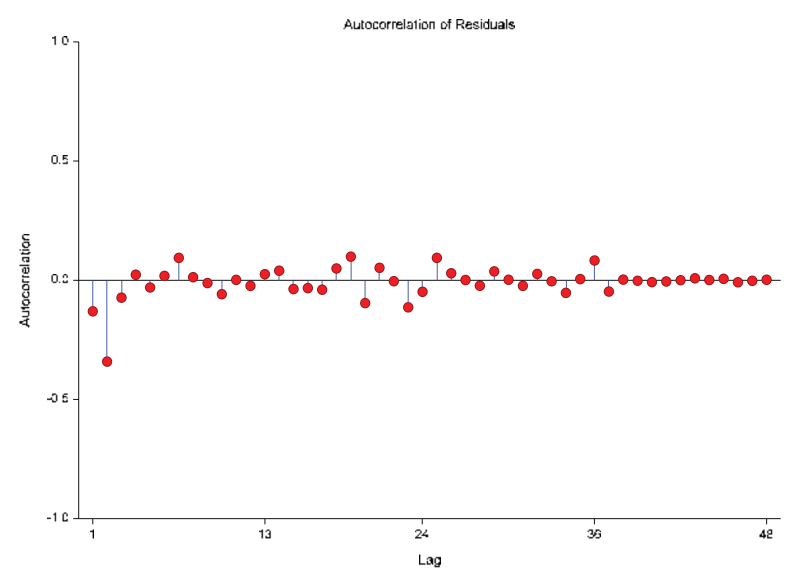
## Model Description Section

| | |
|---|---|
| Series | Chickpea_area-TREND |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Trend Equation | (154040.6) +(-172.8858) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 82.068739 |
| Residual Sum of Squares | 3.811408E+10 |
| Mean Square Error | 7.778383E+08 |
| Root Mean Square | 27889.75 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Chickpea_area-TREND

| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 16.35 | 0.999991 | Adequate Model |

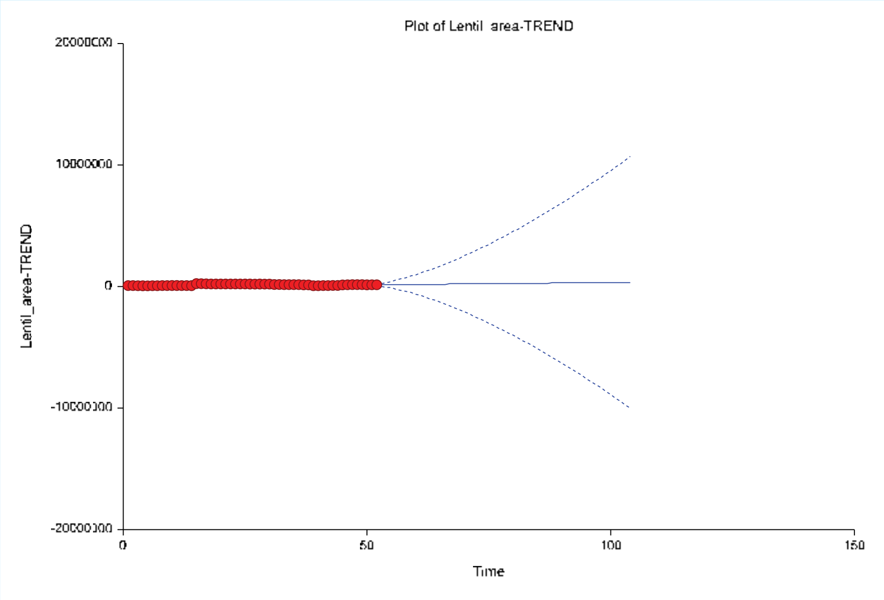
### 3.8 Projection of area of lentil

## Model Description Section

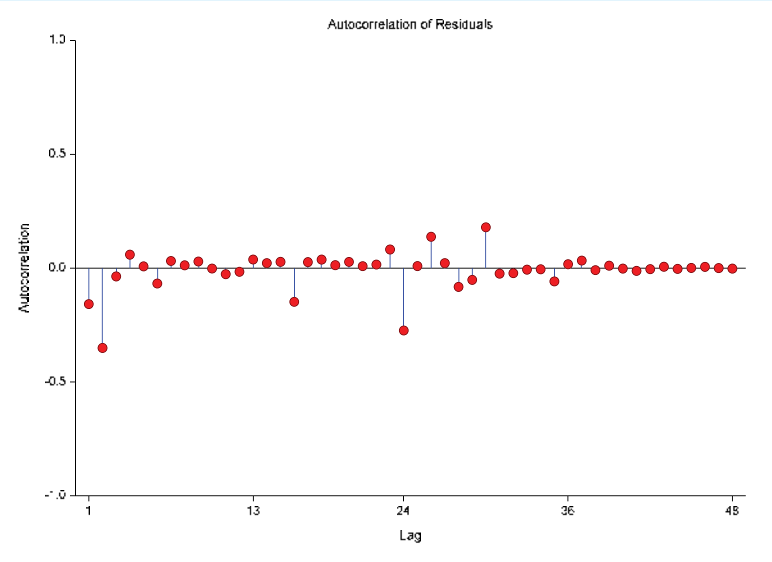
| | |
|---|---|
| Series | Lentil_area-TREND |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Trend Equation | (120614.8) +(764.4985) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 66.722861 |
| Residual Sum of Squares | 5.809999E+10 |
| Mean Square Error | 1.185714E+09 |

Root Mean Square 34434.2

## Forecast and Data Plot




## Autocorrelation Plot Section




## Portmanteau Test Section Lentil_area-TREND

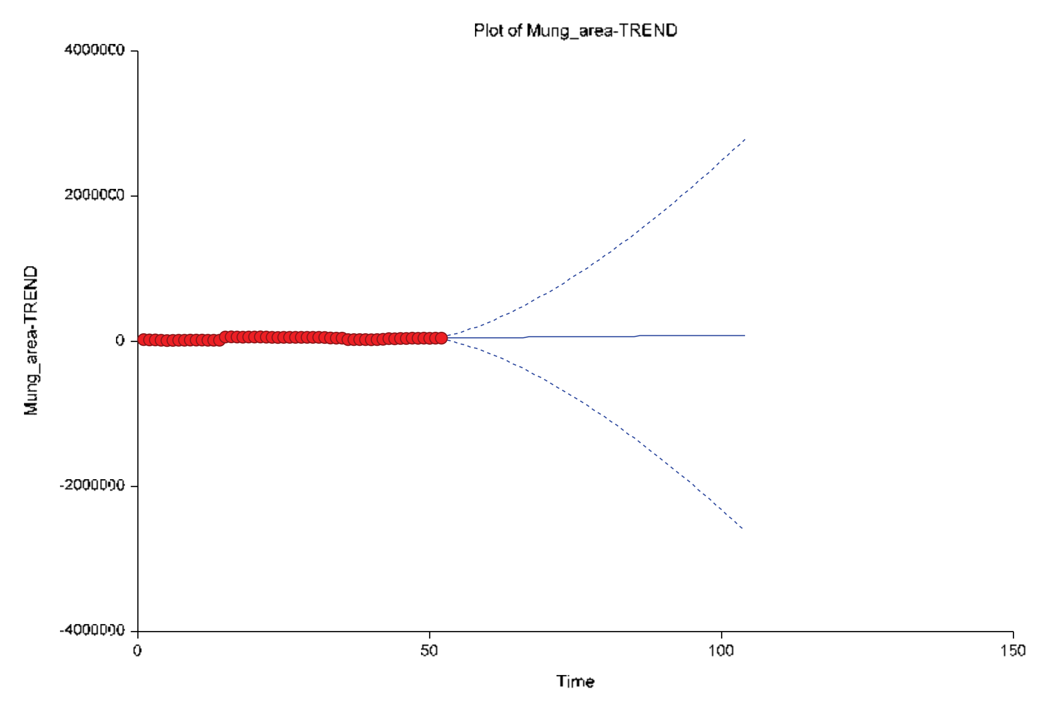
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 27.82 | 0.984342 | Adequate Model |
| 48 | 47 | 27.82 | 0.988268 | Adequate Model |

### 3.9 Projection of area of Mungbean

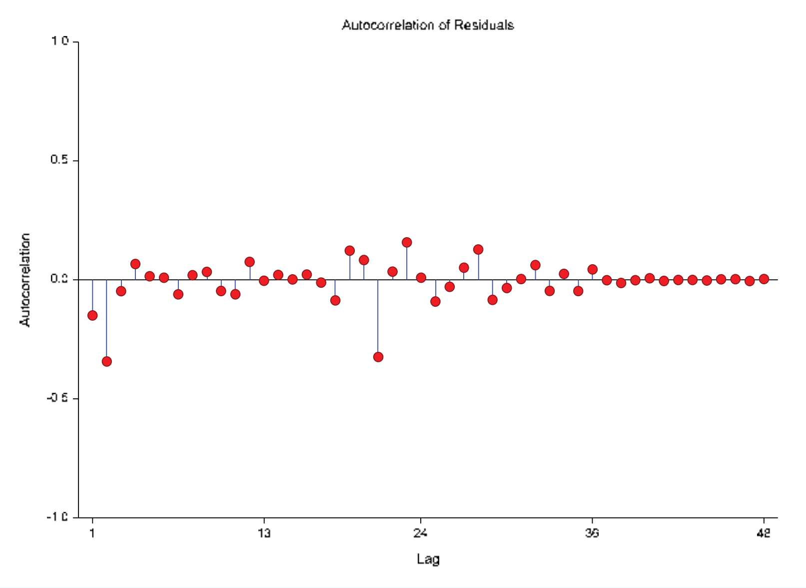
## Model Description Section

| | |
|---|---|
| Series | Mung_area-TREND |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Trend Equation | (27985.57) +(358.4112) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 73.121629 |
| Residual Sum of Squares | 3.993073E+09 |
| Mean Square Error | 8.14913E+07 |
| Root Mean Square | 9027.253 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Mung_area-TREND

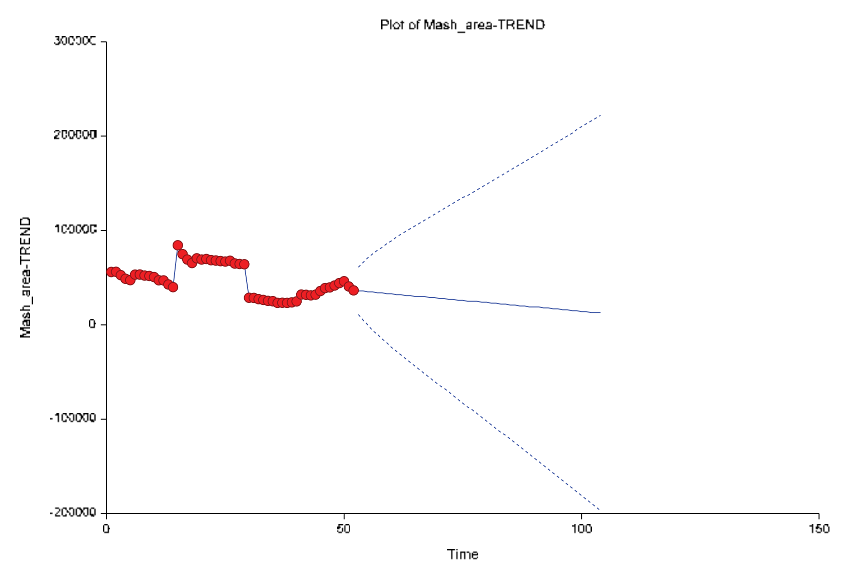
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 29.92 | 0.975276 | Adequate Model |

### 3.10 Projection of area of Blackgram

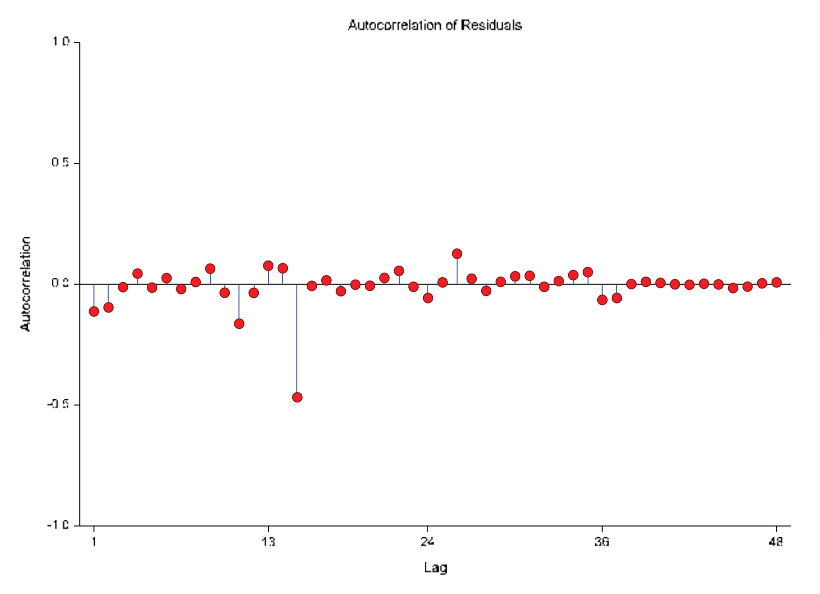
## Model Description Section

| | |
|---|---|
| Series | Mash_area-TREND |
| Model | Regular (0,2,1)  Seasonal (No seasonal parameters) |
| Trend Equation | (63015.27) +(-588.3709) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 20 |
| Pseudo R-Squared | 74.273055 |
| Residual Sum of Squares | 3.752203E+09 |
| Mean Square Error | 7.657557E+07 |
| Root Mean Square | 8750.747 |

## Forecast and Data Plot




## Autocorrelation Plot Section



### Portmanteau Test Section Mash_area-TREND

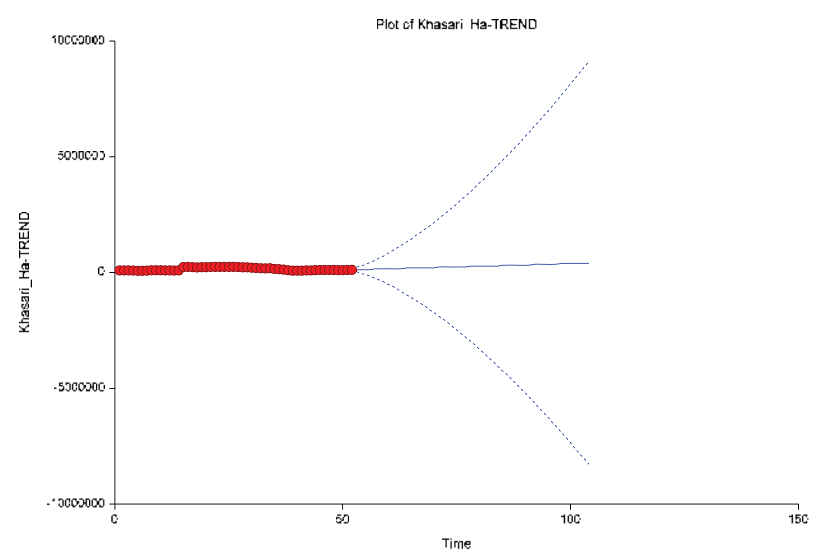
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 26.26 | 0.993819 | Adequate Model |

## 3.11 Projection of area of Gras pea

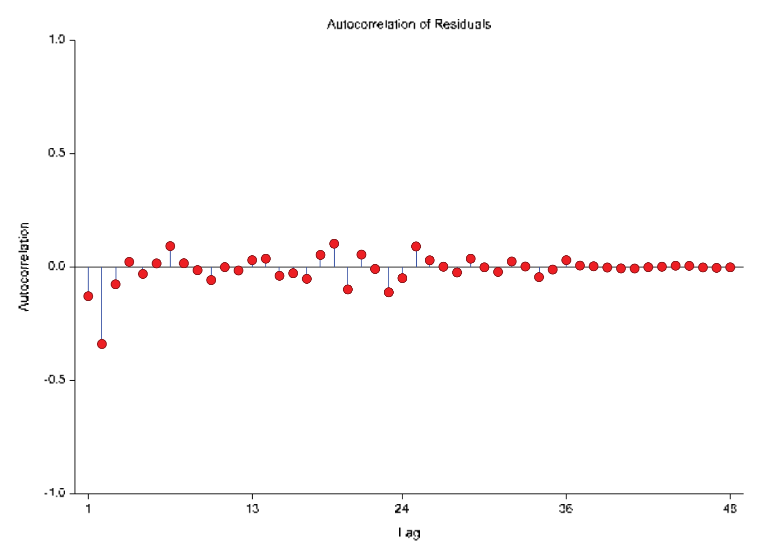
### Model Description Section

| | |
|---|---|
| Series | Khasari_Ha-TREND |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Trend Equation | (154106.6) +(-173.2471) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 82.202080 |
| Residual Sum of Squares | 3.786882E+10 |
| Mean Square Error | 7.728331E+08 |
| Root Mean Square | 27799.88 |

### Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Khasari_Ha-TREND

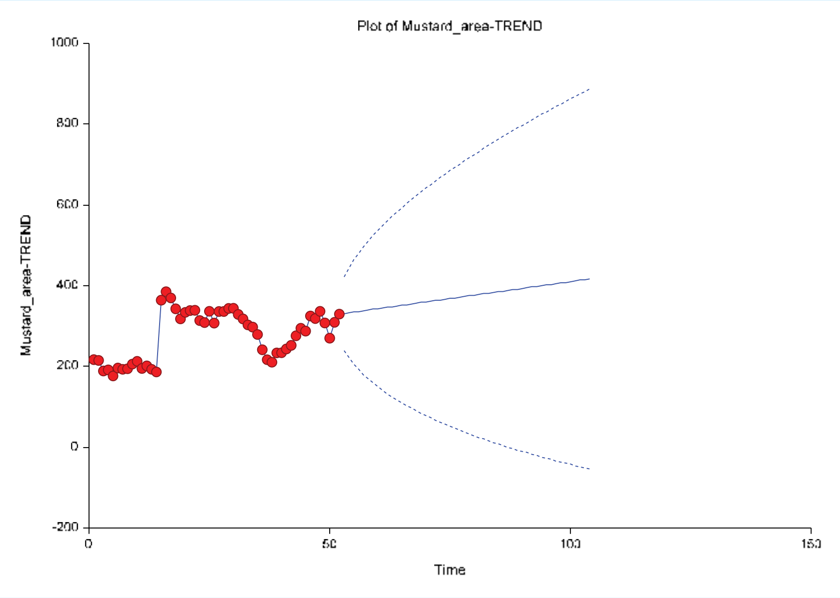
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 14.76 | 0.999998 | Adequate Model |

### 3.12 Projection of area of Mustard

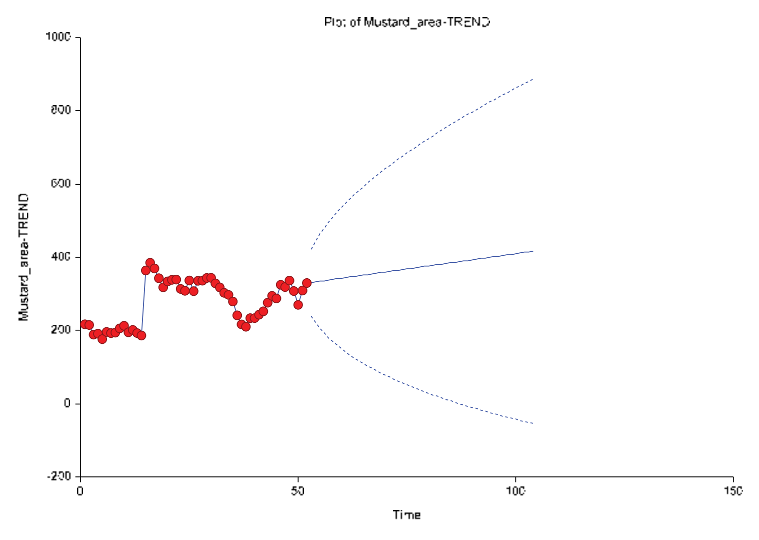
## Model Description Section

| | |
|---|---|
| Series | Mustard_area-TREND |
| Model | Regular (1,1,1) Seasonal (No seasonal parameters) |
| Trend Equation | (232.5177) +(1.672503) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 13 |
| Pseudo R-Squared | 74.723628 |
| Residual Sum of Squares | 48141.31 |
| Mean Square Error | 982.4756 |
| Root Mean Square | 31.34447 |

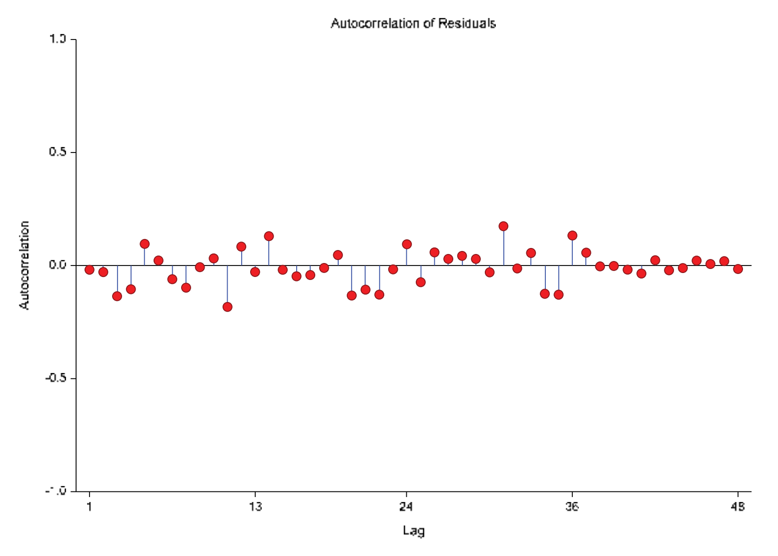
## Forecast and Data Plot




## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Mustard_area-TREND

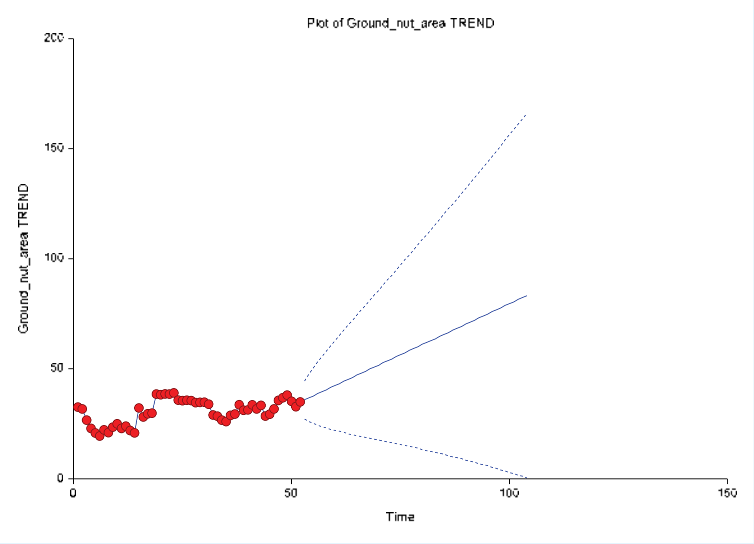
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 46 | 29.09 | 0.975539 | Adequate Model |

