SOUS LE PARRAINAGE DE MONSIEUR LE MINISTRE DE L'AGRICULTURE, DE LA PECHE MARITIME, DU DEVELOPPMENT RURAL ET DES EAUX ET FORETS

UNDER THE SPONSORSHIP OF MR THE MINISTER OF AGRICULTURE, FISHERIES, RURAL DEVELOPMENT, WATER AND FORESTS

PROCEEDINGS / COMPTES RENDUS

2ème Conférence de l'Association Panafricaine du Génie Rural (PASAE - AfroAgEng) sur le thème

ROLE DU GENIE RURAL DANS LA RELEVE DES DEFIS D'UNE SECURITE ALIMENTAIRE GLOBALE

2nd Conference of the Pan African Society for Agricultural Engineering (PASAE - AfroAgEng) on

ROLE OF AGRICULTURAL ENGINEERING IN MEETING THE CHALLENGE OF GLOBAL FOOD SECURITY

10 to 13 Septembre 2019

Conférence Center / Centre de Conférences - Mohammed VI Fondation

Rabat – MOROCCO

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Politiques et strategies nationales de mobilization des eaux et de développement de l'irrigation face aux défis alimentaires : Enjeux et perspectives. *Mr Amadou ABDOU*

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Pays/région	**République du Niger-Pays de l'Afrique de l'Ouest**
Intitulé du projet	**Projet d'Appui à la Sécurité Alimentaire phase 2 (PASA2)**
Type de projet	Projet à couverture inter région (Région de Dosso et de Tillabéry)
Tutelle administrative	Ministère de l'Agriculture et de l'Elevage (MAG/EL)
Tutelle technique	Direction Générale du Génie Rural (DGGR)
Organe de coordination	Unité d'Exécution du Projet (UEP)
Organes d'exécution	Points focaux, services techniques, bureau d'études, comités de gestion, fournisseurs, entrepreneurs
Organes d'orientation	Comité interministériel de Pilotage
Source et nature du financement	Cofinancement : Prêt BADEA et contre partie Etat du Niger
Zone d'intervention	• **Région de Dosso** : 6 départements, 15 communes et 23 sites • **Région de Tillabéry** : 2 départements, 4communes et 7 sites
Domaines d'intervention	Hydraulique agricole, agriculture, environnement, développement social
Montant du financement	• **6.940.000 $USD** soit 3.123.000.000 FCFA • **BADEA** (Prêt) : **6.200.000 $USD** soit 2.790.000.000 FCFA • **Niger** (contre partie) : **740.000 $USD** soit 333.000.000 FCFA
Durée	4 ans (2010-2014)
Date de signature de la convention	23 novembre 2009 au Caire en Egypte
Date d'entrée en vigueur	9 mai 2010
Date de démarrage	30Juin 2010
Date d'achèvement	31décembre 2013
Date de clôture	30 juin 2014
Objectif global du projet	Contribution au renforcement de la sécurité alimentaire et à la réduction de la pauvreté des populations des régions de Dosso et Tillabéry
Objectifs spécifiques du projet	• Contribuer à l'amélioration de la sécurité alimentaire des populations de la zone du projet, grâce à l'augmentation des productions agricoles • Protéger les terres de l'érosion et les villages de l'ensablement

	• améliorer l'exploitation des surfaces irriguées par les eaux pluviales • Contribuer à réduire la pauvreté et lever les souffrances des populations dans les zones cibles
Composantes du projet	• Composante A : Ouvrages hydrauliques • Composante B : Mise en valeur de terres agricoles • Composante C : Equipements de soutien • Composante D : Services des consultants • Composante E : Appui à l'UEP

Résumé du projet

Historique du projet

Le projet d'Appui à la Sécurité Alimentaire phase Il dans les régions de Dosso et Tillabéry (PASA2) est financé conjointement par la Banque Arabe pour le Développement Economique de l'Afrique (BADEA) à hauteur de **6.200.000 $ US** et le Gouvernement de la République du Niger pour sa contribution de **740.000 $ US**. Il fait suite à une première phase d'un projet qui s'est exécuté de mars 2003 à décembre 2009 et qui avait pour objectif global de contribuer à la réduction de la pauvreté dans les régions de Dosso et Tillabéry, par l'amélioration de la sécurité alimentaire en prévoyant la réalisation de micro-barrages, de périmètres villageois, la mise en place d'infrastructures et d'équipements socio-économiques, l'aménagement et la protection des terres de culture et l'appui aux producteurs .