### 3.12 Projection of area of Ground nut

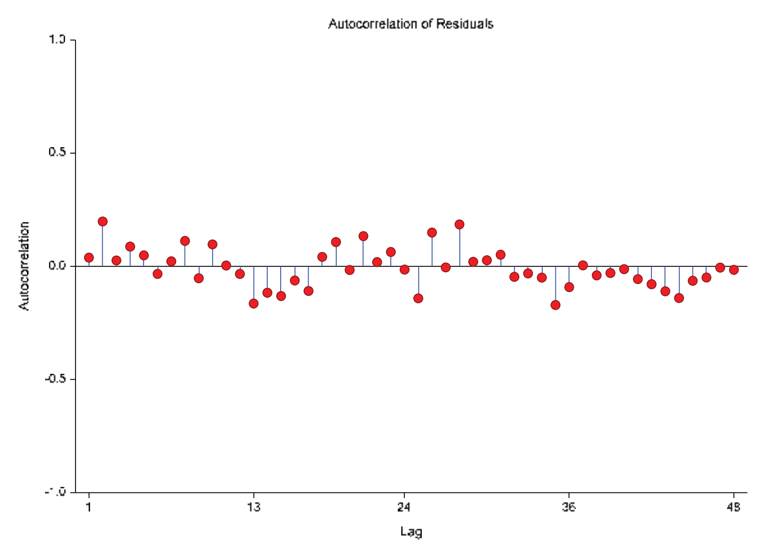
## Model Description Section

| | |
|---|---|
| Series | Ground_nut_area-TREND |
| Model | Regular (0,2,1) Seasonal (No seasonal parameters) |
| Trend Equation | (25.80799) +(0.1837211) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 70.234202 |
| Residual Sum of Squares | 463.0697 |
| Mean Square Error | 9.450402 |
| Root Mean Square | 3.074151 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section Ground_nut_area-TREND

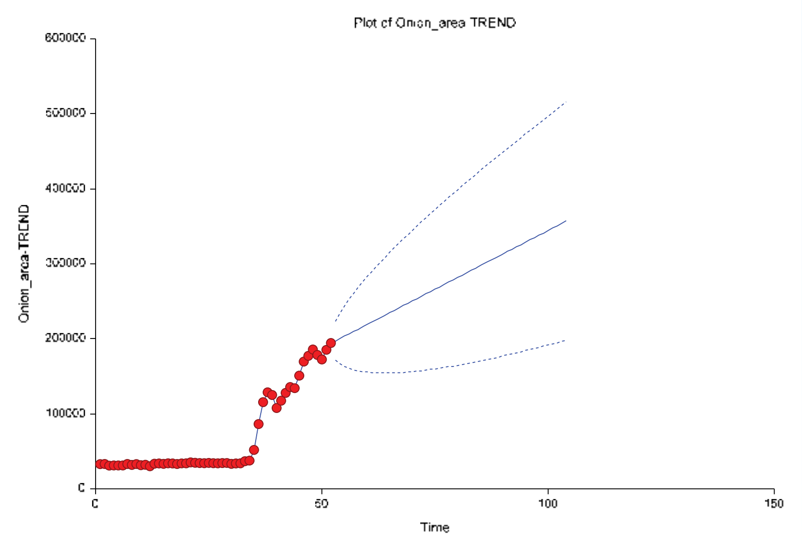
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 46.40 | 0.497292 | Adequate Model |

### 3.13 Projection of area of onion

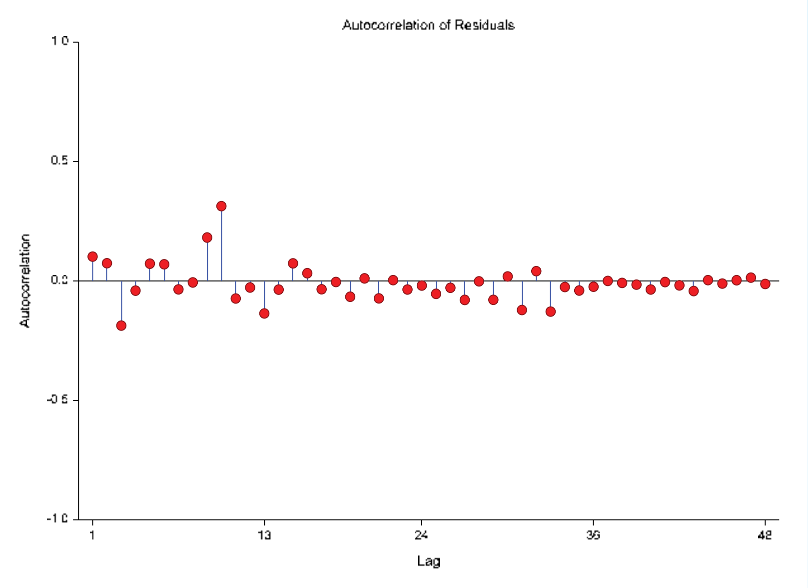
## Model Description Section

| | |
|---|---|
| Series | Onion_area-TREND |
| Model | Regular (0,1,1) Seasonal (No seasonal parameters) |
| Trend Equation | (-12194.21) +(3133.128) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 11 |
| Pseudo R-Squared | 98.496626 |
| Residual Sum of Squares | 2.443224E+09 |
| Mean Square Error | 4.886447E+07 |
| Root Mean Square | 6990.313 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Onion_area-TREND

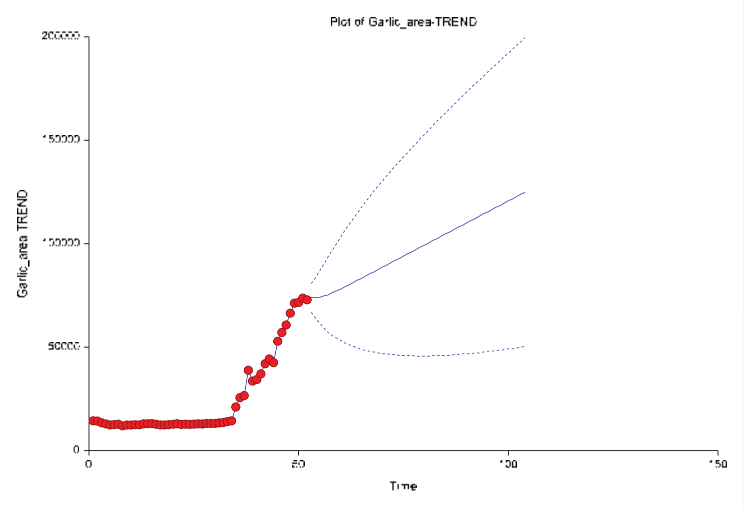
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 24.20 | 0.997648 | Adequate Model |

### 3.14 Projection of area of garlic

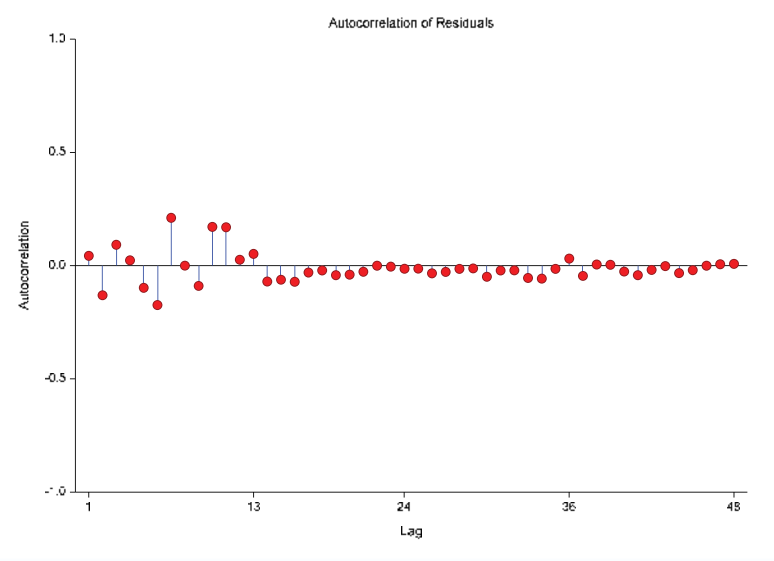
## Model Description Section

| | |
|---|---|
| Series | Garlic_area-TREND |
| Model | Regular (1,1,2) Seasonal (No seasonal parameters) |
| Trend Equation | (-3010.817) +(1066.256) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 10 |
| Pseudo R-Squared | 98.277925 |
| Residual Sum of Squares | 3.47948E+08 |
| Mean Square Error | 7248917 |
| Root Mean Square | 2692.381 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section Garlic_area-TREND

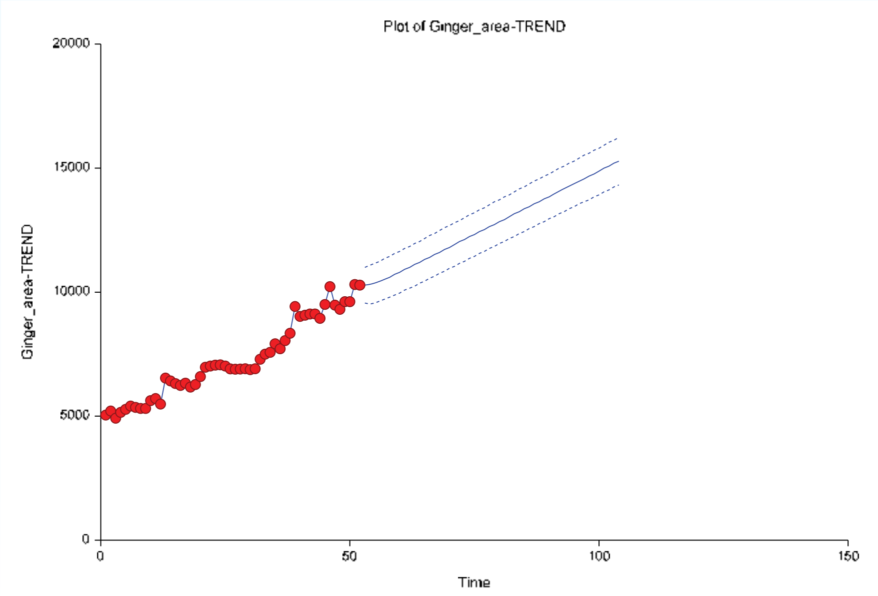
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 45 | 16.60 | 0.999966 | Adequate Model |

### 3.15 Projection of area of ginger

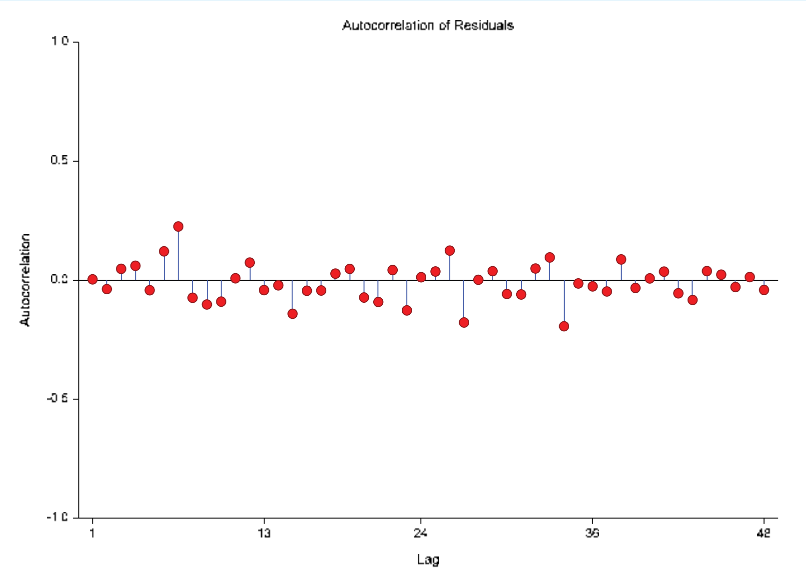
## Model Description Section

| | |
|---|---|
| Series | Ginger_area-TREND |
| Model | Regular (1,1,1) Seasonal (No seasonal parameters) |
| Trend Equation | (4577.217) +(102.0332) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 20 |
| Pseudo R-Squared | 96.551006 |
| Residual Sum of Squares | 4461814 |
| Mean Square Error | 91057.43 |
| Root Mean Square | 301.7572 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Ginger_area-TREND (Continued)

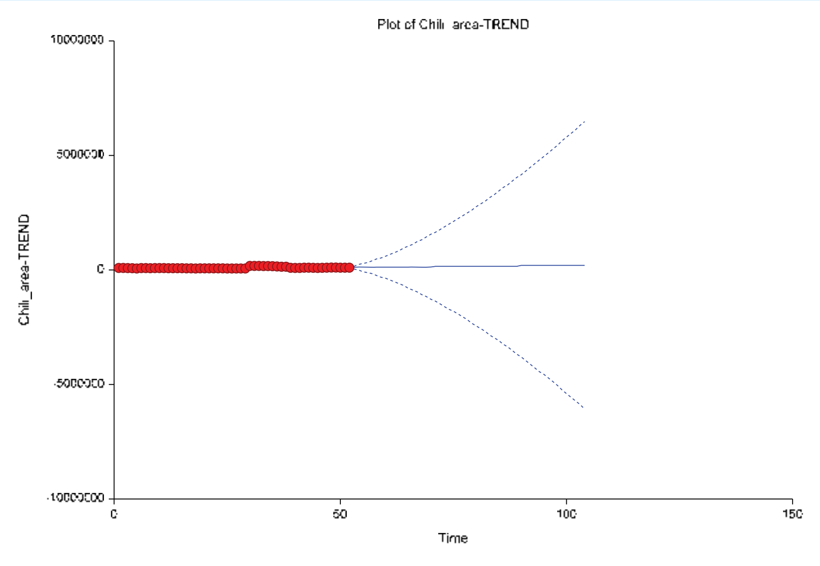
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 46 | 33.83 | 0.908403 | Adequate Model |

### 3.16 Projection of area of chili

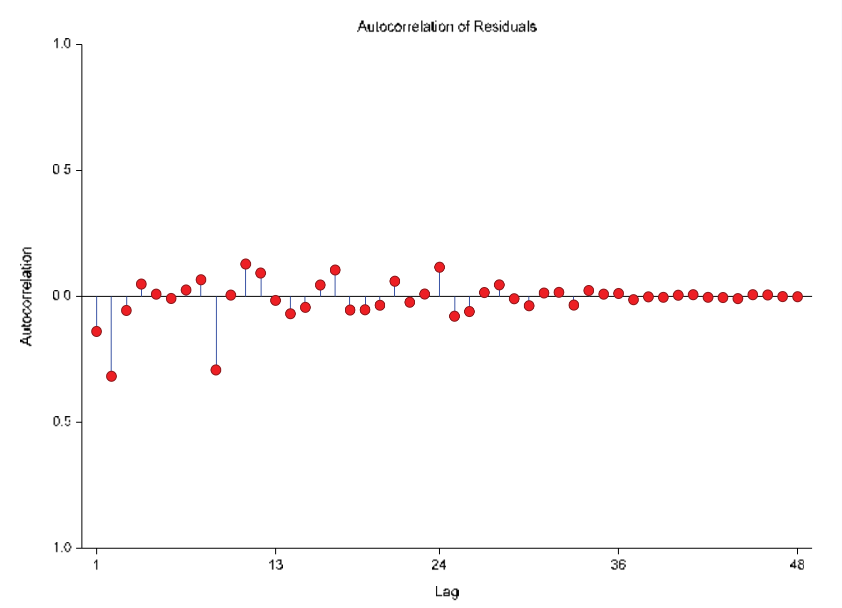
## Model Description Section

| | |
|---|---|
| Series | Chili_area-TREND |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Trend Equation | (71458.84) +(890.006) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 62.229292 |
| Residual Sum of Squares | 2.189501E+10 |
| Mean Square Error | 4.468369E+08 |
| Root Mean Square | 21138.52 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section Chili_area-TREND

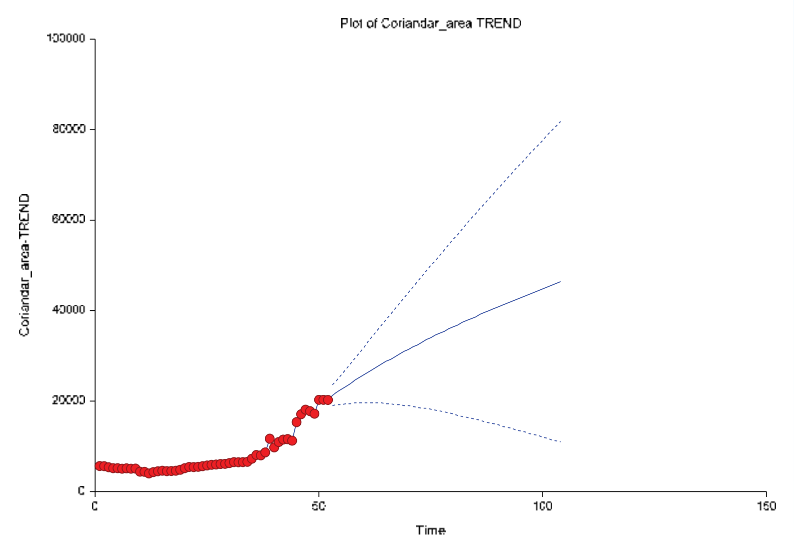
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 20.54 | 0.999724 | Adequate Model |

### 3.17 Projection of area of coriander

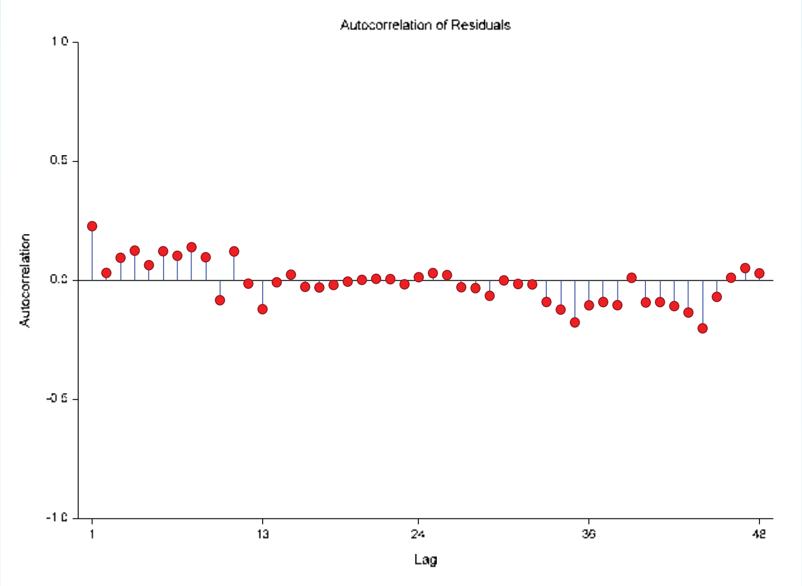
## Model Description Section

| | |
|---|---|
| Series | Coriandar_area-TREND |
| Model | Regular (1,1,2) Seasonal (No seasonal parameters) |
| Trend Equation | (1190.937) +(264.1388) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 20 |
| Pseudo R-Squared | 96.604498 |
| Residual Sum of Squares | 4.042571E+07 |
| Mean Square Error | 842202.4 |
| Root Mean Square | 917.7158 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Coriander_area-TREND

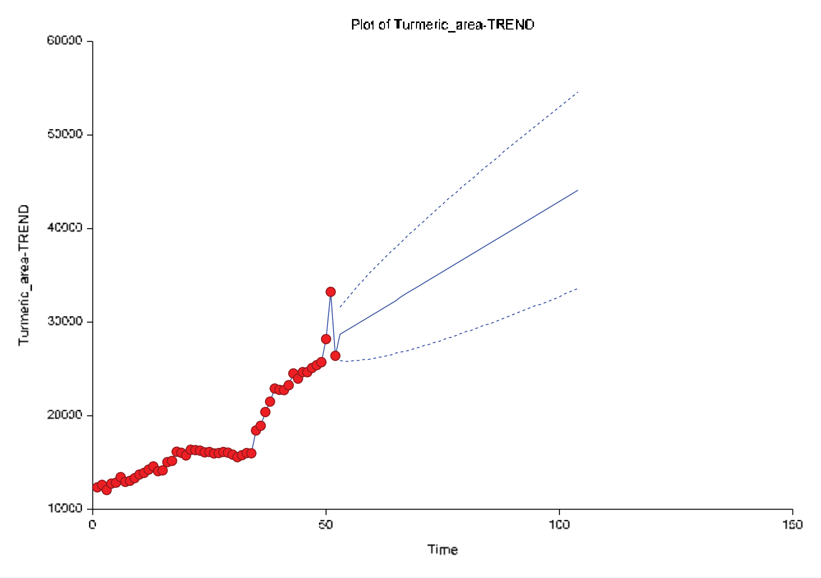
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 45 | 57.36 | 0.102232 | Adequate Model |

### 3.18 Projection of area of turmeric

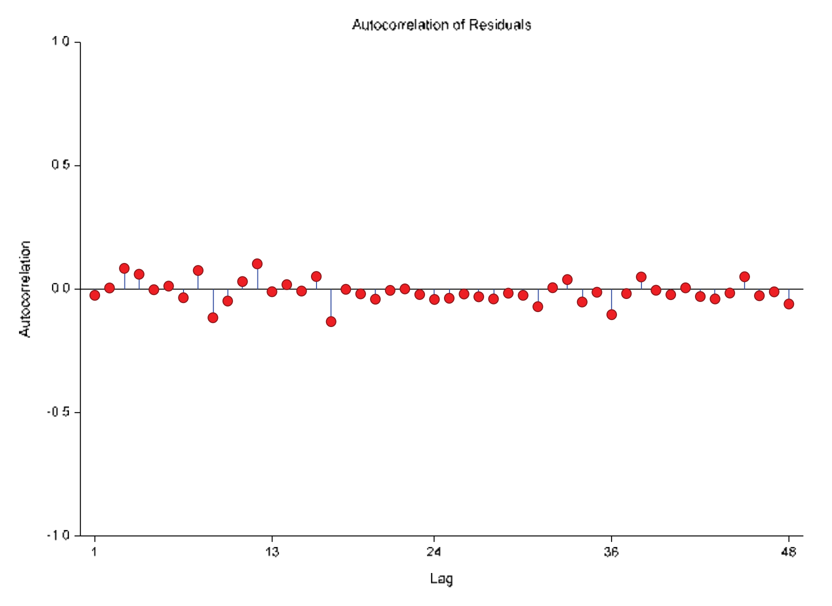
## Model Description Section

| | |
|---|---|
| Series | Turmeric_area-TREND |
| Model | Regular (0,1,1) Seasonal (No seasonal parameters) |
| Trend Equation | (10005.02) +(301.4363) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 16 |
| Pseudo R-Squared | 93.617334 |
| Residual Sum of Squares | 8.124601E+07 |
| Mean Square Error | 1624920 |
| Root Mean Square | 1274.724 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section Turmeric_area-TREND

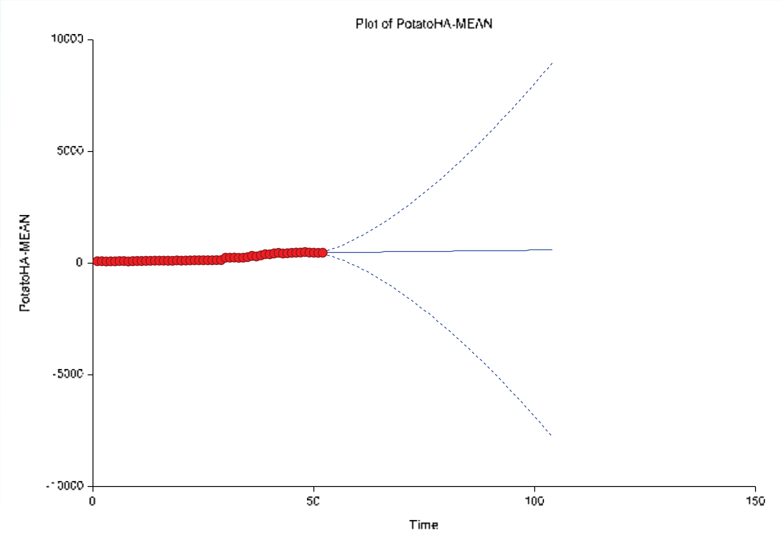
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 11.72 | 1.000000 | Adequate Model |
| 48 | 47 | 14.27 | 0.999999 | Adequate Model |

### 3.18 Projection of area of potato

## Model Description Section

| | |
|---|---|
| Series | PotatoHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 229.4084 |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 96.633254 |
| Residual Sum of Squares | 40005.97 |
| Mean Square Error | 816.4483 |
| Root Mean Square | 28.57356 |