Il faudra rappeler que la mise en œuvre de cette première phase a été affectée, entre autres, par la sous estimation des coûts des principales composantes (ouvrages structurants et aménagements terminaux). D'un coût global initial de **2.800.000.000FCFA**, le coût actualisé de cette phase s'élevait à **4.287.957.480 FCFA.** Avec le coût actualisé des principales composantes et la chute drastique du dollar américain (monnaie d'évaluation du projet) intervenue dans la même période, la première phase du PASA se trouve confrontée non seulement à une insuffisance de ressources financières mais également devant une situation financière limitant les moyens de ses ambitions.

C'est pourquoi**,** le Gouvernement de la République du Niger, a sollicité auprès de la BADEA, le financement de la deuxième phase du PASA, dans le but de consolider les acquis de la précédente phase, mais également d'exécuter l'ensemble des activités non réalisées, afin de renforcer la sécurité alimentaire dans les deux régions, réduire la pauvreté des populations, résorber les poches de déficits chroniques en céréales persistants.

Le projet dont la signature de l'accord de prêt est intervenue le 23 novembre 2009 au Caire en Egypte, mis en vigueur le 9 Mai 2010, intervient dans les régions de Dosso à travers deux départements (Boboye avec 3 sites et Dogondoutchi 4 sites) et Tillabéry à travers le département de Téra avec 3 sites.

Il avait pour objectif, à long terme, de contribuer au renforcement de la sécurité alimentaire et à la réduction de la pauvreté des populations de sa zone d'intervention et l'arrêt progressif de la dégradation des ressources naturelles.

Les objectifs immédiats étaient : l'augmentation de la production agricole à travers le développement des cultures irriguées, la restauration et la protection de l'environnement, et l'augmentation des revenus monétaires des ménages vulnérables de sa zone d'intervention.

La mise en œuvre du projet a été assurée par une Unité d'Exécution du Projet(UEP). L'exécution du projet a été placée sous la tutelle du Ministère de l'Agriculture(MAG) à travers la Direction Général du Génie Rural (DGGR).

La seconde phase du PASA d'une durée de 4ans, est articulée autour de cinq(5) composantes (i) Ouvrages hydrauliques ; (ii) Mise en valeur de terres agricoles ; (iii) Equipements de soutien ; (iv) Services des consultants ; (v) Appui à l'UEP. Le coût total du projet, évalué à 3.123.000.000FCFA en monnaie locale, est cofinancé par la Banque Arabe pour le Développement Economique en Afrique(BADEA) à hauteur de 89.34% et le Gouvernement de la République du Niger à hauteur de 10.66%.

Le projet s'inscrit parfaitement dans la politique agricole du gouvernement de la VIIème République à travers:

- l'axe stratégique 1 de l'Initiative « 3N » (Les Nigériens Nourrissent les Nigériens) : **« Accroissement et diversification des productions agro-pastorales et halieutiques »** qui vise entre autres à améliorer la capacité productive des terres et des eaux ;
- le programme d'investissement prioritaire I (PIP I) : « **accroissement des productions sous irrigation** » qui vise à accroitre la contribution de l'irrigation et de la collecte des eaux de ruissellement à la production agricole nationale ;
- le programme d'investissement prioritaire II (PIP II) : « **Amélioration des niveaux de rendement des cultures pluviales** » visant à augmenter de 35% les rendements sur 25% des superficies cultivées.

Exécution du projet

Le démarrage effectif de l'exécution du PASA2 a été précédé de la satisfaction de plusieurs préalables qui sont :

⇒ Le recrutement d'un ingénieur conseil chargé des études de faisabilité technico-économique des principales activités du projet à savoir les constructions de barrages et des aménagements à travers des études APD ;

⇒ La réalisation d'un diagnostic participatif pour faire un état des lieux et prendre en compte les principales préoccupations des bénéficiaires.

⇒ La mise en place d'un comité de pilotage chargé entre autres du contrôle et du suivi de l'exécution des activités, de définir les orientations et politiques d'intervention du projet. Il a également pour tâches de veiller à atteindre les objectifs du projet et assurer la conformité des actions avec les orientations, stratégies et politiques nationales, d'approuver le programme de travail, le budget annuel et les comptes des fonds du projet, d'examiner les bilans des réalisations et d'assurer l'arbitrage entre les structures impliquées.

⇒ L'appropriation des titres ou prêts fonciers comme garanties foncières pour la réalisation des différentes infrastructures projetées;

⇒ La mise en place d'un encadrement rapproché des paysans sur chacun des sites d'intervention du projet ;

⇒ La mise en place d'un programme global de l'exécution détaillée des activités du projet, étalé sur 4ans et ayant requis l'approbation de la BADEA, conformément à l'accord de prêt;

⇒ La satisfaction de tous les autres préalables à l'entrée en vigueur de l'accord de prêt.

Il faudra signaler par ailleurs, que tout au long de l'exécution des activités du projet, il a été adopté une approche participative qui fait intervenir les acteurs tels que les services techniques, les populations bénéficiaires, les autorités administratives locales, etc... Dans ce sens, la mise en œuvre de toute activité du projet est précédée des actions d'information, de sensibilisation, de concertation avant la mise en place des structures de gestion communautaire que sont les comités villageois de gestion.

Toutes les études qui avaient été menées préalables à la mise en œuvre des activités du projet, ont fait l'objet d'ateliers de validation tant au niveau des chefs lieux de départements concerné qu'au niveau central. Ces ateliers ont vu la participation de tous les acteurs concernés par les interventions du projet.

Le projet s'est appuyé sur les services techniques de l'Etat ci-après, pour mener certaines activités comme les actions de sensibilisation, d'appui conseil, d'encadrement, de renforcement des capacités des paysans : il s'agit du Génie rural, de l'agriculture, de l'environnement, du développement social, de l'hydraulique.

Bilan physique :

Au terme de l'exécution du PASA2, le bilan global de réalisations physiques se présente comme suit:

- ⇒ 9 aménagements de périmètres maraîchers sur 10 prévus, totalisant **154ha**;
- ⇒ La construction d'un seuil sur le Dargol (affluent du Niger) pour alimenter la retenue et recharger la nappe du site d'implantation du périmètre de Bégorou Tondo;
- ⇒ Une digue de protection du village et de ses champs agricoles de Goube zeno;
- ⇒ La réhabilitation et la protection du barrage de Youmban;
- ⇒ La confortation du barrage de Birni N'Lokoyo;
- ⇒ La récupération de plus de **1500h**a de terres agricoles dégradées suivies de leur mise en valeur;
- ⇒ La plantation et le reboisement sur plus de **600ha** à travers la plantation d'arbres;
- ⇒ L'organisation des exploitants des périmètres réalisés en structures de gestion de leur choix;
- ⇒ L'acquisition de divers intrants, petits matériels et outillages agricoles pour appuyer la mise en valeur de périmètres (semences améliorées de céréales, semences potagères, engrais, pesticides, charrettes, charrues, etc…).Ces intrants et petits matériels constituent des fonds de roulement pour les structures de gestion des périmètres mises en place;
- ⇒ L'équipement et la formation de **100** brigadiers phytosanitaires en tenue, casques, lunettes, bottes etc….;
- ⇒ L'acquisition et l'installation de **3** moulins à grains au niveau de trois nouveaux sites et **10** batteuses de mil pour l'allègement du travail domestique des femmes;
- ⇒ La construction de **10** magasins de stockage de céréales;

- ⇒ La mise en place et la formation de plus de **51** comités de gestion de chaque activité réalisée.
- ⇒ Deux voyages d'échanges d'expériences au profit de **20** paysans de la zone d'intervention du projet, au Burkina FASO, dans le domaine de la gestion des petits périmètres irrigués ;
- ⇒ Plusieurs ateliers de concertation autour des thématiques liées aux activités de mise en œuvre du projet (validation des études de faisabilité, mise en place de structures de gestion de périmètres, etc…)
- ⇒ La formation continue de plus de **50** cadres de profils divers, qui a concerné en particulier les cadres du Ministère de l'Agriculture (la tutelle) avec la participation de ceux du Ministère du Plan, de l'Aménagement du Territoire et du Développement Communautaire.