## Forecast and Data Plot



## Portmanteau Test Section Turmeric_area-TREND

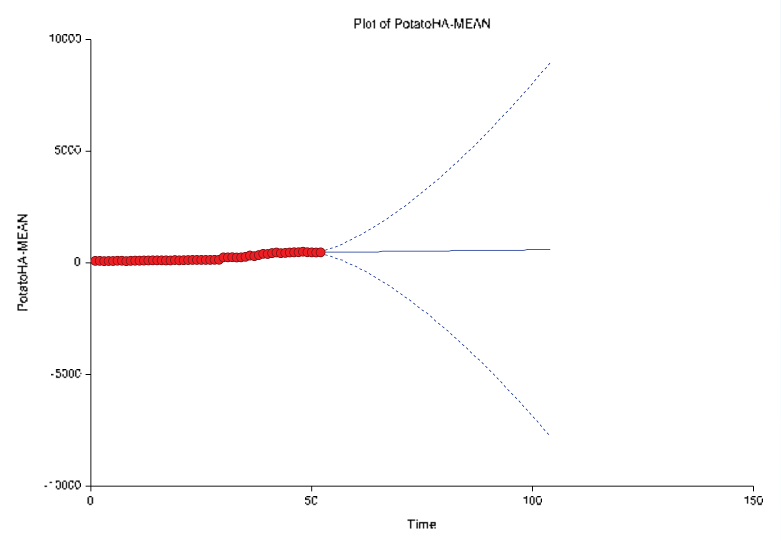
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 11.72 | 1.000000 | Adequate Model |
| 48 | 47 | 14.27 | 0.999999 | Adequate Model |

### 3.18 Projection of area of potato

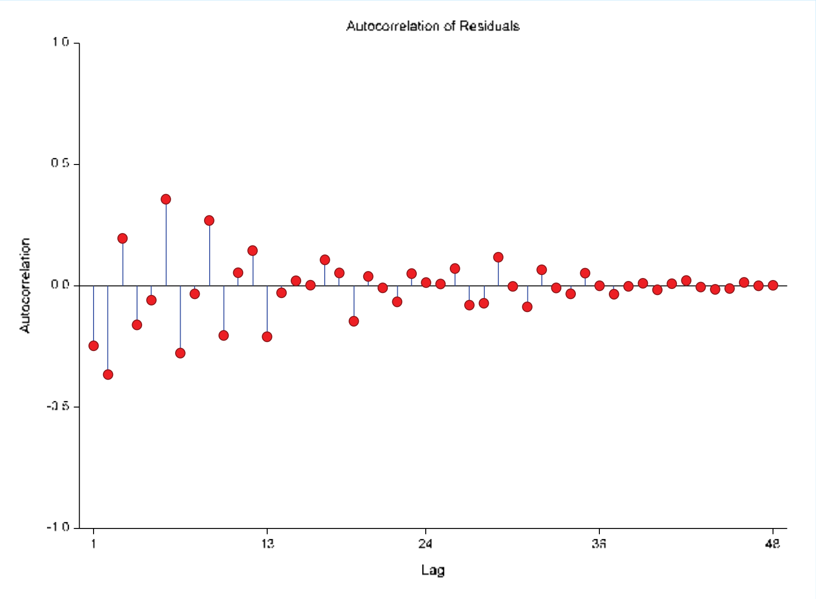
## Model Description Section

| | | |
|---|---|---|
| Series | PotatoHA-MEAN | |
| Model | Regular (1,2,0) | Seasonal (No seasonal parameters) |
| Mean | 229.4084 | |
| Observations | 52 | |
| Missing Values | None | |
| Iterations | 3 | |
| Pseudo R-Squared | 96.633254 | |
| Residual Sum of Squares | 40005.97 | |
| Mean Square Error | 816.4483 | |
| Root Mean Square | 28.57356 | |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section PotatoHA-MEAN

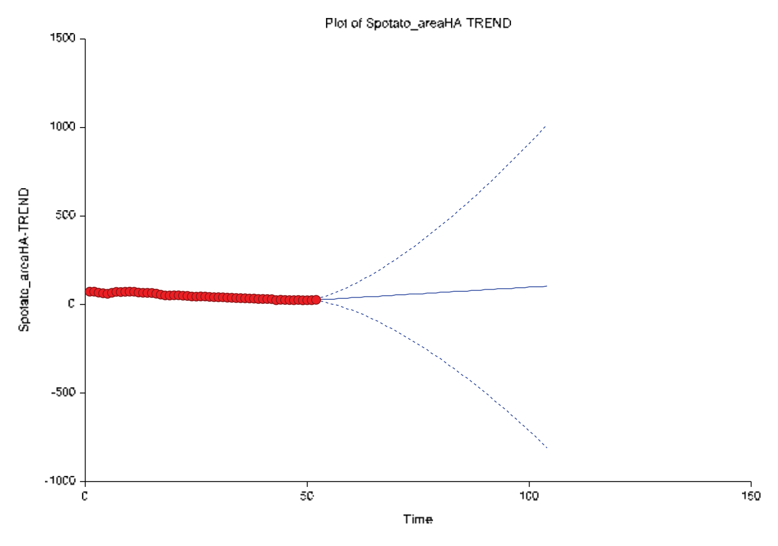
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 50.20 | 0.347627 | Adequate Model |

### 3.19. Projection of area of sweet potato

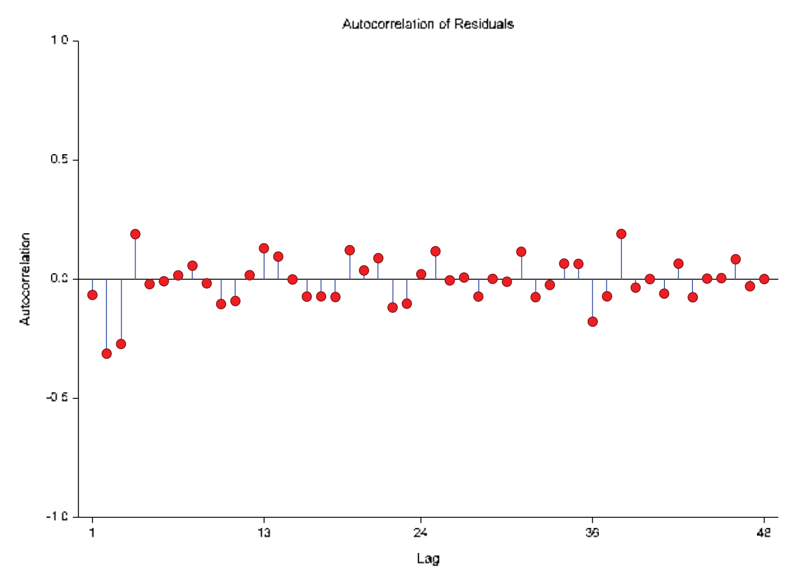
## Model Description Section

| | |
|---|---|
| Series | Spotato_areaHA-TREND |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Trend Equation | (75.22776) +(-1.07513) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 5 |
| Pseudo R-Squared | 97.521403 |
| Residual Sum of Squares | 354.1067 |
| Mean Square Error | 7.226667 |
| Root Mean Square | 2.688246 |

## Forecast and Data Plot




## Autocorrelation Plot Section



### Portmanteau Test Section potato_areaHA-TREND

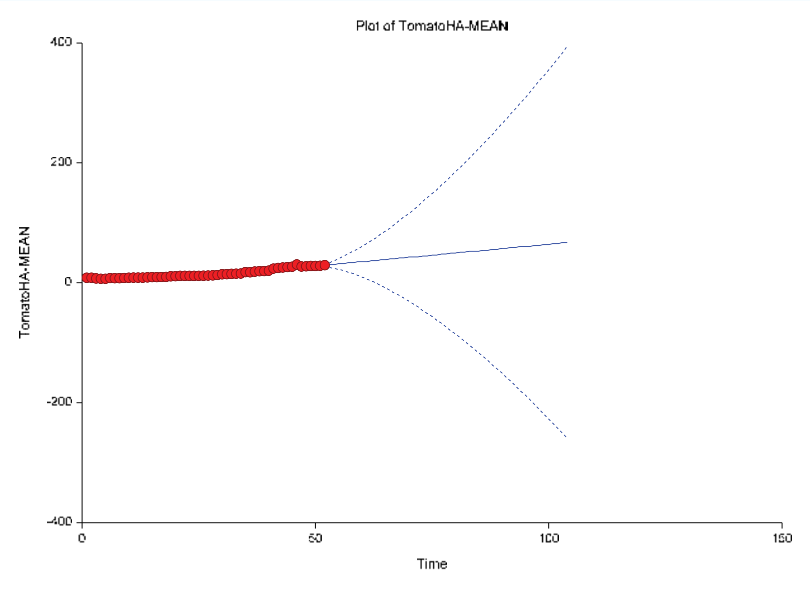
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 49.19 | 0.385328 | Adequate Model |

## 3.20. Projection of area of tomato

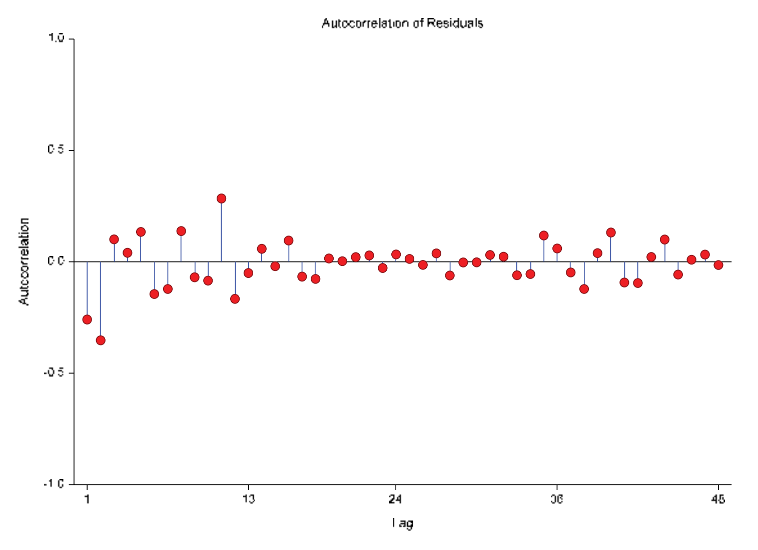
### Model Description Section

| | |
|---|---|
| Series | TomatoHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 15.37419 |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 97.624112 |
| Residual Sum of Squares | 67.49654 |
| Mean Square Error | 1.377481 |
| Root Mean Square | 1.173661 |

### Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section TomatoHA-MEAN

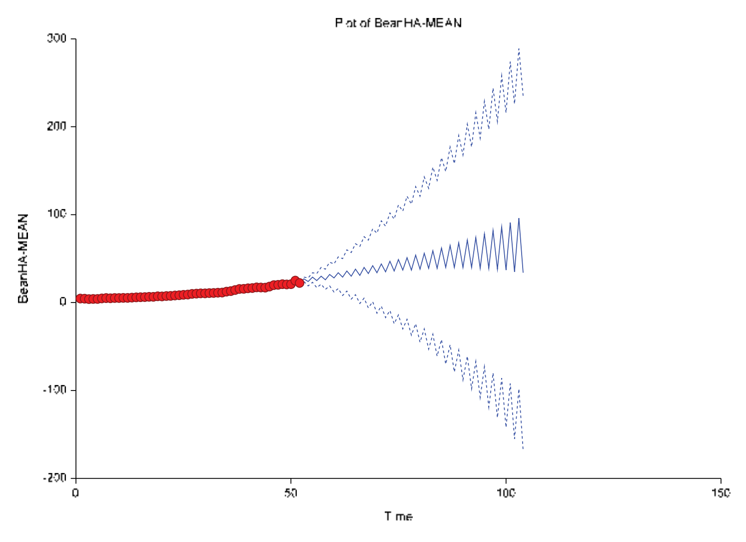
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 49.51 | 0.373199 | Adequate Model |

### 3.21. Projection of area of country bean

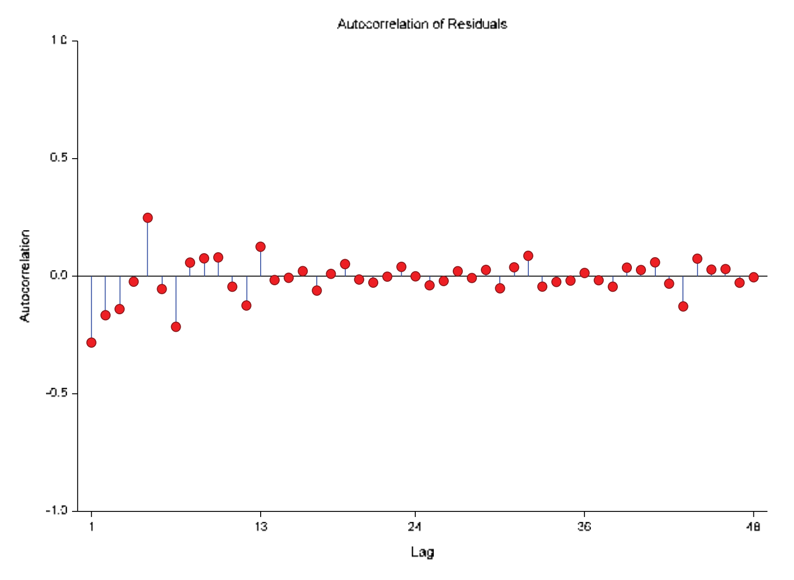
## Model Description Section

| | | |
|---|---|---|
| Series | BeanHA-MEAN | |
| Model | Regular (1,2,0) | Seasonal (No seasonal parameters) |
| Mean | 10.90071 | |
| Observations | 52 | |
| Missing Values | None | |
| Iterations | 14 | |
| Pseudo R-Squared | 97.678071 | |
| Residual Sum of Squares | 40.60328 | |
| Mean Square Error | 0.8286383 | |
| Root Mean Square | 0.9102957 | |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section BeanHA-MEAN

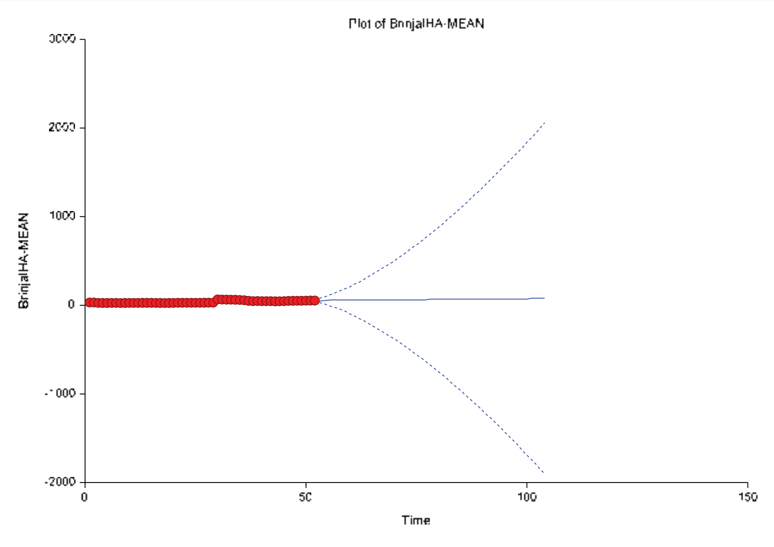
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 30.82 | 0.967137 | Adequate Model |

## 3.22. Projection of area of brinjal

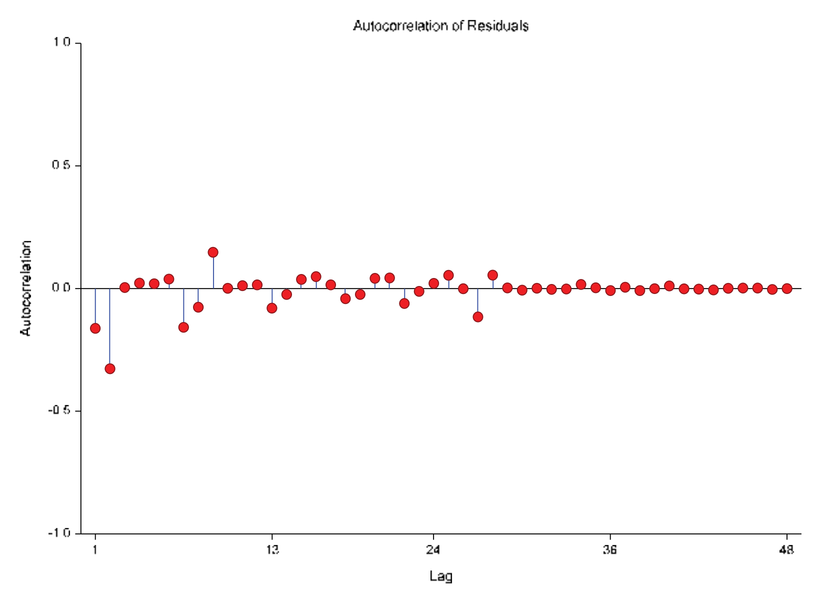
## Model Description Section

| | |
|---|---|
| Series | BrinjalHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 39.065 |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 76.643062 |
| Residual Sum of Squares | 2189.405 |
| Mean Square Error | 44.68173 |
| Root Mean Square | 6.684439 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section BrinjalHA-MEAN

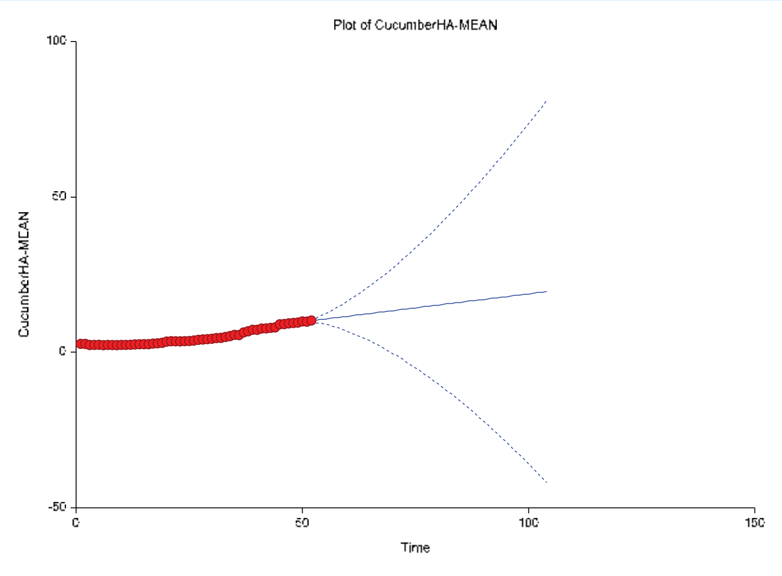
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 15.00 | 0.999998 | Adequate Model |

### 3.23. Projection of area of cucumber

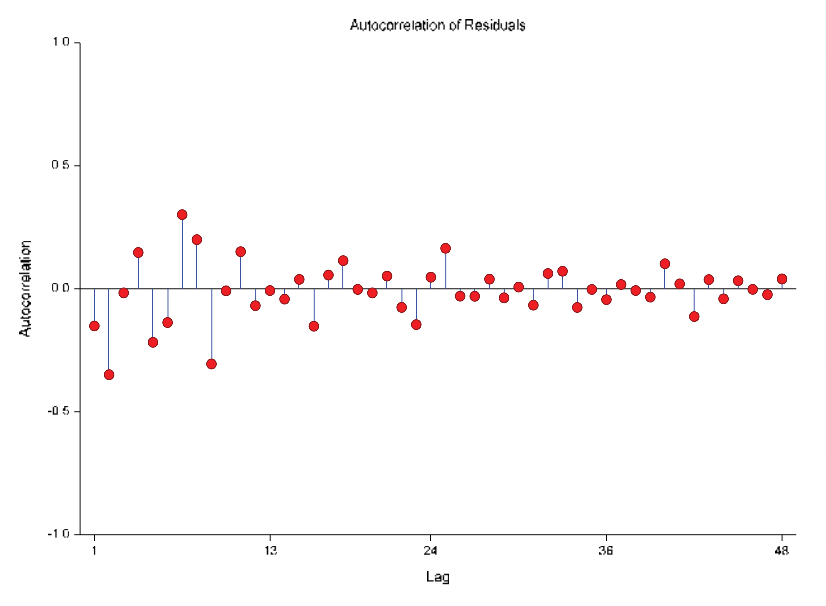
## Model Description Section

| | |
|---|---|
| Series | CucumberHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 4.934616 |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 99.244131 |
| Residual Sum of Squares | 2.629048 |
| Mean Square Error | 0.05365403 |
| Root Mean Square | 0.2316334 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section Cucumber HA-MEAN

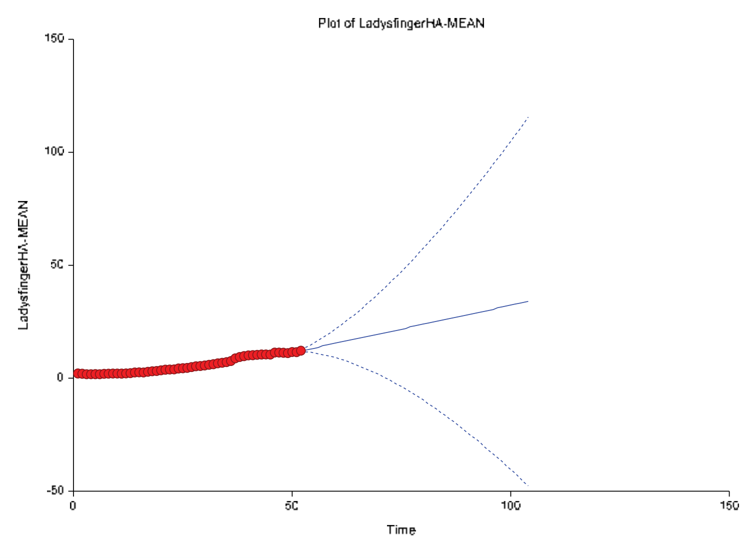
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 51.84 | 0.290791 | Adequate Model |

### 3.24. Projection of area of lady's finger

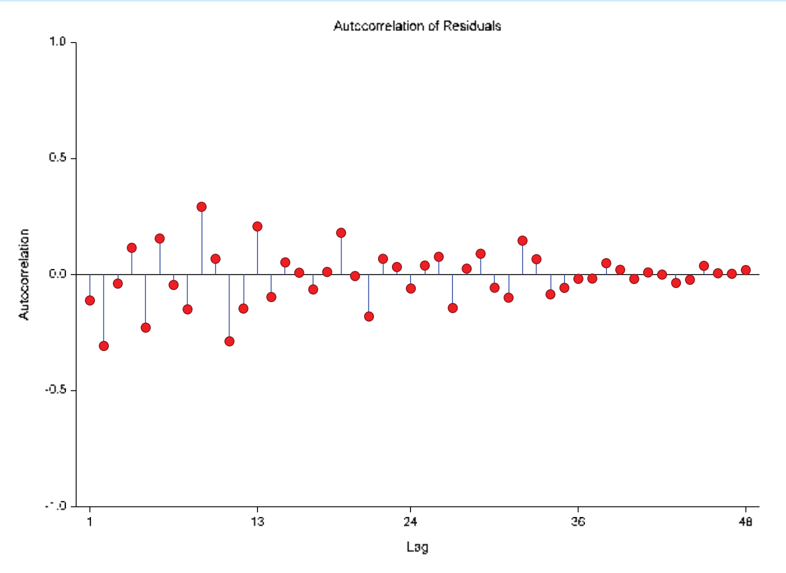
## Model Description Section

| | |
|---|---|
| Series | LadysfingerHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 5.828846 |
| Observations | 52 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 99.461382 |
| Residual Sum of Squares | 3.579345 |
| Mean Square Error | 0.07304785 |
| Root Mean Square | 0.2702737 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Lady's finger HA-MEAN

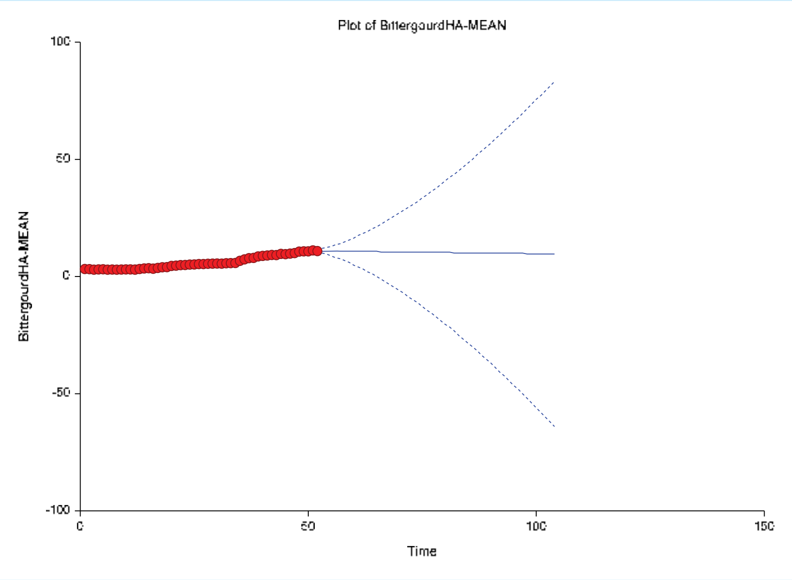
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 50.43 | 0.339302 | Adequate Model |

### 3.25. Projection of area of bitter gourd

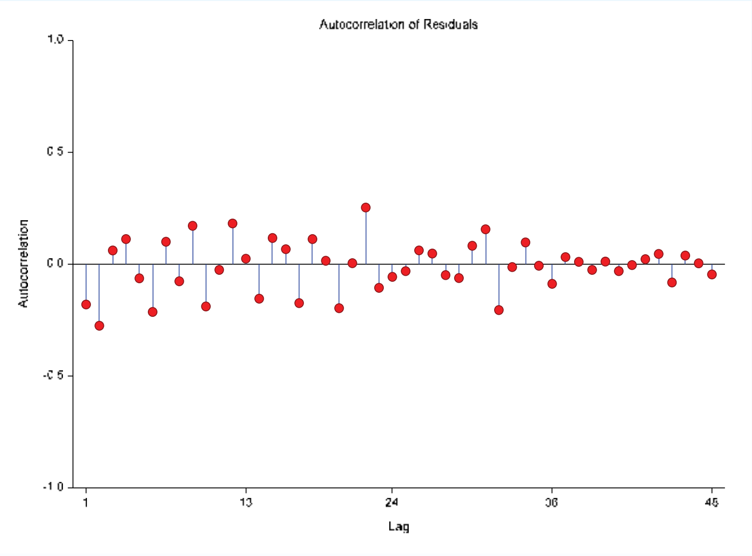
## Model Description Section

| | |
|---|---|
| Series | BittergourdHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 5.9225 |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 99.111166 |
| Residual Sum of Squares | 3.403745 |
| Mean Square Error | 0.06946418 |
| Root Mean Square | 0.2635606 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section BittergourdHA-MEAN

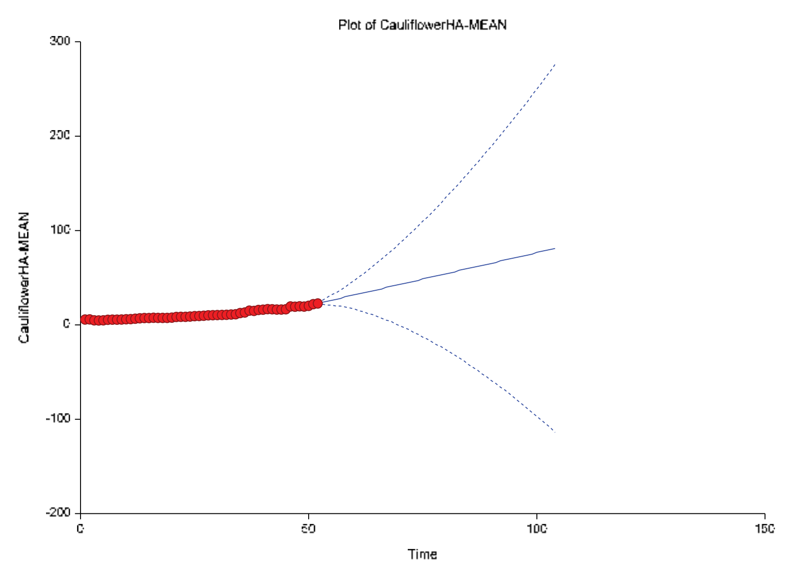
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 55.94 | 0.174439 | Adequate Model |

### 3.26. Projection of area of cauliflower

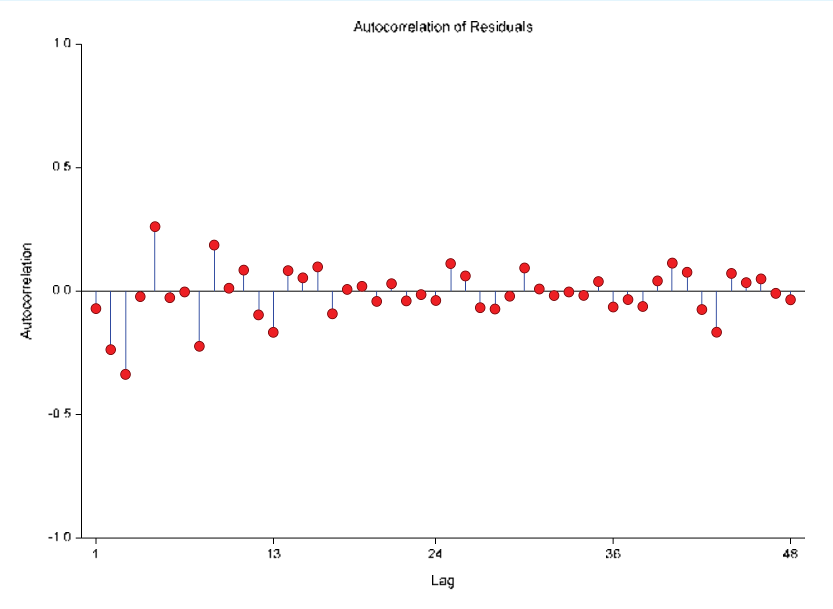
## Model Description Section

| | |
|---|---|
| Series | CauliflowerHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 11.07535 |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 98.228327 |
| Residual Sum of Squares | 24.1833 |
| Mean Square Error | 0.4935367 |
| Root Mean Square | 0.7025216 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section CauliflowerHA-MEAN

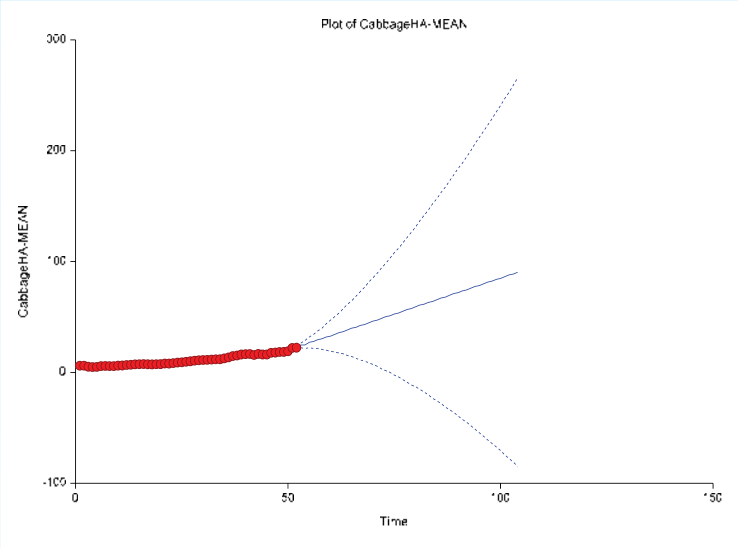
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 50.92 | 0.322030 | Adequate Model |

### 3.27. Projection of area of cabbage

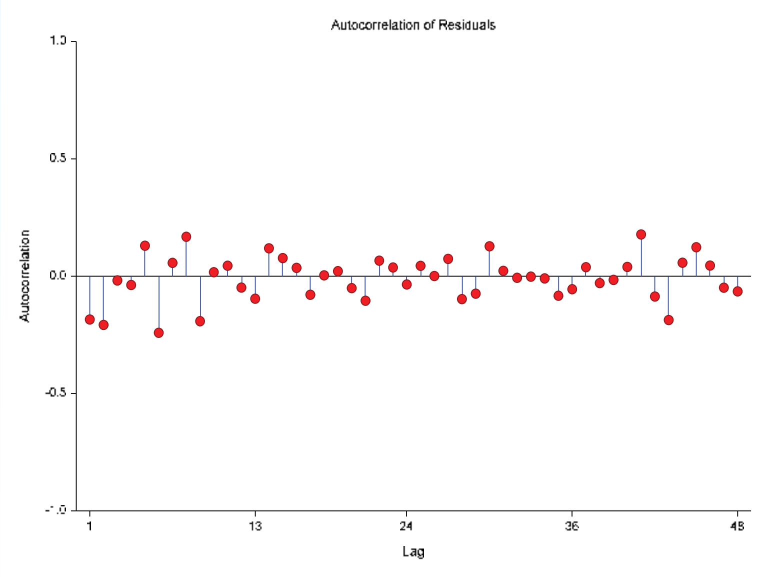
## Model Description Section

| | |
|---|---|
| Series | CabbageHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 11.12053 |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 98.313617 |
| Residual Sum of Squares | 20.87103 |
| Mean Square Error | 0.4259393 |
| Root Mean Square | 0.6526403 |

## Forecast and Data Plot




## Autocorrelation Plot Section




## Portmanteau Test Section CabbageHA-MEAN

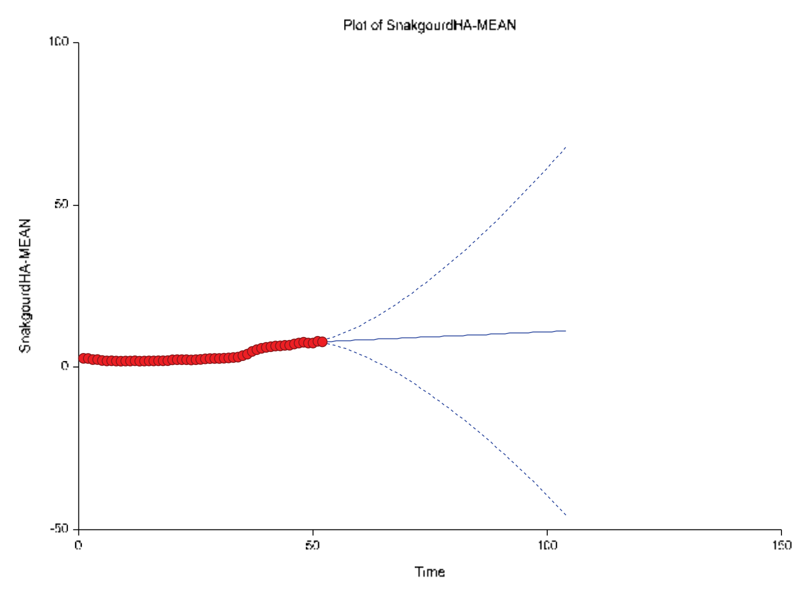
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 59.28 | 0.107834 | Adequate Model |

### 3.28. Projection of area of snake gourd

## Model Description Section

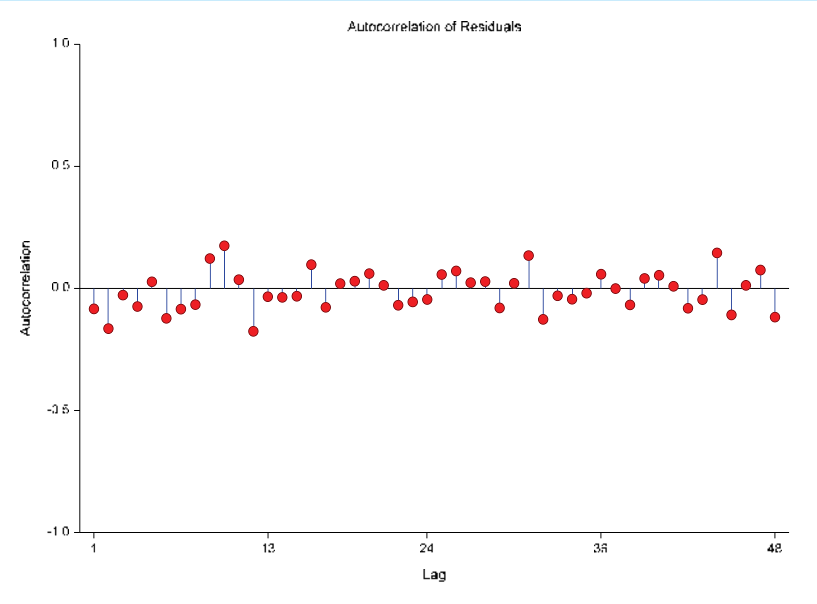
| | |
|---|---|
| Series | SnakgourdHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 3.763654 |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 99.265933 |
| Residual Sum of Squares | 1.715568 |
| Mean Square Error | 0.03501159 |
| Root Mean Square | 0.1871138 |

## Forecast and Data Plot




(a) ACF of per capita calorie supply from rice (b) PACF of per capita calorie supply from rice

## Autocorrelation Plot Section




## Portmanteau Test Section SnakgourdHA-MEAN

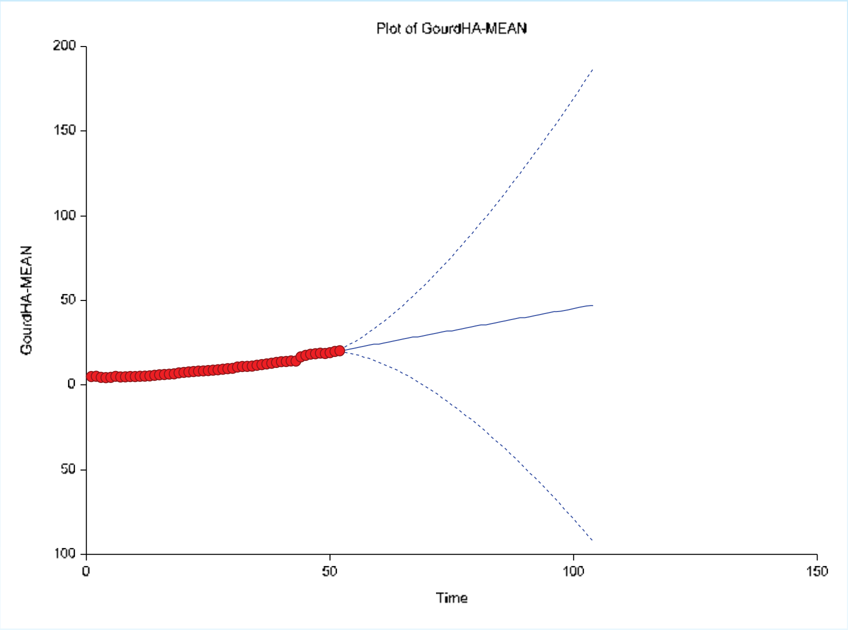
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 49.37 | 0.378555 | Adequate Model |

### 3.29. Projection of area of gourd

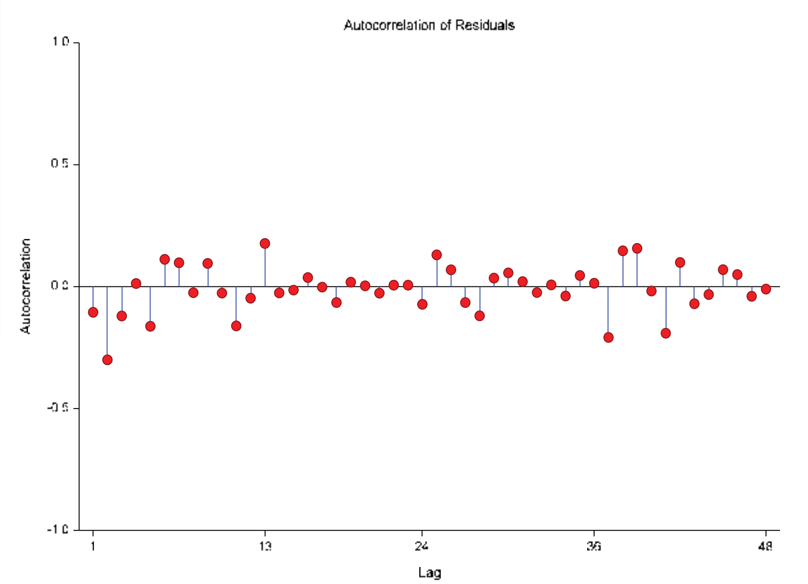
## Model Description Section

| | |
|---|---|
| Series | GourdHA-MEAN |
| Model | Regular (1,2,0) Seasonal (No seasonal parameters) |
| Mean | 10.17935 |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 4 |
| Pseudo R-Squared | 99.117346 |
| Residual Sum of Squares | 10.76135 |
| Mean Square Error | 0.2196195 |
| Root Mean Square | 0.4686357 |

## Forecast and Data Plot




## Autocorrelation Plot Section



## Portmanteau Test Section GourdHA-MEAN

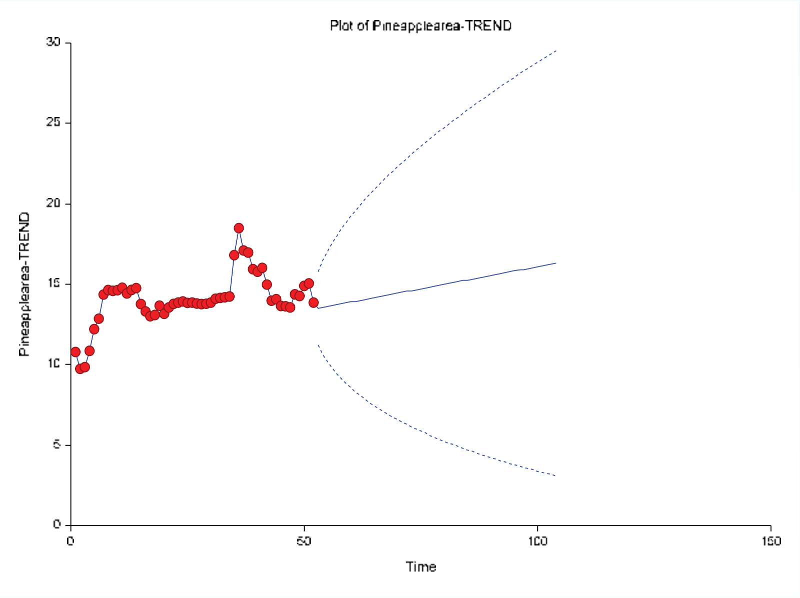
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 57.09 | 0.148628 | Adequate Model |

### 3.30. Projection of area of pineapple

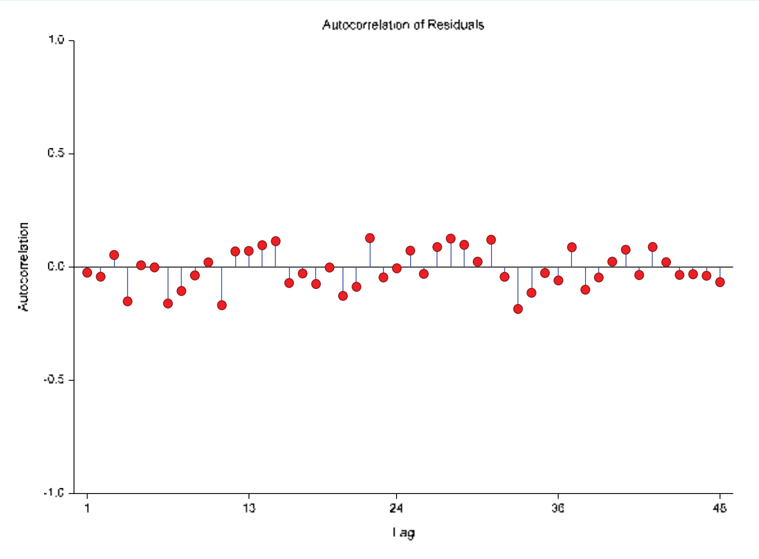
## Model Description Section

| | |
|---|---|
| Series | Pineapplearea-TREND |
| Model | Regular (0,1,1) Seasonal (No seasonal parameters) |
| Trend Equation | (12.60729) +(0.05496457) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 6 |
| Pseudo R-Squared | 81.113416 |
| Residual Sum of Squares | 24.11995 |
| Mean Square Error | 0.482399 |
| Root Mean Square | 0.6945495 |

## Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Pineapplearea-TREND (Continued)

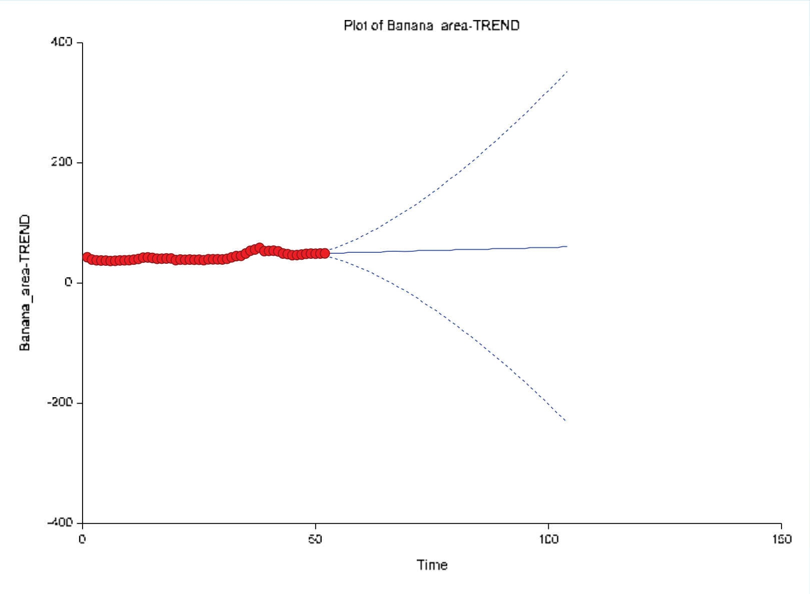
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 41.15 | 0.712447 | Adequate Model |

### 3.30. Projection of area of banana

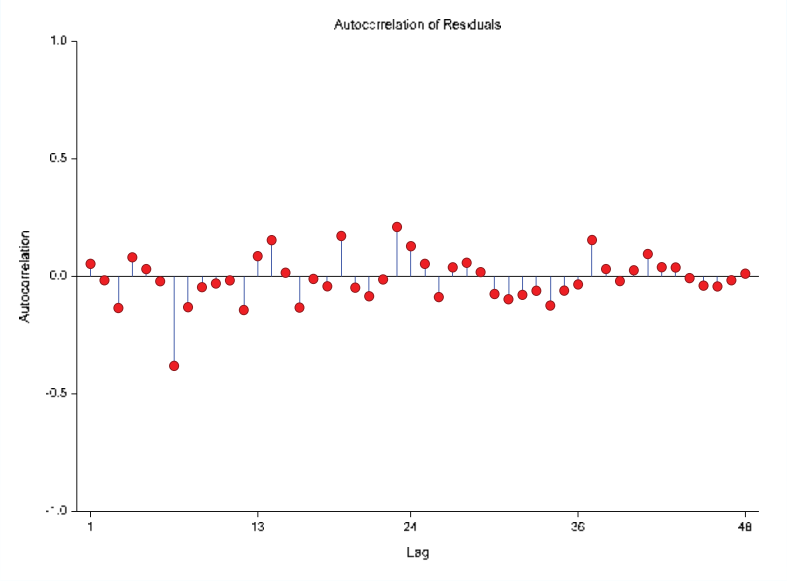
## Model Description Section

| | |
|---|---|
| Series | Banana_area-TREND |
| Model | Regular (0,2,1) Seasonal (No seasonal parameters) |
| Trend Equation | (35.8731) +(0.2944694) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 12 |
| Pseudo R-Squared | 91.409486 |
| Residual Sum of Squares | 151.445 |
| Mean Square Error | 3.090714 |
| Root Mean Square | 1.758043 |