Toutes ces activités ont été exécutées grâce au concours et la collaboration de plusieurs partenaires et structures ci-après : La DGCMP, la Douane, le PAM, les projets de développement et certaines directions régionales de l'Agriculture du Burkina FASO, le code rural, les COFODEP, les institutions de formation (IAV Hassan I au Maroc, SETYM International du Canada),etc….

Bilan financier global :

- Prévision financière globale : **3.123.000.000FCFA** à l'évaluation du projet en 2009 en monnaie locale
- Cumul décaissements : **3.269.147.378 FCFA** en monnaie locale à la date d'achèvement du projet en 2014. Ceci a été obtenu à la faveur du gain du taux d'échange.
- Taux de décaissement : **100%**

Impacts/effets du Projet

L'intervention du projet a suscité une dynamique d'ensemble de développement d'échanges entre villages et entre la zone d'intervention du projet et son environnement. Elle a aussi créé de nouvelles opportunités de génération de revenus et création d'emplois : emplois dans les périmètres maraîchers villageois qui, dans certains cas, utilisent la main d'œuvre des villages avoisinants n'ayant pas bénéficié de l'intervention du projet, emplois liés aux besoins de fonctionnement des organisations des producteurs, emplois liés à l'entretien et au fonctionnement des technologies utilisées.

Les conditions de base, devant permettre une augmentation des productions agricoles, renforcer la sécurité alimentaire et générer des revenus des ménages sont également créées, à travers la réalisation des ouvrages hydrauliques et les infrastructures socio-économiques.

Les conditions d'approvisionnement d'intrants, de petits matériels et outillages agricoles, ont été facilitées par la création de boutiques d'intrants de proximité. Les conditions de cession d'intrants et autres matériels agricoles sont souples. Ces prédispositions créent les conditions d'accessibilité et de disponibilité d'intrants et petits matériels agricoles. Par ailleurs, les réalisations du projet ont eu pour effets immédiats: une disponibilité de l'eau 12mois/12 au niveau des sites aménagés et un approvisionnement en eau potable et un développement des activités de maraîchage à partir des puits maraîchers, grâce à la recharge des nappes.

Les actions menées en matière de mobilisation des eaux et de récupération des terres dégradées ont fortement contribué à la préservation du milieu naturel et à la réduction des effets de l'érosion hydrique en particulier. Au terme du Projet, des améliorations sensibles sont constatées sur la limitation du ruissellement et de l'érosion, la restauration des terres anciennement dégradées et le reverdissement des zones humidifiées, l'augmentation du capital productif.

Eléments de pérennisation des acquis du Projet

La responsabilité des organisations de producteurs à travers la mise en place de structures de gestion de périmètres et les comités villageois de gestion, la mise en place d'un fond de roulement à travers l'acquisition d'intrants, de petits matériels et outillages agricoles pour chaque périmètre, la mise en place d'un encadrement rapproché de producteurs, la rétrocession des infrastructures réalisées aux bénéficiaires sous le contrôle et le suivi des autorités locales, des services techniques compétents, constituent des conditions nécessaires à la pérennisation et à la viabilité des investissements réalisés par le projet.

Difficultés rencontrées

- Longue période entre la signature de l'accord de prêt du projet et le premier décaissement ;
- Le retard dans le démarrage du projet ;

- L’imputation de toutes les charges de fonctionnement de l’UEP à la contre partie nationale dont la mobilisation rend difficile la mise en œuvre efficace du Projet;
- La faiblesse des dotations de l’Etat, l’insuffisance et le retard dans la libération des crédits de fonctionnement et dans le décaissement au niveau du trésor public, la réduction récurrente après collectifs budgétaires, des dotations budgétaires de la contre partie nationale de l’Etat au financement du PASA;
- La lourdeur des procédures de passation des marchés et la saisonnalité de certaines activités du projet (barrages, aménagements) ont retardé à maints égards l’exécution du projet;
- Longueur du circuit d’approbation des marchés ;
- La suspension de décaissements de la BADEA pour non paiement des échéances antérieures de l’Etat, qui a contribué au ralentissement du rythme d’exécution des activités du projet ;
- Le retard dans le paiement des décomptes des fournisseurs et autres prestataires ;
- La défaillance des entreprises attributaires des marchés et leurs reprises (la très faible capacité technique, matérielle et financière des entreprises locales et nationales de travaux publics, représente une contrainte majeure pour les projets d’aménagements au Niger et un risque pour un véritable développement de l’irrigation)