## Forecast and Data Plot




## Autocorrelation Plot Section



**Portmanteau Test Section Banana_area-TREND**

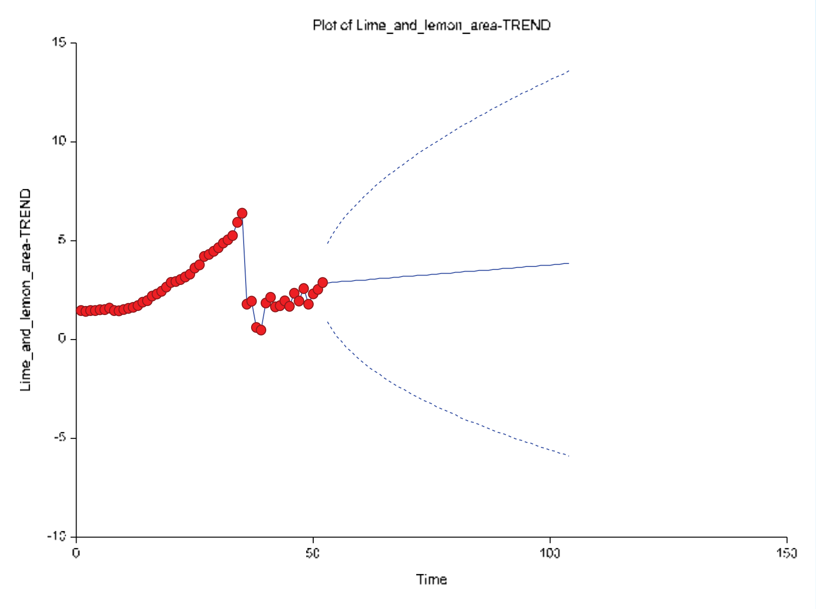
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 44.84 | 0.562496 | Adequate Model |

### 3.30. Projection of area of lime and lemon

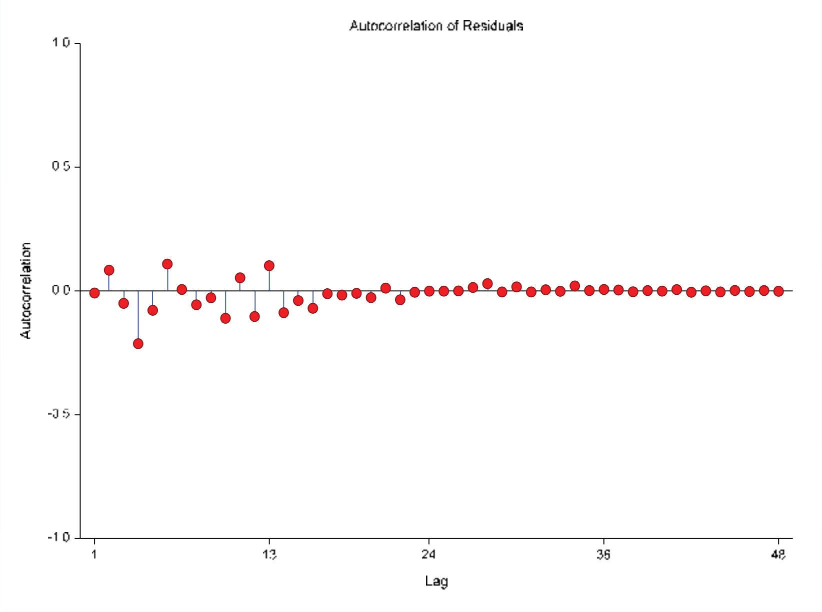
**Model Description Section**

| | |
|---|---|
| Series | Lime_and_lemon_area-TREND |
| Model | Regular (0,1,1) Seasonal (No seasonal parameters) |
| Trend Equation | (2.053631) +(0.01924036) x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 1 |
| Pseudo R-Squared | 68.831804 |
| Residual Sum of Squares | 28.45727 |
| Mean Square Error | 0.5691453 |
| Root Mean Square | 0.7544172 |

## Forecast and Data Plot




## Autocorrelation Plot Section




## Portmanteau Test Section Lime_and_lemon_area-TREND

| Portmanteau | Prob |
|---|---|

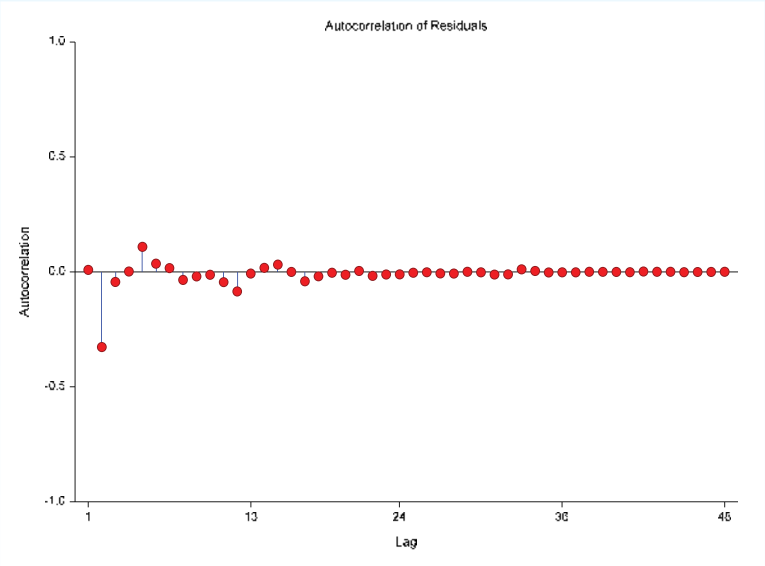
| Lag | DF | Test Value | Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 8.62 | 1.000000 | Adequate Model |
| 48 | 47 | 8.62 | 1.000000 | Adequate Model |

## 3.31. Projection of area of guava

### Model Description Section

| | |
|---|---|
| Series | Guava_area-TREND |
| Model | Regular (1,1,0) Seasonal (No seasonal parameters) |
| Trend Equation | (2.631372) +(0.09473848) x(date) |
| Observations | 52 |
| Missing Values | Detected and replaced using the Average of the Adjacent Values method. |
| Iterations | 3 |
| Pseudo R-Squared | 72.445375 |
| Residual Sum of Squares | 158.8825 |
| Mean Square Error | 3.17765 |
| Root Mean Square | 1.782596 |

### Autocorrelation Plot Section




### Portmanteau Test Section Guava_area-TREND

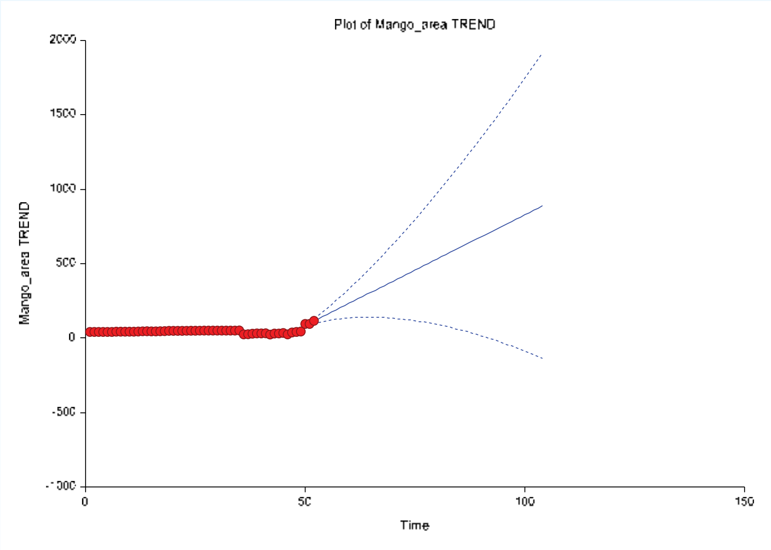
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 8.09 | 1.000000 | Adequate Model |

### 3.31. Projection of area of mango

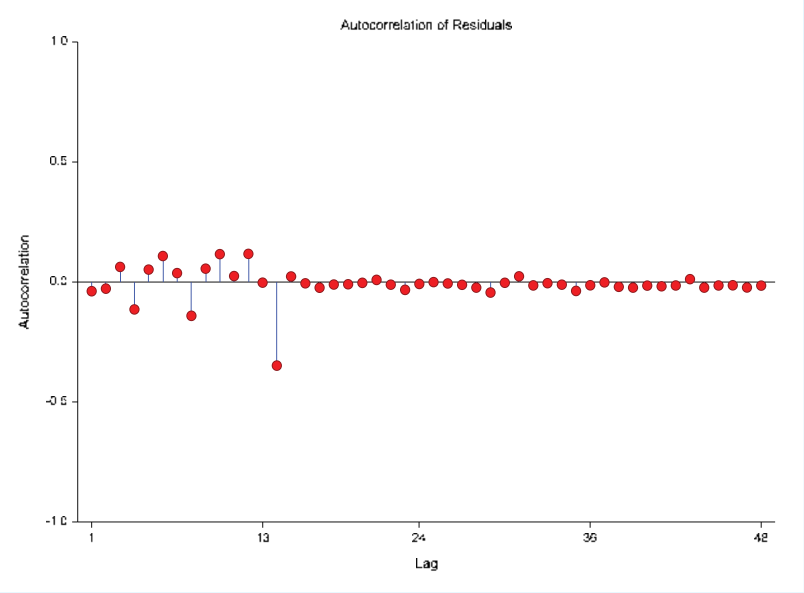
#### Model Description Section

| | |
|---|---|
| Series | Mango_area-TREND |
| Model | Regular(1,2,1) Seasonal(No seasonal parameters) |
| Trend Equation | (40.67487)+(0.1907889)x(date) |
| Observations | 52 |
| Missing Values | None |
| Iterations | 5 |
| Pseudo R-Squared | 73.670654 |
| Residual Sum of Squares | 3579.535 |
| Mean Square Error | 74.57365 |
| Root Mean Square | 8.635604 |

#### Forecast and Data Plot



## Autocorrelation Plot Section




## Portmanteau Test Section Mango_area-TREND

(

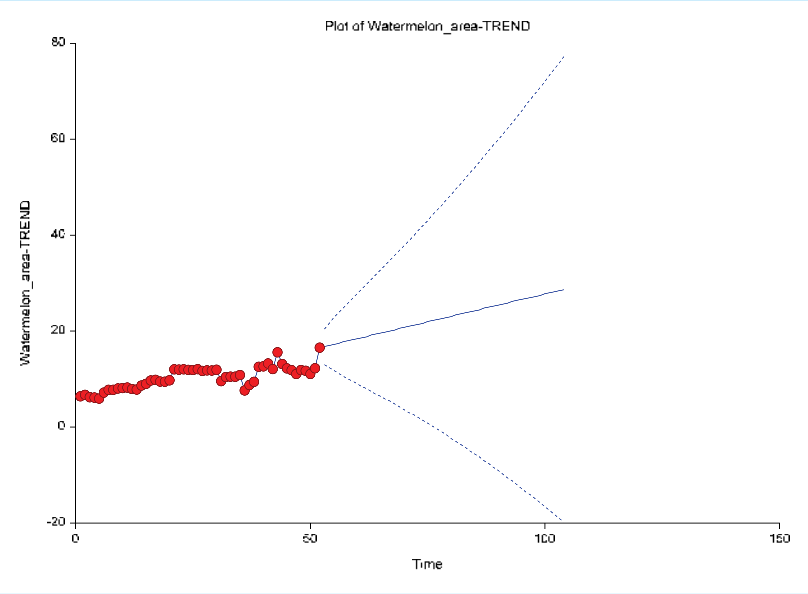
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 46 | 16.60 | 0.999980 | Adequate Model |

### 3.32. Projection of area of water melon

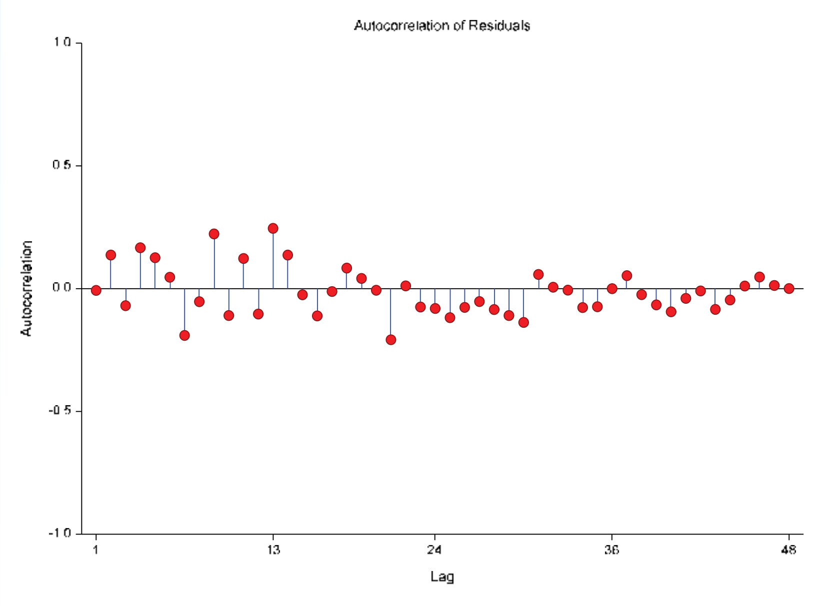
## Model Description Section

| | |
|---|---|
| Series | Watermelon_area-TREND |
| Model | Regular (0,2,1) Seasonal (No seasonal parameters) |
| Trend Equation | (7.015947) +(0.1232543) x(date) |
| | |
| Observations | 52 |
| Missing Values | None |
| Iterations | 20 |
| Pseudo R-Squared | 71.174599 |
| Residual Sum of Squares | 82.60313 |
| Mean Square Error | 1.685778 |
| Root Mean Square | 1.298375 |

## Forecast and Data Plot




## Autocorrelation Plot Section



### Portmanteau Test Section Watermelon_area-TREND

| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 42.52 | 0.618810 | Adequate Model |
| 48 | 47 | 42.52 | 0.658439 | Adequate Model |

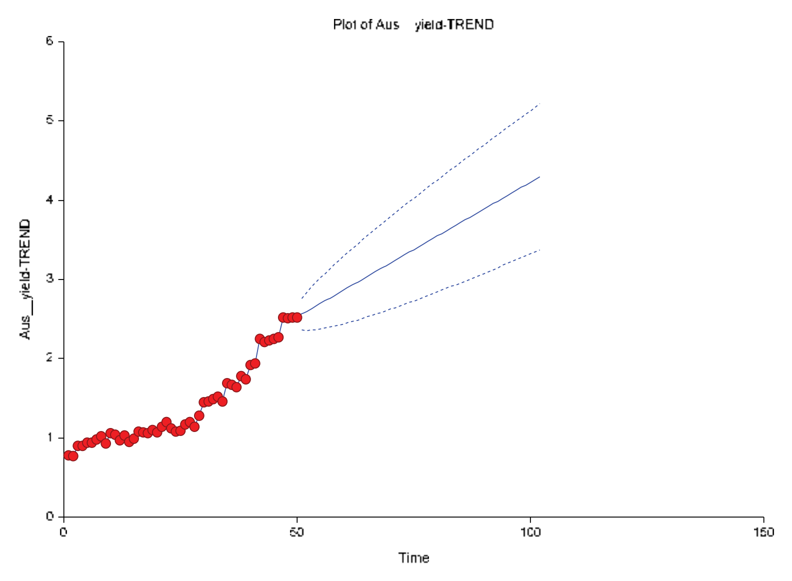
## 4. Crop yield projections

### 4.1 *Aus* rice yield projection

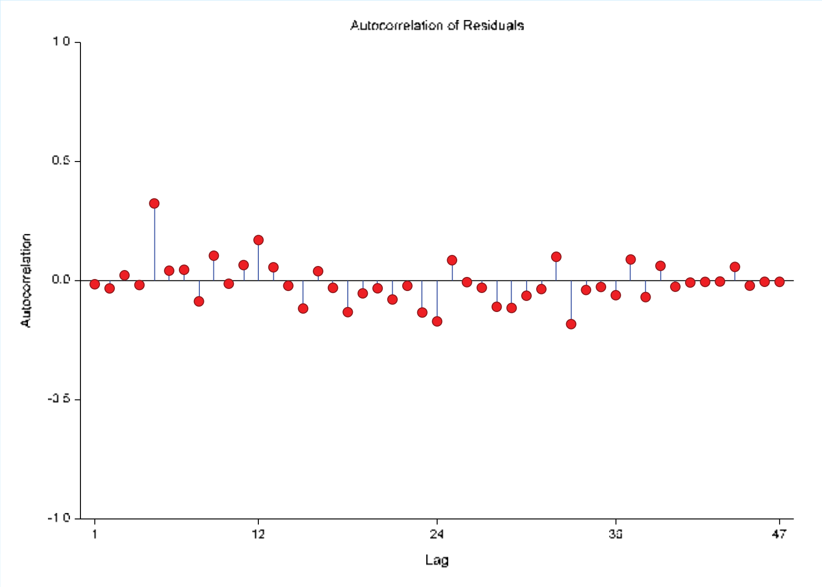
**Model Description Section**

| | |
|---|---|
| Series | *Aus*__yield-TREND |
| Model | Regular(1,1,0) Seasonal(No seasonal parameters) |
| Trend Equation | (0.5544)+(0.03397647)x(date) |
| Observations | 50 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 97.602903 |
| Residual Sum of Squares | 0.3321986 |
| Mean Square Error | 0.006920803 |
| Root Mean Square | 0.08319137 |

### Forecast and Data Plot



## Autocorrelation Plot Section




**Portmanteau Test Section *Aus*__yield-TREND**

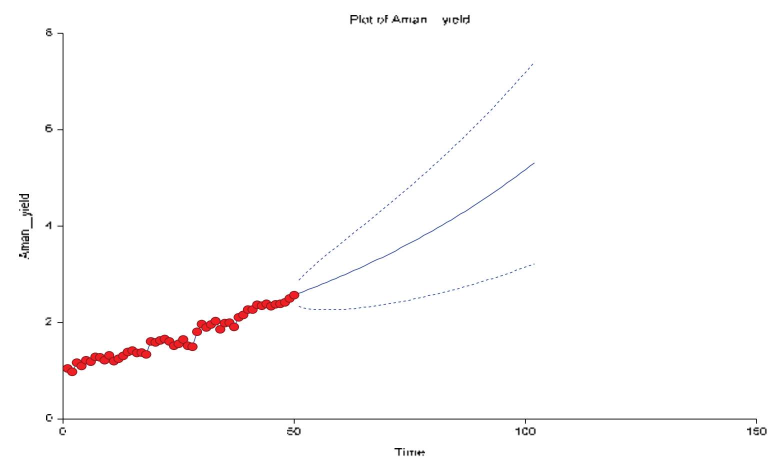
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 35.99 | 0.855310 | Adequate Model |

### 4.2 *Aman* rice yield projection

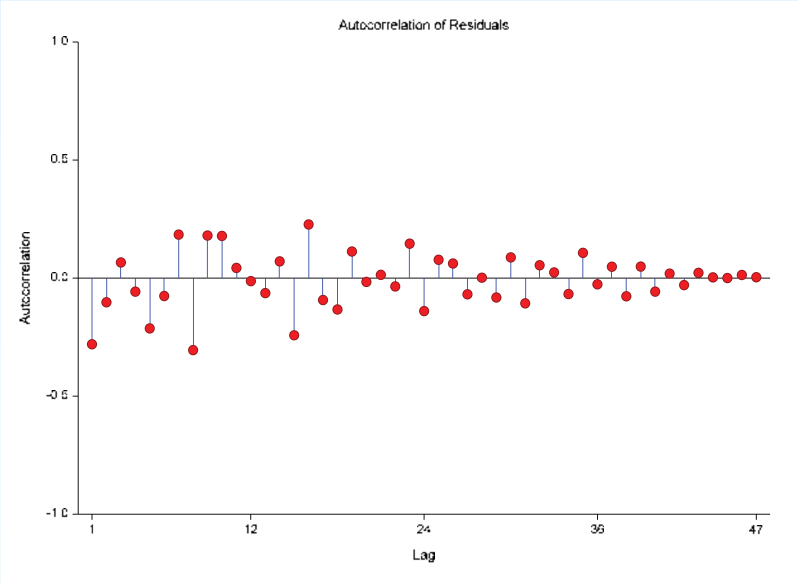
**Model Description Section**

| | | |
|---|---|---|
| Series | *Aman*__yield | |
| Model | Regular (1,0,0) | Seasonal (No seasonal parameters) |
| Observations | 50 | |
| Missing Values | None | |
| Iterations | 4 | |
| Pseudo R-Squared | 95.434040 | |
| Residual Sum of Squares | 0.4669256 | |
| Mean Square Error | 0.009529094 | |
| Root Mean Square | 0.09761708 | |

## Forecast and Data Plot




## Autocorrelation Plot Section




**Portmanteau Test Section** ***Aman*****__yield )**

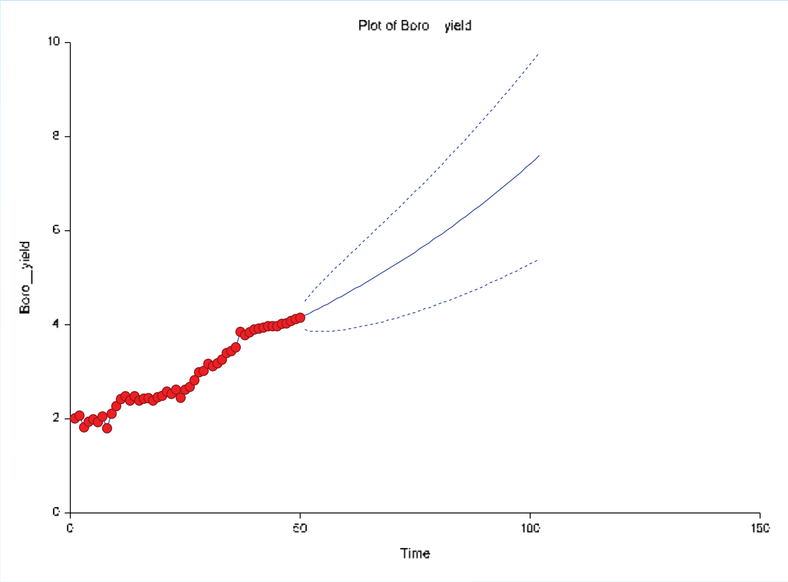
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 48.71 | 0.364554 | Adequate Model |

## 4.3 *Boro* rice yield projection

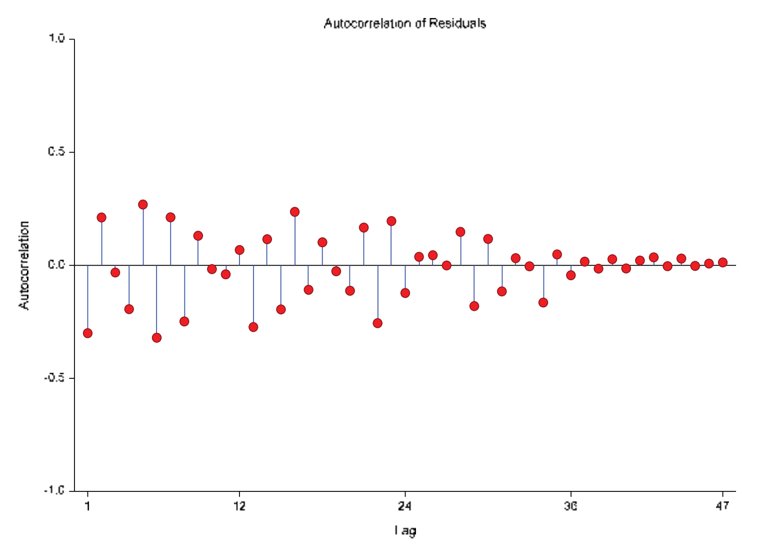
**Model Description Section**

| | | |
|---|---|---|
| Series | *Boro*__yield | |
| Model | Regular (1,0,0) | Seasonal (No seasonal parameters) |
| Observations | 50 | |
| Missing Values | None | |
| Iterations | 4 | |
| Pseudo R-Squared | 97.905125 | |
| Residual Sum of Squares | 0.5942407 | |
| Mean Square Error | 0.01212736 | |
| Root Mean Square | 0.1101243 | |