CONCLUSIONS

- Les objectifs assignés à ce projet ont été atteints et ce malgré les retards accumulés dans sa mise en œuvre. L’encadrement des bénéficiaires devra être poursuivi pour assurer la pérennisation des acquis du projet et les services du Ministère de l’Agriculture doivent continuer ce travail afin que l’impact du projet soit positif;

- L’implication des cadres du Ministère de l’Agriculture dans l’exécution du projet a contribué au renforcement des capacités de ceux-ci qui peuvent exécuter des projets similaires sans un appui d’assistance technique extérieure. Egalement, l’implication des services techniques et des autorités administratives locales dans le suivi et le contrôle de la gestion des ouvrages réalisés par l'Etat est un gage de sécurisation et de pérennisation des investissements;

- L'organisation, l'encadrement et le renforcement des capacités des bénéficiaires entrepris par le projet, demeurent des actions préalables à la valorisation des investissements.

- L'Unité d'Exécution a réussi à capitaliser sur les expériences des projets similaires dans la sous région (Burkina Faso, Maroc), a développé une forte synergie et partenariat fécond avec les projets/programmes et services techniques de l'Etat.

Cependant, il faut noter les retards considérables dans l'exécution des activités sur le terrain dus entre autres à la lenteur dans les procédures de passation des marchés, dans la libération et les décaissements de fonds de contrepartie et à la défaillance des entreprises attributaires des marchés dans l'exécution de certains travaux notamment les aménagements, ont occasionné le non respect du planning et des délais d'exécution de certaines activités. Malgré ces retards, l'exécution du projet s'est déroulée dans de bonnes conditions, dans la limite du délai conventionnel, avec un taux de décaissement de 100%, grâce à la mobilisation des services étatiques, des bénéficiaires, des autorités administratives et coutumières, de la Direction Générale du Génie Rural et de la Banque, coordonnée et animée par une coordination du projet motivée.

La sécurisation foncière, l'organisation, l'encadrement et le renforcement des capacités des producteurs demeurent des actions préalables incontournables à la réalisation et à la valorisation des investissements réalisés.

ENSEIGNEMENTS TIRES

Tirant les leçons des deux phases du PASA, nous dirons ceux-ci :

- Le fait qu'une étude de faisabilité n'a pas été faite avant la préparation du projet, est un frein et un handicap pour un démarrage effectif et pour la mise en œuvre efficace du projet ;

- La réalisation tardive des ouvrages n'a pas permis un encadrement approprié des bénéficiaires et une exploitation opérationnelle des superficies aménagées ;

- La longueur des procédures d'acquisition a contribué énormément au retard accusé par le projet ;

- Le retard dans le décaissement de la contrepartie de l'Etat a eu des conséquences négatives sur la performance de l'Unité d'exécution du projet ;

- Les expériences accumulées par les agents de l'Administration dans l'exécution du projet sont un acquis pour le pays ;

- La très faible capacité technique, matérielle et financière des entreprises locales et nationales de travaux publics, représente une contrainte majeure pour les projets d'aménagement au Niger et un risque pour un véritable développement de l'irrigation ;

- L'approche participative, qui nécessite l'implication des populations à toutes les étapes du processus de mise en œuvre du projet (réalisation du diagnostic participatif, planification, mise en œuvre et suivi évaluation des activités), est une approche qui s'adapte aux conditions socio-culturelles de sa zone d'intervention ;

- L'implication et la responsabilisation de toutes les parties prenantes les populations bénéficiaires, les autorités administratives et coutumières, ainsi que les différents services techniques, à travers de multiples rencontres d'échanges et de réflexions et un partenariat franc et sincère, à tous les niveaux de prise de décision. Par ailleurs, la responsabilisation des organisations à la base constitue une des conditions nécessaires à la durabilité et à la viabilité des investissements réalisés par le projet. Cette responsabilisation doit être progressive et soutenue par le renforcement de leurs capacités d'organisation et de gestion ;

- La bonne réactivité de la BADEA et du Gouvernement de la République du Niger dans le suivi du porte feuille du PASA2 a permis la célérité qui a conduit à l'exécution du projet dans le délai conventionnel. En effet, après l'entrée en vigueur du Projet, la BADEA, a satisfait à tous ses engagements en apportant avec diligence au Projet les ressources financières nécessaires à sa mise en œuvre, conformément à l'accord de prêt. Elle a, à travers ses experts, suivi convenablement l'exécution du projet, grâce à des missions de supervision relativement fréquentes et à des contacts réguliers par messagerie électronique et par téléphone. Elle a su traiter avec discernement les différents dossiers soumis à son appréciation dans des délais relativement courts ;

- Le Gouvernement a, à travers les actions conjuguées de la Direction Générale du Génie Rural du Ministère de l'Agriculture et celles des directions centrales du Ministère du Plan, ses services de l'Administration territoriale et technique, tant au niveau régional que départemental, satisfait globalement à ses engagements contractuels. Il a pu mobiliser une équipe complète pour l'exécution du projet et assurer sa contrepartie financière pour son bon fonctionnement.

RECOMMANDATIONS

Pour le Gouvernement de la République du Niger

- Accroître sa contribution financière pour couvrir toutes les dépenses au fonctionnement nécessaires et non couvertes par la BADEA;
- Veuillez à la mise à disposition régulière et dans les délais du montant suffisant des fonds de contre partie relatifs aux projets pour améliorer leur performance;
- Contribuer à l'allégement des procédures d'appels d'offres et de passation des marchés, d'acquisition des biens, services et travaux et des lourdeurs administratives génératrices de retards préjudiciables au projet ;
- Améliorer le respect des accords et des conditions générales afférents aux prêts afin de se conformer aux calendriers d'exécution approuvés ;
- Prendre des dispositions pour diligenter le paiement des échéances échues issues des engagements antérieurs de l'Etat vis-à-vis de ses partenaires techniques et financiers ;
- Prendre les dispositions pour rationaliser le délai de traitement des dossiers en établissant un chronogramme engageant les deux parties (unités de gestion des projets et partenaires) ;
- Contribuer à promouvoir les entreprises nationales dans le secteur de l'irrigation en particulier et le secteur de travaux publics en général, à travers le renforcement de leurs capacités tant technique, matériel que financier;
- Avant l'introduction de toute requête de financement d'une nouvelle formulation de projet auprès de la BADEA, il est nécessaire, pour assurer une bonne qualité du Projet à son démarrage, de lancer les études et de préparer les DAO à travers les études de faisabilité technico-économique, durant le processus de préparation et de formulation

du Projet, et disposer d'un vrai document de projet bancable. Avec une telle démarche, on assurera un démarrage effectif du Projet dès sa mise en vigueur;

- Sécuriser les acquis de développement institutionnel par la poursuite des programmes de renforcement des capacités adaptées, destinées aussi bien qu'aux organisations des bénéficiaires qu'au personnel d'encadrement.
- Mettre en place un encadrement rapproché des producteurs, par l'affectation d'agent sur chaque périmètre maraîcher, afin d'assurer la pérennité des investissements;
- Prévoir/préparer la mise en place de stocks de pièces détachées des GMP, ainsi que les modalités d'approvisionnement et de vente desdites pièces ;
- Prévoir la formation des maintenanciers locaux des GMP et pompes immergées, moulins et batteuses, en vue de pérenniser les acquis.