### Forecast and Data Plot




## Autocorrelation Plot Section




## Portmanteau Test Section *Boro*__yield

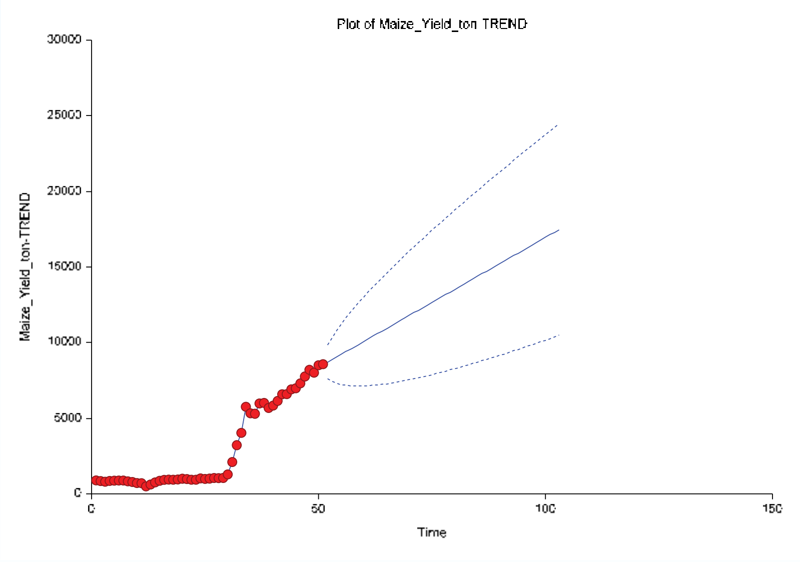
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 75.03 | 0.004387 | Inadequate Model |

### 4.4 Maize yield projection

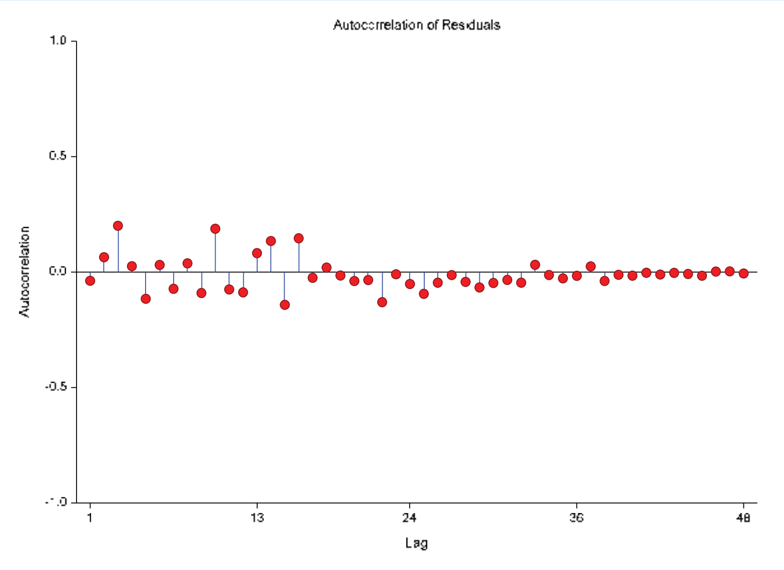
**Model Description Section**

| | |
|---|---|
| Series | Maize_Yield_ton-TREND |
| Model | Regular (1,1,0) Seasonal (No seasonal parameters) |
| Trend Equation | (-1378.425) +(171.9625) x(date) |
| | |
| Observations | 51 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 98.532044 |
| Residual Sum of Squares | 5991320 |
| Mean Square Error | 122271.8 |
| Root Mean Square | 349.6739 |

**Forecast and Data Plot**



## Autocorrelation Plot Section




## Portmanteau Test Section Maize_Yield_ton-TREND

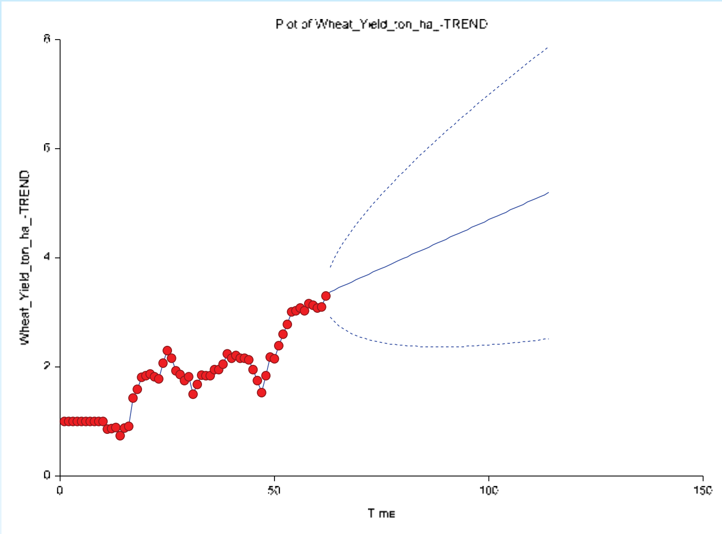
| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 48 | 47 | 18.60 | 0.999934 | Adequate Model |

## 4.5 Wheat yield projection

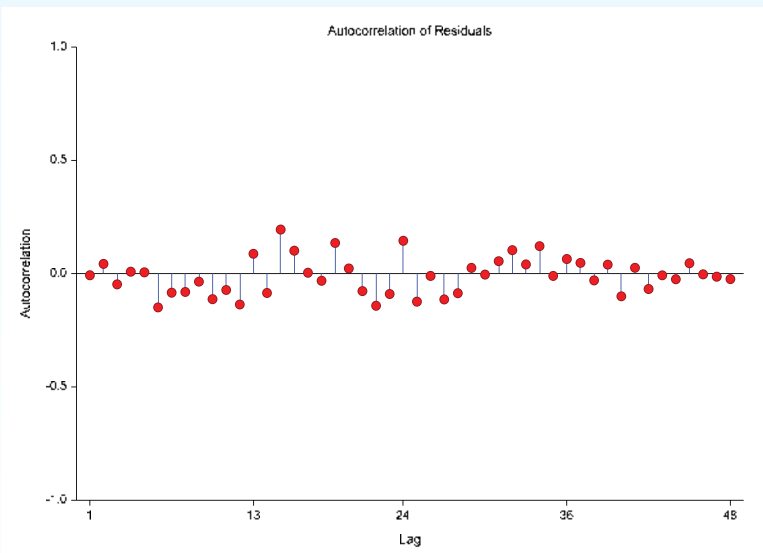
## Model Description Section

| | |
|---|---|
| Series | Wheat_Yield_ton_ha_-TREND |
| Model | Regular(1,1,0) Seasonal(No seasonal parameters) |
| Trend Equation | (0.7500899)+(0.0355783)x(date) |
| | |
| Observations | 62 |
| Missing Values | None |
| Iterations | 3 |
| Pseudo R-Squared | 95.725371 |
| Residual Sum of Squares | 1.316982 |
| Mean Square Error | 0.02194969 |
| Root Mean Square | 0.1481543 |

## Forecast and Data Plot




## Autocorrelation Plot Section




## Portmanteau Test Section Wheat_Yield_ton_ha_-TREND

| Lag | DF | Portmanteau Test Value | Prob Level | Decision (0.05) |
|---|---|---|---|---|
| 47 | 46 | 31.66 | 0.946911 | Adequate Model |
| 48 | 47 | 31.82 | 0.955889 | Adequate Model |

**Annex 5. Results of Validation Workshops**

Four validation workshops were conducted at Bogura, Rajshahi, Jashore and Patuakhali with the purpose to know technology adopted, productivity, potential growth of yields of selected crops, challenges faced by the farmers and validate results of the ARIMA models.

**Validation Workshop at Bogura**

Rice (*Aman, Aus* and *Boro*), vegetables, spices, potato, sweet potato and banana are the main crops grown in this area. The varieties cultivated are: BRRI 33, 48, 65, 82, BINA 19, Mniket for *Aus*; BRRI 11, 33, 34, 49, 51, 52, 73, 75, 87, 93, BINA 17, Swarna for *Aman*; BRRI 28, 29, 58, 74, 81, 84, 86, 88, 89, Kataribhogh, Zive patel, SLSH, ACI 2 for *Boro*; pakri, BARI potato 8, 25 for potato; BARI onion 1, 4 for onion; BARI garlic 1, 3 for garlic; Manik, Bijliplus, BARI ginger 1, 2 for ginger; Magura, BARI chili 4 for chili; BARI 1, 2, 3 for pointed gourd; Marbel, captain for cauliflower; Naresh 101, Etlas 70 for cabbage; Nabab, Tia, Glory for bitter gourd; Mental, Chumki, Green ball, BT brinjal 1, 4, BARI 12 for brinjal.

The yield per hectare for major crops are: *Aman* 5.4 MT; *Boro* 7 MT; Potato 30-35 MT; Sweet potato 20-25 MT; Onion 10-18 MT; Garlic 8-9MT; Chili 25-30 MT; Ginger 30-34 MT; Turmeric 10-30 MT; Coriander 6 MT; Brinjal 20-23 MT; Cauli flower 42 MT; Cabbage 46 MT; Pointed gourd 13 MT; Bitter gourd 15 MT; Okra 10 MT; Bottle gourd 158-168 MT; Radish 21-34 MT; and yard long bean 51-54 MT.

All banana and a few rice farmers applied compost and for that reason banana's yield reportedly rose by 50%. No farmer is found to use Guti urea or AWD technologies in this area. Only vegetable producers use hybrid seeds and increased the yield by 150%. While majority of farmers stated to use good quality seeds for all types of crops. A few farmers reportedly used IPM technologies and stress tolerant varieties. Majority banana farmers and a few spices farmers practices improved weed management.

The major problems stated are: high price of Hybrid seeds, not getting fair price for the produce, lack of technical knowledge for production, nonavailability of agricultural weather information, lack of man power in government sector, non availability of good quality seeds, available of land for producing spice is meager, and high wages of labour during peak seasons.

**Validation Workshop at Rajshahi**

The main crops grown in this area are: *Aus*, *Aman, Boro*, Wheat, Maize, Jute, Potato, Sugarcane, Lentil, Black Gram, Mung, Till, Gram, Onion, Garlic, Chili, Coriander, Brinjal, Bitter gourd, Pumpkin, Okra, Cucumber, Cauliflower, Cabbage, Tomato, Mango, Guava, and Dragon.

The varieties cultivated for different crops are: BRRI 48, 58, 82 for *Aus*; BRRI 11, 34, 49,51,52, 81, 87, Guti Swarna, Swarna for *Aman*; BRRI28, 29, 50, 81, 89, Jirashail for *Boro*; BARI Wheat26, 28, 30, 32, 33 for wheat; BARI lentil 3,8 for Lentil; BARI Gram5 for Gram; Local, BARI Black Gram3 for Black Gram; BARI Mustard9, 14, 15, 17, 18, TORI-7 for Mustard; Hybrid, Local for Cucumber; Hybrid 422 for Brinjal; Hybrid for

Cauliflower and Cabbage; Himsagor, Fazlee, Langra, Lokkhonvog, Amropali, BARI4, Totapuri, Gourmoti, Banana, Ashwina, Chosa, Hariavanga, Suneg for Mango.

**The yield per hectare stands at:** *Aus* 4.8-5.4 MT; *Aman* 5.7-7.2 MT; *Boro* 6.6-9.3 MT; Wheat 2.7-4.5 MT; Lentil 1.5-2.3 MT; Black Gram 1.0 MT; Brinjal 76.4 MT; Cucumber 53.7-57.3 MT; Pumpkin 14.0 MT; and Guava 17.9 MT. Because of adopting improved varieties, the yield increased ranges from 15% for *Aman* rice to 188% for mustard.

A significant number of Mango, Guava and mustard farmers applied compost for crop cultivation, for which production rose by 20-25%. Application of Guti urea, using Hybrid seeds, practice of IPM and using flood resistant varieties are very rare in this area. About 100% mango farmers are reported to adopt alternate wetting and drying method for irrigation. Majority of spices farmers stated to use good quality seeds. Majority of mango farmers are practicing improved weed management. The major problems mentioned are: Not getting fair price due defective marketing system: absence of processing industries and export; Faulty marketing system of fertilizer; farmers are not well informed about the new varieties/technologies; small farmers facing problem to get irrigation water; lack of good seeds; absence of training on pest/disease control, and need more short duration and stress resilient varieties.

**Validation Workshop at Jashore**

The main crops grown in this area are: *Aus, Aman, Boro,* Wheat, Maize, Jute, Potato, Sweet Potato, Oilseeds, Spices, different types of vegetable like Brinjal, Pointed Gourd, Cucumber, Snake gourd, Bottle gourd, Papaya, Okra, Pumpkin, Bean, Tomato, Cauliflower, Cabbage etc., Mango, Litchi and Watermelon. The important varieties cultivated are: Ball Brinjal, Chega Brinjal, Vangor Brinjal for Brinjal; Baropata, Shila, Baromasi, Golpata Nargis, Alavi Green, Green Line, Moyna Pakhi, Thailand-1, Paragas, Moyna Moti for cucumber; Ninja, Hybrid-11, Bigshort, Monobox, Mono White, White Metal for cauli flower; and Tropical Quick, Quicker, Green-60, Early Hot, Atom for cabbage.

The yield per hectare for different varieties of vegetables are: Brinjal (Ball) 45 MT; Brinjal (Chega) 87 MT; Brinjal (Vangor) 69 MT; Cucumber (Baropata) 17 MT; Cucumber (Shila) 27 MT; Cucumber (Baromasi) 16 MT; Cucumber (Golpata) 30 MT; Cucumber (AlaviGreen) 30 MT; Cucumber (Green Line) 45 MT; Cucumber (Moyna Pakhi) 18 MT; Cucumber (Thailand1) 30 MT; Cucumber (Moynamoti) 18 MT; Cucumber (Pagasas) 45 MT; Cucumber (Green Line) 35 MT. Because of cultivating improved varieties, yield augmented by 40% for cucumber and 13-25% for brinjal, while cauliflower's and cabbage's yield rose by 35-40%.

Application of compost is very common for brinjal, cauliflower and cabbage cultivation, whereas use of Guti urea is very rare. A few farmers practice AWD method. Almost all producers use good quality seeds for brinjal and cauliflower/cabbage cultivation, which enhances the yield 20-50%. Again, a small group of producers practice IPM technologies and use stress tolerant varieties. About 90% Cabbage/Cauliflower farmers adopted improved weed management practices. The major problems identified are: Non availability of seed timely, absence of irrigation facilities, lack of technological knowledge, infected/attacked by various diseases and insects.

**Validation Workshop at Patuakhali**

The major crops grown in this area are: *Aus, Aman, Boro,* Jute, Wheat, Maize, Potato, Sweet potato, Lentil, Mung bean, Pea, Grass pea, Onion, garlic, Coriander, Sesame, Groundnut, Watermelon, different types of vegetables such as Danta, Snake Gourd, Sponge Gourd, Bitter gourd, Yard long bean, Ash Gourd, Water spinach, Bottle Gourd, Pumpkin, Brinjal, Papaya, Cucumber, Tomato, carrot and lalshak. The popular varieties include: BARI 1, 2, local for Grass pea; BARI 5 ,6, local for Lentil; and BARI mug 6 for Mug bean.

The per hectare yield of different crops are calculated at: Grass pea 0.8-1.2 MT; Lentil (local) 1 MT, Lentil (HYV) 1-1.2 MT; Mug bean 1.5 MT. Yield increased due to adoption of improved varieties ranged from 10% for grass pea to 75% for Mug bean.

Use of compost, adoption of alternate wetting and drying method and use of flood resilient and Hybrid varieties are found absent in this area. Guti urea was used by 80% grass pea farmers and most of farmers are reported to use good quality seeds. However, Majority of lentil producers cultivated drought resilient varieties. Improved weed management was practiced by most of lentil and mug bean farmers. The important problems faced by farmers are: lack of knowledge about improved varieties of seed; non-availability of improved/good seeds; diseases infection and pest attack; and absence of post-harvest processing etc.

**Bogura Validation Workshops-FGD Data**

**Table 5.1. Main crops cultivated in Bogura**

| Crop season | Crops cultivated |
|---|---|
| **Kharif 1** | *Aus* Rice, Banana, Gourd, Karala, Patal, Ginger,Turmeric, Chili, Yard long bean |
| **Kharif 2** | *Aman* Rice, Banana, Reddish, Lady's Finger, Brinjal, Gourd, Chili |
| **Rabi** | *Boro* Rice, Potato, Sweet Potato, Cauliflower, Cabbage, Brinjal, Chili, Onion, Garlic, Coriander |

**Table 5.2. Popular crop varieties cultivated in Bogura**

| Crop season | Crops cultivated | Name of Varieties cultivated |
|---|---|---|
| **Kharif 1** | *Aus* Rice | BRRI-48, BRRI-65, BRRI-82, BINA-19, BRRI-33, Katari, Miniket |
| | Gourd | Dayna, Borsha, Chisti |
| | Karala | Nabab, Tia, Glory |
| | Patal | BARI-1, BARI-2, BARI-3 |
| | Chili | Magura, Sony, BARI Chili-2, Manik, Local, Bindi |
| | String Bean | Sufola, Lalteer |
| | Ginger | BARI Ginger-1, BARI Ginger-2 |
| | Turmeric | Kukurmoni, BARI Turmeric-4 |
| | Banana | Chompa, Sobori, Sagor |

| Crop season | Crops cultivated | Name of Varieties cultivated |
|---|---|---|
| **Kharif 2** | *Aman* Rice | BRRI-11, BRRI-33, BRRI-34, BRRI-49, BRRI-51, BRRI-52, BRRI-73, BRRI-75, BRRI-87, BRRI-93, BINA-17, SWARNA (Indian) |
| | Radish | KTX, Mollika, Tajakishtan |
| | Lady's Finger | Sumi |
| | Gourd | BARI Gourd-4, Hybrid |
| | Chili | BARI Chili-2, Magura, Sony, Manik, Hybrid |
| **Rabi** | *Boro* Rice | BRRI-28, BRRI-29, BRRI-58, BRRI-74, BRRI-81, BRRI-84, BRRI-86, BRRI-88, BRRI-89, Kataribhog, Ziva Patel (Indian), Hybrid: SLSH, ACI-2, ACI-694, Kehra , Babilion-2. |
| | Brinjal | Mental, Chumki, Greenball, BT Brinjhal-4, BT Brinjhal-1, BARI-12. |
| | Cauliflower | Marbel, Captain |
| | Cabbage | Noresh 101, Etlas 70. |
| | Chili | Manik, Bijli Plus, Magura, Local, Balijuri, BARI Chili-4 |
| | Potato | Pakri, BARI Potato-8, BARI Potato-25 |
| | Sweet Potato | Local, BARI Sweet Potato-8 |
| | Onion | BARI Onion-1, Taherpuri, BARI Onion-4 |
| | Garlic | BARI Garlic-1, BARI Garlic-3 |
| | Coriander | Morokok |

## Table 5.3. Yield of popular crop varieties cultivated in Bogura

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 1** | Gourd (Dayna, Borsha, Chisti) | 18806 | 18.81 | 5 |
| | Karala (Nabab, Tia, Glory) | 14478 | 14.48 | 5 |
| | Patal (BARI-1, BARI-2, BARI-3) | 12985 | 12.99 | 7 |
| | Banana (Champa) | 73359 | 73.36 | 10 |
| | Banana (Sobori) | 37050 | 37.05 | |
| | Banana (Sagor) | 59280 | 59.28 | |
| | Rice (BRRI-33) | 5434 | 5.43 | 20 |
| | Rice (Katari) | 6916 | 6.92 | 20 |
| | Rice (Miniket) | 6916 | 6.92 | 20 |
| | Chili (Magura) | 24700 | 24.70 | 25 |
| | Chili (Soni) | 29640 | 29.64 | 25 |
| | Chili (BARI Chili-2) | 27170 | 27.17 | 25 |
| | Chili (Manik) | 5970 | 5.97 | 30 |
| | Chili (BARI Chili-2) | 4478 | 4.48 | 20 |
| | Chili (Magura) | 5075 | 5.07 | 22 |
| | Chili (Bindi) | 2985 | 2.99 | 5 |
| | Ginger (BARI Ginger-1) | 29851 | 29.85 | 25 |
| | Ginger (BARI Ginger-2) | 34328 | 34.33 | 35 |
| | Turmeric (Kukurmoni) | 10448 | 10.45 | 5 |
| | Turmeric (BARI Turmeric-4) | 29851 | 29.85 | 30 |
| | String Bean (Sufola) | 53846 | 53.85 | 60 |
| | String Bean (Lalteer) | 50635 | 50.64 | 60 |
| **Kharif 2** | Radish (KTX) | 34030 | 34.03 | 10 |
| | Radish (Mollika) | 20748 | 20.75 | 50 |
| | Radish (Tajakistan) | 21242 | 21.24 | 50 |
| | Lady's Finger (Sumi) | 10150 | 10.15 | 5 |
| | Gourd (BARI Gourd-4 | 158080 | 158.08 | 50 |
| | Gourd (Hybrid) | 167960 | 167.96 | 50 |
| | Chili (Magura) | 24700 | 24.70 | 25 |
| | Chili (Soni) | 27170 | 27.17 | 25 |
| | Chili (BARI Chili-2) | 29640 | 29.64 | 25 |
| | Chili (Local) | 2985 | 2.99 | 3 |

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha | Yield increase (%) |
|---|---|---|---|---|
| **Rabi** | Brinjal (Mental, Chumki, Greenball, BARI-12) | 20298 | 20.30 | 6 |
| | Brinjal (Mental) | 19760 | 19.76 | 30 |
| | Brinjal (BT Brinjal-4) | 23465 | 23.47 | 30 |
| | Brinjal (BT Brinjal-1) | 22230 | 22.23 | 30 |
| | Cauliflower (Marbel, Captain) | 41792 | 41.79 | 7 |
| | Cabbage (Noresh 101, Etlas 70) | 45821 | 45.82 | 8 |
| | Chilli (Manik, Bijli Plus, Magura) | 17463 | 17.46 | 5 |
| | Chili (Bogura Local) | 7463 | 7.46 | 5 |
| | Chili (Bali jhuri Chili) | 7463 | 7.46 | 5 |
| | Chili (BARI Chili-4) | 14925 | 14.93 | 10 |
| | Potato (Pakri) | 17290 | 17.29 | 40 |
| | Potato (BARI Potato-8) | 29640 | 29.64 | 40 |
| | Potato (BARI Potato-25) | 34580 | 34.58 | 40 |
| | Sweet Potato (Local) | 19760 | 19.76 | 40 |
| | Sweet Potato (BARI Sweet Potato-8) | 24700 | 24.70 | 40 |
| | Onion (BARI Onion -1) | 10448 | 10.45 | 5 |
| | Onion (BARI Onion -4) | 17910 | 17.91 | 12 |
| | Garlic (BARI Garlic-1) | 7463 | 7.46 | 20 |
| | Garlic (BARI Garlic-3) | 8955 | 8.96 | 25 |
| | Coriander (Morokok) | 5970 | 5.97 | 50 |

## Table 5.4. Status of technology adoption in Bogura

| Technology adopted | % of farmers adopted | | | | | Results: Yield increase (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potato | Veget able | Banana | Spices | Rice | Potato | Veget able | Banana | Spices | Rice |
| Application of vermin-compost/compost | 2 | 5 | 100 | 1 | 30 | 5 | 7 | 50 | 1 | 35 |
| Application of Guti Urea | | | | | | | | | | |
| Alternate wetting and drying irrigation: (AWD) | | | | | | | | | | |
| Using hybrid seeds | 0 | 70 | | 3 | 1 | 0 | 150 | | 60 | 20 |
| Use good quality seeds | 80 | 80 | 90 | 80 | 80 | 15 | 15 | 80 | 25 | |
| Practice IPM | 20 | 5 | 10 | 3 | 5 | 5 | | 10 | 10 | |
| Cultivate Flood resilient rice variety | 10 | | | | | | | | | |
| Cultivate Drought resilient variety | | 3 | | | | | 10 | | | |
| Improved Weed management practices | 40 | | 60 | 30 | | 10 | | 30 | 25 | |
| Other technology | | | 90 | | | 40 | | 50 | | |

## Table 5.5. Constraints and solutions in Bogura

| Major constraints | Solutions |
|---|---|
| 1. Farmers cannot preserve hybrid seeds | 1. To increase the supply of foundation and certified seeds |
| 2. The farmer does not get a fair price | 2. Ensuring fair prices through improved market management. |
| 3. Lack of technical knowledge | 3. To arrange technical training in the field. |
| 4. Problems in obtaining agricultural weather information | 4. Improving agro-meteorological technology and expanding to union level. |
| 5. Lack of man power in government sector. | 5. Increased manpower at government sector. |
| 6. Farmers are not interested to received new technology. | 6. Ensuring supply and use of quality seeds timely. |
| 7. Lack of mechanical technology and low market price during the season. | 7. Discovery of rice varieties with permanent quality. |
| 8. Lack of quality pesticides. | 8. Increase the knowledge of farmers regarding crop production and mechanical assurance. |
| 9. Seed insufficiency | 9. Ensuring supply and supervision of quality pesticides. |
| 10. Inadequacy of performance of seed | 10. The supply of improved quality seeds should be increased |
| 11. Lack of farmer awareness | 11. Field exhibition and training should be increased |
| 12. Lack of knowledge of the farmer | 12. Travel needs to be increased to motivate farmers |
| 13. Lack of good quality seeds and varieties | 13. Ensure flow of information |
| 14. High price of hybrid seeds | 14. Introduce crop insurance |
| 15. Lack of timely delivery of information to farmers | 15. To make the supply easily available by informing the farmers about quality seeds and varieties |
| 16. The land available for spice cultivation spice is very low | 16. Exhibition on advanced varieties and technologies |
| 17. Workers are not available due to high wages | 17. Provide necessary solutions for control of banana blight |
| 18. When the banana peel comes out, the banana tree falls or bursts | 18. Use of agricultural mechanization required for banana cultivation |

## Rajshahi Validation Workshops- FGD Data

## Table 5.6. Main crops cultivated in Rajshahi

| Crop season | Crops cultivated |
|---|---|
| **Kharif 1** | Mango, Rice, T.*Aus*, Wheat, Maize, .Pulses, Potato, Oilseed, Karala, Mung, Til, Maize, Brinjal, Mango, Guava, Jute, China |
| **Kharif 2** | Mango, *Aman* Rice, Pumpkin, Lady's Finger, Cucumber, Black Gram, Maize, Brinjal, Vegetables, Guava, Chili, Dragon |
| **Rabi** | Pumpkin, Cauliflower, Cabbage, Brinjal, *Boro* Rice, Guava, Mustard, Lentil, Wheat, Potato, Onion, Garlic, Tomato, Maize, Onion, Coriander, Vegetables, Pulses, Sugarcane, Chili, Gram |

## Table 5.7. Popular crop varieties cultivatedin Rajshahi

| Crop season | Crops cultivated | Name of Varieties cultivated |
|---|---|---|
| **Kharif 1** | Mango | Himsagor, Fazlee, Langra, Lokkhonvog, Amropali, BARI-4, Totapuri, Gourmoti, Banana, Ashwina, Chosa, Hariavanga, Suneg |
| | Rice | BRRI Rice-82, 48, 58 |
| **Kharif 2** | Cucumber | Hybrid, Local |
| | Pumpkin | |
| | Rice | Guti Swarna, BRRI Rice-81, 34, 51, 52, 49, 87, Swarna, BR-11 |
| | Black Gram | Local, BARI Black Gram-3 |
| **Rabi** | Rice | BRRI-28, 29, 50, 81, 89, Jirashail |
| | Cauliflower | Hybrid |
| | Cabbage | Hybrid |
| | Brinjal | Hybrid- 422 |
| | Mustard | BARI Mustard-14, 9, 17, 18, 15, TORI-7. |
| | Wheat | BARI Wheat-26, 28, 30, 32, 33 |
| | Lentil | BARI Lentil-8, BARI Lentil-3 |
| | Gram | BARI Gram-5 |

## Table 5.8. Yield of popular crop varieties cultivated in Rajshahi

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 1** | Mango (Himsagor) | | | 50 |
| | Mango (Fazlee) | | | 30 |
| | Mango (Langra) | | | 30 |
| | Mango (Lokkhonvog) | | | 40 |
| | Mango (Amropali) | | | 90 |
| | Mango (BARI-4) | | | 90 |
| | Mango (Totapuri) | | | 30 |
| | Mango (Ashwina) | | | 60 |
| | Mango (Gourmoti) | | | 60 |
| | Banana | | | 70 |
| | Mango (Katimon) | | | 30 |
| | BRRI Rice -48 | 5373 | 5.37 | |
| | BRRI Rice -82 | 4776 | 4.78 | |
| **Kharif 2** | Cucumber (Hybrid) | 57313 | 57.31 | 50 |
| | Cucumber (Local) | 53731 | 53.73 | 50 |
| | Pumpkin | 14030 | 14.03 | 40 |
| | Rice (Swarna) | 5672 | 5.67 | 15 |
| | ice (BRRI Rice-81) | 6567 | 6.57 | 15 |
| | Rice - BINA-7 | 5672 | 5.67 | |
| | Rice - Swarna | 6269 | 6.27 | |
| | BRRI Rice-51 | 5672 | 5.67 | |
| | BRRI Rice-87 | 7165 | 7.16 | |
| | BRRI Rice-75 | 6269 | 6.27 | |
| | BARI Black Gram-3 | 1045 | 1.04 | 50-60 |
| **Rabi** | Brinjal (Hybrid-422) | 76418 | 76.42 | 40 |
| | Guava (Thai-5,8,10) | 17910 | 17.91 | |
| | BARI Mustard-14 | 1500 | 1.50 | 188 |
| | BARI Mustard-17 | 1800 | 1.80 | 125 |
| | BARI Mustard-18 | 2300 | 2.30 | 188 |
| | BARI Mustard-9 | 1600 | 1.60 | 100 |
| | BARI Mustard-15 | 1500 | 1.50 | 88 |
| | TORI-7 | 800 | 0.80 | |
| | BARI Wheat-26 | 2687 | 2.69 | |

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| | BARI Wheat-28 | 2985 | 2.98 | 10 |
| | BARI Wheat-30 | 3881 | 3.88 | 30 |
| | BARI Wheat-32 | 3881 | 3.88 | 30 |
| | BARI Wheat-33 | 4478 | 4.48 | 40 |
| | Rice (Jira) | 5970 | 5.97 | |
| | BRRI Rice - 28 | 6567 | 6.57 | |
| | BRRI Rice-29 | 8060 | 8.06 | |
| | BRRI Rice-81 | 7165 | 7.16 | |
| | BRRI Rice-84 | 6866 | 6.87 | |
| | BRRI Rice - 89 | 8060 | 8.06 | |
| | BRRI Rice - 92 | 9254 | 9.25 | |
| | BARI Lentil-8 | 1642 | 1.64 | 30-40 |
| | BARI Gram | 1343 | 1.34 | |

## Table 5.9. Status of technology adoptionin Rajshahi

| Technology adopted | % of farmers adopted | | | | | | Yield increase (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mango | Guava | Mustard | Wheat | Rice | Gram/Lentil/Black gram | Mango | Guava | Mustard | Wheat | Rice | Gram/Lentil/Black gram |
| Application of vermin-compost/compost | 40 | 90 | 3 / 50 | 1 | 1 | 0 | 20 | 25 | 10-20 / 10-15 | 60 - 70 | | |
| Application of Guti Urea | 0 | | 0 | | 0.1 | 0 | 0 | | | 60 - 70 | | |
| Alternate wetting and drying irrigation: (AWD) | 100 | | 0 | | 0.2 | 0 | 0 | | | 70 - 80 | | |
| Using hybrid seeds | | | 0 | | 5 | 0 | 50 | | | | 1-2 | |
| Use good quality seeds | | 40 | 80 | | 10 | 80/80/10 | 100 | 20 | 50 | 80 - 90 | 4-5 | 0/30-40/80 |
| Practice IPM | | 20 | 0 | | 20 | 0 | 20 | 10 | | | 8-70 | |
| Cultivate Flood resilient rice variety | 0 | | | | 5 | | | | | | | |
| Cultivate Drought resilient variety | 0 | 15 | 0 | | 3 | 100 | | | | 70 - 80 | | |
| Improved Weed management practices | 90 | | 10 | | 10 | 0/20/0 | 90 | 25 | 5-15 | 60 - 70 | | 0/50/0 |
| Other technology | | | 10 | | | 90 | | 15 | 30-45 | 10 - 15 | | 20/50/60 |

## Table 5.10. Constraints and Solutionsin Rajshahi

| Major constraints | Solutions |
|---|---|
| 1. Marketing system is inadequate | 1. Improving the market system, increasing international industry, and increasing exports. |
| 2. Problems of raw material processing industry and small-scale export | 2. Powdery milk and tolerant varieties are required |
| 3. Irrigation problems of small farmers | 3. Pruning is required |
| 4. Fertilizer prices and market system are defective | 4. Informing the farmers about new varieties. |
| 5. 5. Not informing the farmers about new varieties | 5. Good seed supply |
| 6. Not being aware of the allocation of exhibition plots | 6. Grants to actual farmers |
| 7. Farmers are reluctant to introduce new varieties | 7. Ensuring fair prices of produced products |
| 8. Lack of good seeds | 8. Increase monitoring of agricultural manpower at field level |
| 9. Not getting a fair price for the produced product | 9. Skill development of marginal farmers through adequate training |
| 10. Failure to include real farmers in government grants or exhibitions | 10. Cultivation of short-term paddy in *Aman* season |
| 11. In the case of BARI Mustard-14, the problem arises when it rains in late October to early November. | 11. 100% wheat farmers need training |
| 12. Due to long term paddy cultivation in *Aman* season, BARI Mustard 14 and 17 are facing problems. | 12. Supply of quality seeds to 100% |
| 13. Invasion of pest | 13. Provide training on modern machinery and technology |
| 14. Lack of knowledge of farmers about technology and varieties | 14. Creating representative farmers and operators |
| 15. Lack of technical knowledge and skills about machinery and modern technology | 15. Creation and training of mechanic cum operations |
| 16. Lack of quality equipment as per demand | 16. Use of heat and drought tolerant and disease resistant varieties |
| | 17. Proper sowing and proper care |
| | 18. Use of balanced fertilizer. |
| | 19. Use of modern and machinery technology such as bed planter, sider and strip tillage |
| | 20. Sowing wheat seeds in line |
| | 21. Weed control at the right time |
| | 22. Timely irrigation management |
| | 23. Rat control |
| | 24. The use of conservational agricultural technology |
| | 25. Creating local seed entrepreneurs |
| | 26. Increasing production of seeds by BADC |
| | 27. To train farmers on pest control and management techniques. |

## Jessore Validation Workshops-FGD DATA

### Table 5.11. Main crops cultivated in Jashore Sadar

| Crop season | Crops cultivated |
|---|---|
| **Kharif 1** | Bitter gourd, Brinjal, Cowpea, Cucumber, Pumpkin, Chilli, *Aus* Rice, Snake, Bottle Gourd, Jute, Mung, Till, Bulbous root of the arum, Patol, Papaya, Puishak, Red Spinach,Green Vegetables |
| **Kharif 2** | Papaya, Bottle Gourd, Zucchini, Snake gourd<br>Lady's Finger, T.*Aman* Rice, Purple Yam, Bean, Tomato, Cucumber, Patol, Sponge gourd, Watermelon, Pumpkin, Puishak, Kalmi Shaak, Green Vegetables, Red Spinach, Lady's Finger, Chili, Mango, Litchi |
| **Rabi** | Olkopi, Cauliflower, Cabbage, Red amaranth, Green Vegetable, Bean, Kochu, Radish, Carrot, Chili, Onion, Garlic, Coriander, *Boro* Rice, Tomato, Brinjal, Cowpea, Turnip, Spinach, Potato Broccoli, Spinach, Red Spinach, Bottle Gourd, Mustard, Lentil, Gram, Wheat, Maize, Sunflower, Sweet Potato |

### Table 3.2. Popular crop varieties cultivatedin Jashore Sadar

| Crop season | Crops cultivated | Name of Varieties cultivated |
|---|---|---|
| **Kharif 1** | Brinjal | Ball Brinjal |
| | Cucumber | Baropata(Endhira),Shila(Lalteer),Baromasi(Lalteer), Golpata Nargis, Alavi Green(Lalteer), Green Line(United) |
| **Kharif 2** | Brinjal | Chega Brinjal |
| | Cucumber | Alavi, Green Line, Moyna Pakhi, Thailand-1, Paragas(Masud Seed), Moyna Moti |
| **Rabi** | Caulifloer | Ninja, Hybrid-11, Bigshort, Monobox, Mono White, White Metal |
| | Cabbage | Tropical Quick, Quicker, Green-60, Early Hot, Atom |
| | Brinjal | Vangor Brinjal |
| | Cucumber | Alavi, Pagasas, Green Line |

### Table 5.12. Yield of popular crop varieties cultivatedin Jashore Sadar

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 1** | Brinjal (Ball Brinjal) | 44478 | 44.48 | 12.5 |
| | Cucumber (Baropata-Endhira) | 16803 | 16.80 | 40 |
| | Cucumber (Shila-Lalteer) | 26687 | 26.69 | 40 |
| | Cucumber (Baromasi- Lalteer) | 15814 | 15.81 | 40 |
| | Cucumber (Golpata Nargis) | 29949 | 29.95 | 40 |
| | Cucumber (Alavi Green) | 44478 | 44.48 | 40 |
| | Cucumber (Green Line-United) | 44478 | 44.48 | 40 |
| **Kharif 2** | Brinjal (Chega Brinjal) | 86485 | 86.49 | 25 |
| | Cucumber (Alavi) | 29652 | 29.65 | 40 |
| | Cucumber (Green Line) | 29652 | 29.65 | 40 |
| | Cucumber (Moyna Pakhi) | 17791 | 17.79 | 40 |
| | Cucumber (Thailand-1) | 29652 | 29.65 | 40 |
| | Cucumber (Pagasas-Masud Seed) | 32617 | 32.62 | 40 |
| | Cucumber (Moynamoti) | 17791 | 17.79 | 40 |
| **Rabi** | Cauliflower – Ninja 50. 54, 55, 56, 58 | | | 35-40 |
| | Cabbage – 85,90,92,105 | | | 35-40 |
| | Brinjal (Vangor Brinjal) | 69188 | 69.19 | 17 |
| | Cucumber (Alavi) | 44478 | 44.48 | 40 |
| | Cucumber (Pagasas) | 44478 | 44.48 | 40 |
| | Cucumber (Green Line) | 34594 | 34.59 | 40 |

### Table 5.13. Status of technology adoptionin Jashore Sadar

| Technology adopted | % of farmers adopted | | | Yield increase (%) | | |
|---|---|---|---|---|---|---|
| | Cauli/ Cabbage | Brinjal | Cucumber | Cauli/ Cabbage | Brinjal | Cucumber |
| Application of vermin-compost/compost | 80 | 70 | | 30 | 10 | |
| Application of Guti Urea | 1 | | | 20 | | |
| Alternate wetting and drying irrigation: (AWD) | 40 | | | 10 | | |
| Using hybrid seeds | | | | | | |
| Use good quality seeds | 85 | 90 | | 50 | 20 | 50 |
| Practice IPM | 30 | 50 | | 20 | 10 | |
| Cultivate Flood resilient variety | 20 | | | 10 | | |
| Cultivate Drought resilient variety | 20 | | | 10 | | |
| Improved Weed management practices | 90 | | | 30 | | 5-15 |
| Other technology | | | | | | 30-45 |

### Table 5.14. Constraints and Solutionsin Jashore Sadar

| Major constraints | Solutions |
|---|---|
| 1. Lack of timely seed technology | 1. Make seed technology readily available |
| 2. Irrigation system is not readily available | 2. Improving irrigation system |
| 3. Lack of technological knowledge | 3. Receive training on technology |
| 4. Lack of knowledge to identify diseases and insects | 4. Cultivation through IPM technology |
| 5. Do not cultivate in the same field | 5. Get training on crop diseases and insects |
| 6. Attacked by bacteria | 6. Simultaneous cultivation in the same field. |
| 7. BSFB fail and tip piercing insects | |
| 8. Leaf wrinkles | |
| 9. Infected by virus and falling basil | |

## Patuakhali Validation Workshops- FGD DATA

### Table 5.15 Main crops cultivated in Patuakhali

| Crop season | Crops cultivated |
|---|---|
| **Kharif 1** | T.*Aus*, Sesame, Danta, Snake Gourd, Luffa, Yard long bean, Wax Gourd, Patshak, Water spinach, Gourd, Pumpkin, Eggplant, Papaya, *Aus*, Jute |
| **Kharif 2** | T.*Aman*, Bitter gourd, Gourd, Pumpkin, Cucumber, Yardlong Bean, Eggplant, Tomato, Papaya, *Aman* Rice |
| **Rabi** | Mung Bean, Black pea, Lentils, Sesame, Water melon, Muskmelon, Cucumber, Bitter Gourd, Bean, Luffa, Sunflower, Eggplant, Tomato, Chili, Ground Nut, Maize, Potato, Pumpkin, Carrot, Papaya, Lalshak, Onion, Garlic, Coriander, Wheat, Groundnut, Grass Pea, *Boro* Rice, Chili, Watermelon, Sweet Potatoes |

## Table 5.16. Popular crop varieties cultivated

| Crop season | Crops cultivated | Name of Varieties cultivated |
|---|---|---|
| **Kharif 1** | Grass Pea | BARI-1, BARI-2, Local |
| | Lentil | Local, BARI-6, BARI-5 |
| **Kharif 2** | | |
| **Rabi** | Mung Bean | BARI Mung-6 |

## Table 5.17. Yield of popular crop varieties cultivated

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 1** | Grass Pea (BARI Grass pea-1) | 1200 | 1.20 | 33 |
| | Grass Pea (BARI Gras Pea-2) | 1100 | 1.10 | 22 |
| | Grass Pea (Local) | 800 | 0.80 | 10 |
| | Lentil (Local) | 950 | 0.95 | |
| | Lentil (BARI-6) | 1200 | 1.20 | 25 |
| | Lentil (BARI-5) | 1000 | 1.00 | |
| **Rabi** | Mung Bean (BARI-6) | 1450 | 1.45 | 75 |

## Table 5.18. Status of technology adoption

| Technology adopted | % of farmers adopted | | | Results: Yield increase (%) | | |
|---|---|---|---|---|---|---|
| | Grass Pea | Lentil | Mung Bean | Grass Pea | Lentil | Mung Bean |
| Application of vermin-compost/compost | | | | | | |
| Application of Guti Urea | 80 | | | 50 | | |
| Alternate wetting and drying irrigation: (AWD) | | | | | | |
| Using hybrid seeds | | | | | | |
| Use good quality seeds | 25 | 80 | 80 | 22-33 | 30 | 80 |
| Practice IPM | | 5 | 15 | | | .1 |
| Cultivate Flood resilient rice variety | | | | | | |
| Cultivate Drought resilient variety | | 70 | | | 50 | |
| Improved Weed management practices | | 100 | 50 | | 80 | 50 |
| Other technology (Specify) | | 75 | 10-15 | | | 10-15 |

## Table 5.19. Constraints and Solutions

| Major constraints | Solutions |
|---|---|
| 1. Farmar has Lack of knowledge about improved varieties. | 1. To increase the knowledge of farmers through regular training. |
| 2. Lack of availability of improved varieties of seeds. | 2. Creating agri-entrepreneurs for seed production |
| 3. Lack of timely supply of seeds | 3. Timely supply of seeds is ensured. |
| 4. Late Sowing | 4. (Blide Attack) Resistant Varieties Need. |
| 5. Low Land | 5. Heat and salt tolerant need. |
| 6. Blide attack at Branching | 6. Post-Harvest processing technology adoption. |
| 7. Post-harvest processing. | 7. Ensuring good quality seeds of improved varieties. |
| 8. Lack of good quality seeds and unawareness of farmers. | 8. To increase the availability of integrated pest management tools and to provide training. |
| 9. Unawareness of the use of insect and diseases pest management technology. | 9. Beribadha and switch gate to make face farming risk free, Canal excavation needs to be developed. Besides, waterlogging and salinity tolerant varieties need to be developed. |
| 10. Since mung bean is a risky crop, farmers are reluctant to accept expensive intercrops. | 10. Fertilizer pesticides should be used as per the advice of agriculture officials. |
| 11. Pesticide abuse (not taking the advice of agricultural officials) | 11. Light irrigation should be arranged. |

**Annex 6 Results of Focus Group Discussion**

For the purpose of understanding the varieties of selected crops cultivated, their yield, technologies adopted, problems faced and possible solutions and validate results of ARIMA models, Focus Group Discussion (FGD) with farmers and different stakeholders were conducted in different locations of Bangladesh. Theresults obtained from FGDs in different places are discussed below.

**Pabna**

The important crops cultivated in this area are: Rice, wheat, maize, jute, potato, pulses, oilseeds, spices, vegetables as well as mango. The main varieties cultivated include BRRI 19, 21, 48, 81 for *Aus*; BRRI 7, 17, 26, 48, 49, 58, 75, 82, 87 for *Aman*; BARI 26, 30, 32 for wheat; MK 40 for maize; Indian, Baraun, BADC, Chaka for Jute; BARI 36, 41, 53, 63 for Potato; BARI 14, 17 for Mustard; BARI 3, 4 for Sesame; BARI 6 for Mung bean; and BARI begun for Brinjal.

The yield per hectare of major crops stands at: *Aus* 4.5 MT; *Aman* 5-6 MT; Jute 3-4 MT; Wheat 3 MT; Maize 10 MT; Mustard 1.2 MT; Potato 21 MT; Onion 19.5 MT; lentil 2 MT. In case of Mango, it ranges from 4 MT to 30 MT for different varieties. Due to adoption of improved varieties, the yield rose by 5% for BARI mango variety to 40% for BARI 8 lentil variety.

The yield increased by 20-30% after using compost by almost all wheat and mango farmers. All Mango farmers reportedly used Guti (granular) urea. About Alternate wetting and drying irrigation (AWD), 100% mustard and 30% wheat farmers adopted this technology and the yield increased by 90% and 30% respectively. Four-fifth of lentil farmers and two-fourth wheat farmers used hybrid seeds while all wheat and onion farmers and majority mustard and lentil farmers used good quality seeds. Practicing of IPM technology is not satisfactory as very few farmers adopted it. Only in case of mustard cultivation stress tolerant varieties are cultivated in this location. Improved weed management is practiced by majority of cultivators in this area. The important problems identified are: nonavailability of good quality seeds, lack of proper training, nonexistence of irrigation facilities, lack of knowledge and nonavailability of new technology and damage of crops by natural calamities.

**Chilmari, Kurigram**

Rice, Jute, Maize, Potato, Lentil, Black Gram, Grass pea, Pea, Black gram, Mustard, Groundnut, Onion, Garlic, Vegetables are the main crops grown in this area. The important varieties of crops grown in this area include: BINA 7, BRRI 17, 28, 81 for *Aus*; Ganjia (Local) for *Aman*; OVI-1, NAVI, Indian Variety, ROBI-1, N-8, N-7, Kenaf for Jute; BARI 25, 36, 37, 39, 40, 41, 47, 48, 53, 62 for Potato; BARI 3,4,5,6 for lentil; BARI 5,7,9,11 for chickpea; Local Khesari, BARI- 3 for Grass pea, BARI 14,15,18 for mustard; BARI nut 4,8,9 for groundnut; BARI sunflower 1,2 for sunflower; BARI 1,2 for onion, and BARI 1,2,3,4 for garlic.

The yields of different crops estimated at: Rice (HYV) 8MT; Rice (Local) 2MT; Jute 1-5 MT; Maize 12 MT; Potato 6 MT; Lentil 1-1.5 MT; Grass Pea 1-1.4 MT; Chick Pea 3 MT; Black Gram 1.5-1.7 MT; Mustard 1.5-2 MT; Groundnut 1-2 MT; Sunflower 2 MT; Onion 12 MT; and Garlic 9 MT. The yield increased due to cultivation of improved varieties ranges from 55% for rice to 10% for Potato, chickpea and garlic.

One-half of lentil farmers are reported to use compost and yield increased by15%. Due to use Guti urea by all groundnut farmers, yield rose by 20%. About 70% to 80% yield increased owing to applying AWD method by majority of lentil producers. Only black gram farmers used Hybrid seeds but most of the lentil and groundnut farmers reportedly used good quality seeds. All famers cultivated flood resilient seeds for ground nut and grass pea production while in case of lentil drought resilient varieties were used by 100% lentil producers. Only mustard farmers are found to adopt improved weed management practice. Farmers are reported to encounter different problems such as nonavailability of irrigation facilities; timely nonavailability of quality seeds; lack of knowledge, consciousness, adoption demonstration and training; attack by different diseases and pests and high marketing costs etc.

**Palashbari, Gaibandha**

The important crops cultivated in this area are: *Aman*, *Boro*, Jute, Maize, Potato, Mustard, Banana and different types of vegetables such as Cucumber, Okra, Brinjal, Teasle gourd, Pointed gourd, Lalshak, Arum, Cauliflower, Cabbage, Radish, Bean, Pumpkin, Bottle Gourd, Carrot, etc.

The important varieties of crops cultivated in this area are: Hybrid 89,1203 for *Aus*; BRRI11, 49, 52, Shawrna, Guti, Kalojira, Ranjit for *Aman*, BRRI28, 29, 81, 89 and Hybrid 28 for *Boro*; Cardinal, Pakri, Astrix, BARI Potato 28, Granular, Sunflower, Romana, Azesta, Lalpagri, Fatapakhi for Potato; Enak40, Hybrid546, BARI Maize 9 for Maize; Tosa, Local for Jute; BARI 4,14, Tory for Mustard; Hybrid for cucumber, Pumpkin and Pointed gourd; Lalteer, Srimoti, Khirshapati, Narikel jhupi, Shinghnath for Brinjal; Sylheti, Purikochu, Local for Taro; Tashaddhiman, Local for Radish; Snow white for Cabbage; Atlas for Cauliflower; and Ranghin Shagor, Sobri, BARI Banana 4, Chini Champa, Kanaibishi for Banana.

The yields of different crops are estimated at: *Aman* 4-5 MT; Maize 11-15 MT; Potato 15-24 MT; Mustard 5 MT; Brinjal 21-25 MT; Pointed Gourd 24 MT; Taro 11-16 MT; and Banana 90 MT.

Application of compost is very common for banana, Maize and potato cultivation and by applying this the yield rose by 30 to 100%. Regarding guti urea application, 90% Maize farmers used it. While, all Banana farmers and 90% Maize farmers practiced AWD methods for irrigation. Majority of farmers used good quality seeds but a few of them cultivate Hybrid seeds. Cultivation of stress tolerant varieties and adoption of weed management practice is rare in this location. The main problems identified are: infection of diseases and pest attack; lower prices at harvest time; lack of warehouse for storing perishable crops temporarily; nonavailability of good seeds timely; lack of irrigation facilities, high cost of marketing etc.

## FGD – Pabna Sadar

### Table 6.1 Main crops cultivated in Pabna

| Crop season | Crops cultivated |
|---|---|
| **Kharif 1** | Jute, *Aus* Rice, Sesame, Mung bean, Onion, Garlic |
| **Kharif 2** | *Aman* Rice, Black gram, Brinjal |
| **Rabi** | *Boro* Rice, Wheat, Maize, Mustard, Lentil, Grass pea, Pea, Potato, Lal shak, Spinach, Radish, Cabbage, Cauliflower, Bottle Gourd, Tomato, Carrot,Brinjal,Mango |

### Table 6.2. Popular crop varieties cultivatedin Pabna

| Crop season | Crops cultivated | Name of Varieties cultivated |
|---|---|---|
| **Kharif 1** | Jute | Indian, BADC, Chaka, baurani |
| | Sesame | BARI-3, BARI-4, BARI-4, Local |
| | Mung Bean | BARI-6 |
| | Potato | BARI-36, BARI-41, BARI-63, BARI-53 |
| | *Aus* Rice | BARI-21, BARI-19, BARI-81, BARI-48 |
| **Kharif 2** | *Aman* Rice | BINA-7, BARI-17, BARI-49, BARI-48, BARI-58, BARI-26, BARI-82, BARI-87, BARI-75 |
| | Brinjal | BARI Bagun |
| **Rabi** | Maize | MK40 |
| | Cowpea | Local |
| | Gourd | Hybrid |
| | Mustard | BARI-14, BARI-17, Tory-7, BARI-14, BARI-17, BARI-18, BARI-11, BARI-18 |
| | Wheat | BARI-26, BARI-30, BARI-32, BARI-28, BARI-26, BARI-33 |
| | Lentil | BARI-3, BARI-5, BARI-6, BARI-7, BARI-8, BARI-84 |
| | *Boro* Rice | BARI-28, BARI-29, BARI-88, BARI-89 |

### Table 6.3. Yield of popular crop varieties cultivatedin Pabna

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 1** | Jute (Indian) | 3706 | 3.71 | |
| | Sesame (Local) | 1730 | 1.73 | |
| | Mung bean (BARI-6) | 1977 | 1.98 | |
| | Potato (BARI-34) | 21004 | 21.00 | 30 |
| | Jute (Chaka) | 2965 | 2.97 | 20 |
| | *Aus* Rice (BRRI-48) | 4448 | 4.45 | 20 |
| | Sesame (BARI-4) | 1112 | 1.11 | 20 |
| | Mango (BARI-4) | 14925 | 14.93 | 30 |
| | Mango (Amropali) | 11194 | 11.19 | |
| | Mango (BARI-11) | 3731 | 3.73 | 5 |
| **Kharif 2** | *Aman* Rice (BINA-7) | 5931 | 5.93 | 20 |
| | *Aman* Rice (BRRI-17) | 5436 | 5.44 | |
| | *Aman* Rice (BRRI-49) | 6425 | 6.42 | |
| | *Aus* Rice (BRRI-48) | 11861 | 11.86 | |
| | *Aman* Rice (BINA-17) | 5931 | 5.93 | 30 |
| | Mango (Local) | 29851 | 29.85 | |
| | Mango (Gopalbhogh) | 11194 | 11.19 | |
| | Mango (Langra) | 29851 | 29.85 | |
| | *Aman* Rice (BINA-87) | 5931 | 5.93 | 25 |

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| Rabi | Maize (MK-40) | 10378 | 10.38 | |
| | Cowpea (Local) | 1977 | 1.98 | |
| | Onion (Taherpuri) | 19521 | 19.52 | |
| | Mustard (BARI-14) | 1236 | 1.24 | |
| | Wheat (BARI-26) | 2718 | 2.72 | 30 |
| | Lentil (BARI-8) | 1637 | 1.64 | 40 |
| | Lentil (BARI-6) | 1832 | 1.83 | |
| | Lentil (BARI-7) | 1832 | 1.83 | |
| | Wheat (BARI-28, BARI-30, BARI-32) | 2965 | 2.97 | 30 |
| | Mango BARI-(Gurmoti) | 7463 | 7.46 | 10 |

## Table 6.4. Status of technology adoptionin Pabna

| Technology adopted | % of farmers adopted | | | | | Yield increase (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Onion | Wheat | Lentil | Mango | Mustard | Onion | Wheat | Lentil | Mango | Must ard |
| Application of vermin-compost/compost | | 90 | | 95 | 20 | | 30 | | 20 | 60 |
| Application of Guti Urea | | 0 | | 100 | | | | | | 0 |
| Alternate wetting and drying irrigation (AWD) | | 30 | | | 100 | 30 | | | | 90 |
| Using hybrid seeds | | 40 | 80 | | 10 | | | | | 30 |
| Using good quality seeds | 100 | 100 | 90 | | 60 | 80 | | | | 60 |
| Practice IPM | 30 | | | | 20 | 30 | | | | 20 |
| Cultivate Flood resilient rice variety | 0 | | | | 80 | 0 | | | | 0 |
| Cultivate Drought resilient variety | 0 | | | | 80 | 0 | | | | 20 |
| Improved Weed management practices | 100 | | 85 | 50 | 90 | 30 | | | | 20 |
| Other technology | | | | 50 | 6 | 100 | | | 10 | |

## Table 6.5. Constraints and Solutionsin Pabna

| Major constraints | Solutions |
|---|---|
| 1. Lack of knowledge and information | 1. Providing Training |
| 2. Lack of field Demonstration. | 2. Demonstrations and field visit |
| 3. Lack of good quality seeds | 3. Ensuring good quality seeds. |
| 4. Lack of proper Training | 4. Ensuring market value of the Crop produced |
| 5. Lack of irrigation | 5. Ensuring irrigation system |
| 6. Lack of pesticides | 6. Supply of Excellent pesticides |
| 7. Contaminated Pesticides | 7. Supply good quality seed based on necessity. |
| 8. Lack of knowledge about new technology. | 8. Ensuring training arrangements. |
| 9. The machines needed to use the new technology are not readily available | 9. Provides quality finished and reliable seeds. |
| 10. Lack of quality completed and reliable work. | 10. Can be solved special technical arrangements. |
| 11. Mangoes are damaged due to extreme drought and heavy rains or natural calamities. | 11. Market monitoring is required. |

## FGD – Chilmari, Kurigram

### Table 6.6. Main crops cultivated in Chilmari

| Crop season | Crops cultivated |
|---|---|
| **Kharif 1** | Lentil, Groundnut, Kaun Rice, Jute, Vegetables, *Aus* Rice |
| **Kharif 2** | Lentil, Groundnut, Black Gram |
| **Rabi** | Grasspea, Mustard, Lentil, Groundnut, Black gram, Pea, Cowpea, Potato, Maize, Onion, Garlic, *Boro*Rice |

### Table 4.2. Popular crop varieties cultivatedin Chilmari

| Crop season | Crops cultivated | Name of varieties cultivated |
|---|---|---|
| **Kharif 1** | Lentil | BARI-5, BARI-6 |
| | *Aus* Rice | BINA-7, BINA- 17, BINA- 28, BINA-81 |
| | Jute | OVI-1, NAVI, Indian Variety, ROBI-1, N-8, N-7, Kenaf |
| | Maize | Hybrid |
| | Groundnut | BARI Nut-4, BARI Nut-9 |
| **Kharif 2** | Lentil | BARI-3, BARI-4 |
| | *Aman* Rice | Ganjia (Local) |
| | Chickpea | BARI-9, BARI-5, BARI-7, BARI-11 |
| | Sunflower | Sunflower- 2, Sunflower-3 |
| | Potato | BARI-53, BARI-41, BARI-62, BARI-25, BARI-36, BARI-37, BARI-39, BARI-40, BARI-41, BARI-47, BARI-48 |
| **Rabi** | Lentil | BARI-5, BARI-6 |
| | Groundnut | BARI Nut- 4, BARI Nut- 8, BARI Nut-9 |
| | Black Gram | BARI Mash-3, BARI-1, BARI-2 |
| | Mustard | BARI-18, BARI-14, BARI-15 |
| | Grasspea | Local Khesari |
| | Onion | BARI-1, BARI-2 |
| | Garlic | BARI-1, BARI-2, BARI-3, BARI-4 |
| | Grass pea | BARI- 3 |

### Table 6.7. Yield of popular crop varieties cultivatedin Chilmari

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 1** | Lentil (BARI-5, BARI-6) | 1493 | 1.49 | 40 |
| | Rice (BINA-7) | 8377 | 8.38 | 55 |
| | Rice (BINA-17) | 8377 | 8.38 | 55 |
| | Rice (BINA-28) | 8228 | 8.23 | 55 |
| | Rice (Ganjia) | 2224 | 2.22 | |
| | Rice (BIRI-28) | 5092 | 5.09 | 37.5 |
| | Jute (OVI-1) | 1796 | 1.80 | 33 |
| | Jute (NAVI) | 2394 | 2.39 | 33 |
| | Jute (Kenaf, Robi-1, N-8, N-7) | 899 | 0.90 | 50 |
| | Maize (Hybrid) | 11861 | 11.86 | |
| | Jute (Robi) | 1606 | 1.61 | 20 |
| | Grass Pea (BARI-1) | 899 | 0.90 | |
| | Grass Pea (BARI-3) | 1423 | 1.42 | 30 |
| | Groundnut (BARI-4,9) | 1348 | 1.35 | 10 |

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 2** | Lentil (BARI-3, BARI-4) | 957 | 0.96 | 50 |
| | Grass Pea (BARI-1) | 899 | 0.90 | |
| | Grass Pea (BARI-3) | 1423 | 1.42 | 30 |
| | Chick Pea (BARI Chick Pea-10) | 2995 | 3.00 | 10 |
| | Sunflower-2,3 | 2097 | 2.10 | 20 |
| | Potato (BARI Potato-62) | 5990 | 5.99 | 10 |
| **Rabi** | Lentil (BARI-5, BARI-6) | 1154 | 1.15 | 35 |
| | Groundnut (BARI-4) | 1730 | 1.73 | 50 |
| | Groundnut (BARI-8) | 2095 | 2.10 | 50 |
| | Groundnut (BARI-9) | 2095 | 2.10 | 50 |
| | Blackgram(BARI Mash-3) | 1648 | 1.65 | 50 |
| | Mustard (BARI-14) | 1497 | 1.50 | 40 |
| | Mustard (BARI-15) | 1497 | 1.50 | 40 |
| | Mustard (BARI-18) | 2095 | 2.10 | 40 |
| | Grass Pea(BARI Grass Pea-3) | 1360 | 1.36 | 50 |
| | Onion (BARI-4) | 11981 | 11.98 | 20 |
| | Garlic-1,2,3,4 | 8985 | 8.99 | 10 |
| | Black Gram-3 | 1498 | 1.50 | 20 |

## Table 6.8. Status of technology adoptionin Chilmari

| Technology adopted | % of farmers adopted | | | | | Yield increase (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lentil | Ground nut | Grass Pea | Black Gram | Mus tard | Lentil | Ground nut | Grass Pea | Black Gram | Mus tard |
| Application of vermin-compost/compost | 50 | 5 | 0 | | 20 | 15 | 4 | 5 | 40 | 20 |
| Application of Guti Urea | | 100 | 0 | | 100 | 5 | 20 | | | 20 |
| Alternate wetting and drying irrigation: (AWD) | 90 | 0 | 0 | 20 | 50 | 70-80 | 0 | | | 60 |
| Using hybrid seeds | | | | 60 | | | | | | |
| Use good quality seeds | 90 | 100 | 30 | | 50 | 65 | 30 | 20 | 10 | 50 |
| Practice IPM | 10 | 6.60 | | | 50 | 10 | 10 | | | 30 |
| Cultivate Flood resilient rice variety | 10 | 100 | 100 | | 40 | 70 | 100 | 20 | | 90 |
| Cultivate Drought resilient variety | 100 | 0 | 0 | | 60 | 90 | 0 | 20 | | 50 |
| Improved Weed management practices | | 0 | | | 60 | 100 | 0 | | | 40 |
| Other technology | | | | | | 20 | 50-60 | | | 40 |

## Table 6.9. Constraints and Solutionsin Chilmari

| Major constraints | Solutions |
|---|---|
| 1. Irrigation problems | 1. Ensuring timely provision of seeds and irrigation |
| 2. Problems with quality seeds and seeds are not available on time. | 2. Ensuring good quality seeds |
| 3. Transportation and travel problems | 3. Ensuring adequate training and weather information |
| 4. Lack of knowledge, consciousness, adopting, demonstration, training, field day and good quality seeds | 4. Ensuring to provide saplings |
| 5. Insect problems | 5. More training required for improved production technology |
| 6. Imports are not available | 6. Construction of roads for improved transportation |
| 7. Unavailability of quality seeds | 7. Ensuring seed and fertilizer dealer at the local level |
| 8. Heavy rain damages the sown seeds that create the great loss | 8. Ensuring disease resistance variety |
| 9. Intensive attack of powdery milidion during mature stage | 9. 9. Improving transportation system through bridge and roads |
| 10. Marketing cost is so high due to distance from village to market. | 10. To take effective measures in flood prone areas. |
| 11. Arrange for training on how to plant new varieties. | 11. To arrange for direct supply of seeds to the char areas. |
| 12. Flood | 12. To take measures of solar power to solve the problem of irrigation |
| | 13. Government officials in charge of farmers are always in touch and solve any problem |
| | 14. To provide government allowances to the farmers in the char areas and extend a helping hand. |

## FGD - Palashbari Gaibandha

## Table 6.10. Main crops cultivated in Palashbari

| Crop season | Crops cultivated |
|---|---|
| **Kharif 1** | Cucumber, Okra, Brinjal, Kakrol, Patol, Aroid, Potato, Banana |
| **Kharif2** | *Aman* Rice, Banana, Lady's Finger, Brinjal, Kakrol, Cucumber, Lalshak, Arum, Potato, Jute |
| **Rabi** | *Boro* Rice, Potato, Cauliflower, Cabbage, Radish, Bean, Pumpkin, Gourd, Carrot, Aroid, Purikochu, Mileti, Maize, Mustard |

## Table 6.11. Popular crop varieties cultivatedin Palashbari

| Crop season | Crops cultivated | Name of Varieties cultivated |
|---|---|---|
| Kharif 1 | 1.*Aus*h Rice | Hybrid-1203, Hybrid-89 |
| | 2.Taro | Sylheti, Purikochu Loca;l |
| | 3.Cucumber | Hybrid |
| | 4.Pumpkin | Hybrid |
| | 5.Brinjal | Lalteer, Brinjal, Srimoti, Khirshapati, Narikel jhupi, Shinghnath, |
| | 6.Patal | Hybrid |
| | 7.Potato | Strick |
| | 8.Banana | Bari Banana-4 |
| Kharif 2 | 1.*Aman* Rice | Shawrna, Guti Shawrna, Rice BR-11, Kalojira, Ranjit |
| | 2.BIRI Rice | BRRI-49, BRRI-52 |
| | 3.Banana | Ranghin Shagor, Sobri Banana, BARI Banana -4, Chini Champa, Kanaibishi |
| | 4.Jute | Tosha Jute, Local Jute |
| Rabi | 1.Rice | BRRI-28, 29, 81, 89 and Hybrid-28 |
| | 2.Potato | Cardinal, Pakri, Astrix, BARI Potato -28, Granlu, Sunflower, Romna, Azesta, Lalpagri, Fatapakhi |
| | 3.Radish | Tashaddhiman , Local |
| | 4.Cabbage | Snow white |
| | 5.Cauliflower | Atlas |
| | 6.Maize | Enak-40, Hybrid-546, BARI Maize-9, Hybrid |
| | 7.Mustard | BARI-14, BARI-4, Tory |
| | 8. Rice | Hybrid-28 |

## Table 6.12. Yield of popular crop varieties cultivatedin Palashbari

| Crop season | Varieties cultivated | Yield (kg/ha) | Yield (MT/ha) | Yield increase (%) |
|---|---|---|---|---|
| **Kharif 1** | 1.Brinjal (Shingnath | 25373 | 25.37 | 100 |
| | 2.Brinjal (Khirshapati) | 20896 | 20.90 | 100 |
| | 3.Patal (Hybrid) | 23881 | 23.88 | |
| | 4.Taro (Sylheti) | 16062 | 16.06 | 30 |
| | 5.Taro (Purikochu) | 11120 | 11.12 | |
| **Kharif 2** | 1.Banana (BARI Banana-4) | 89552 | 89.55 | 50 |
| | 2*Aman*. Rice (Sorna) | 3707 | 3.71 | |
| | 3.*Aman*Rice (Guti swarna) | 4201 | 4.20 | 20 |
| | 4.*Aman*Rice (Ranjit) | 4695 | 4.69 | 15 |
| | 5.*Aman*Rice (BR-11) | 4448 | 4.45 | |
| **Rabi** | 1.Potato (Cardinal) | 23881 | 23.88 | 150 |
| | 2. Potato (Cardinal) | 19768 | 19.77 | 20 |
| | 2.Potato (Sunflower) | 20896 | 20.90 | 120 |
| | 3. Potato (Pakri) | 14826 | 14.83 | |
| | 4. Potato (Astrix) | 22239 | 22.24 | 30 |
| | 5.Maize (Hybrid BARI-14) | 10448 | 10.45 | 25 |
| | 6.Mustard (BARI-14) | 5373 | 5.37 | 80 |
| | 7.Mustard (Tori) | 4744 | 4.74 | |
| | 8. Maize (Enak-40) | 10448 | 10.45 | 30 |
| | 9.Maize (Hybrid-546) | 12537 | 12.54 | 60 |
| | 10.Maize (BARI Maize-9) | 14925 | 14.93 | 50 |

## Table 6.13. Status of technology adoptionin Palashbari

| Technology adopted | % of farmers adopted | | | | | Yield increase (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Potato | Vegetable | Banana | Musta rd | Mai ze | Potato | Vegetable | Banana | Musta rd | Mai ze |
| Application of vermin-compost/compost | 60 | | 100 | 25 | 80 | 70 | | 50 | 100 | 30 |
| Application of Guti Urea | 0 | | | 0 | 90 | 0 | | | | 40 |
| Alternate wetting and drying irrigation: (AWD) | 0 | | 100 | 10 | 90 | 0 | | | 50 | 25 |
| Using hybrid seeds | 20 | | | | 30 | | | 60 | 90 | |
| Use good quality seeds | 80 | | 50 | 70-80 | 25 | | | 20 | 100 | 100 |
| Practice IPM | 0 | | 10 | 10 | 90 | | | 30 | 0 | |
| Cultivate Flood resilient rice variety | 0 | | | 30-40 | 20 | | | | 60 | 60 |
| Cultivate Drought resilient variety | 0 | | | 40 | | | | | | 80 |
| Improved Weed management practices | | | | | 10 | | | | 90 | 90 |
| Other technology | | | 100 | | 90 | | | 50 | 80 | 10 |

## Table 6.14. Constraints and Solutionsin Palashbari

| Major constraints | Solutions |
|---|---|
| 1. Rat Attack | 1. Need improved varieties |
| 2. Late Blight (Disease) | 2. Farmers need training to control the disease |
| 3. Prices are lower when picking potatoes | 3. Ensuring good seasonal and fair prices |
| 4. Lack of fair price | 4. Adequate arrangements for warehousing |
| 5. Lack of warehousing | 5. Research is needed to make good quality seeds |
| 6. Insect attack and problems | 6. To provide solar powered irrigation system |
| 7. Birds attack on mustard field | 7. Management of local banana marketing system |
| 8. Lack of irrigation facilities | 8. Needed govt. financial assistance for proper transportation arrangements of banana |
| 9. There is no temporary banana storage | 9. There is no preservation for banana and lack of proper pricing. |
| 10. The cost of transportation is higher in marketing | 10. The transportation cost of marketing is high so whole transportation system should be improved |
| 11. Lack of timely seeds | 11. Good quality pesticides need to be supplied and used. |
| 12. When the corn plant grows a little bigger, it dies, that is, when it becomes thora, it no longer grows. | 12. Regular supervision of agricultural officers in the field. |
| 13. Corn leaves turn white | 13. Provide advice on how to take effective measures to solve maize diseases. |

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## Pictorial View

*National Workshop at BARC*

*Inception Workshop at BARC*








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