Pour la BADEA

- Accroître sa contribution financière dans les dépenses de fonctionnement de projet, en prenant en compte sur les fonds de prêt, pour rendre la gestion de projet efficace et beaucoup plus autonome (indemnités, carburant, frais de séjour, fond de roulement);
- Financer une nouvelle formulation de projet, évaluée sur la base des études de faisabilité technico-économique préalables, qu'elle contribuera à financer, en vue d'assurer une bonne qualité et un démarrage effectif du projet, dès sa mise en vigueur;
- Accroître également sa contribution financière dans les investissements et élargir le champ d'intervention du projet, pour répondre à la demande en services sociaux de base, notamment la santé et l'éducation, ainsi que les actions de désenclavement des pistes de desserte des zones à haut potentiel de production et de crédit agricole pour financer les intrants, les équipements de production et de transformation de produits agricoles (motopompes, décortiqueuses, motoculteurs, moulins, batteuses, charrues, charrettes et panneaux solaires et tout autre équipement nécessaire au développement des activités agricoles dans l'aire d'intervention du Projet).
- Prendre toutes les dispositions pour traiter à temps les dossiers de demande de non objection des projets;
- Prendre des dispositions pour accompagner l'Etat, dans la promotion des entreprises et des bureaux d'études nationaux, intervenant dans le secteur de l'irrigation en particulier et le secteur de travaux publics en général, à travers le renforcement de leur capacité technique;

- Prendre les dispositions pour actualiser les montants de financement acquis en tenant compte de la fluctuation des taux d'échange ;
- Prendre les dispositions pour financer les gaps occasionnés par la baisse des taux d'échange;
- Prendre les dispositions pour renforcer les capacités des responsables des structures de gestion des projets et programmes;

- Prendre les dispositions pour rationaliser le délai de traitement des dossiers en établissant un chronogramme engageant les deux parties (unités de gestion des projets et partenaires).

Agriculture solidaire, levier pour l'émergence de la classe moyenne en monde rurale. *Mr ELMAHDI ARRIFI*

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Abstract/Résumé (max. 2000chars):

Le Plan Maroc Vert, lancé depuis 2008, est une **stratégie agricole inclusive** qui prend en compte l'ensemble des territoires, des exploitations et des filières agricoles. Le Pilier II du Plan Maroc Vert consacré au **développement solidaire de la petite agriculture**, concerne principalement les zones les plus difficiles, lesquelles rassemblent la grande majorité des exploitations du pays, et les plus pauvres d'entre elles.

Pour cela, l'approche adoptée repose sur une intervention de l'Etat en «mode projet» dans le cadre d'un partenariat avec les bénéficiaires regroupés au sein d'organisations professionnelles (associations ou coopératives, et Groupement d'intérêt Economique).

Durant la période 2010-2019, le Département de l'Agriculture a lancé **985 projets** au profit de **733.000 petits agriculteurs** (soit 94% de l'objectif 2020). Le budget alloué à ce jour par l'Etat à ces projets a atteint 14,5 Milliards de Dirhams.

La mise en œuvre des projets pilier II a contribué à la création de **66,8 millions de JT,** a généré un chiffre d'affaires cumulé de l'ordre de **12,6 Milliards DH** et a séquestré **1,9 millions de tonnes Eq CO2**.

Text of the abstract/Texte du résumé

Le développement de l'agriculture solidaire « le pilier II » bénéficie d'une attention particulière dans le Plan Maroc Vert à travers la mise en œuvre de projets solidaires et inclusifs, techniquement faisable économiquement viable et socialement approprié au niveau des zones fragiles (montagnes, oasis, plaines et plateaux du semi-aride).

Les enjeux sont à la fois de développement économique, de lutte contre la pauvreté, et de sécurité alimentaire avec une prise en compte de la gestion durable des ressources naturelles.

Le PMV envisage la réalisation, à l'horizon 2020, de 911 projets sociaux en faveur de 779.635 exploitants pour un coût prévisionnel dépassant 18 milliards de dirhams.

L'approche « Pilier II» du PMV vise le développement des projets agricoles économiquement viables reposant essentiellement sur une intervention directe de l'Etat au niveau de certaines zones marginales (zones bour défavorable, de montagne ou oasienne) et ce, en prenant en considération la sauvegarde des ressources naturelles.

L'objectif visé est l'accroissement de la production des filières végétales et animales des zones défavorisées en vue d'améliorer le revenu agricole des exploitants.

Pour atteindre cet objectif, la stratégie du PMV a opté pour 3 catégories de projet pilier II:

Projets de reconversion

Il s'agit de projets de reconversion des filières de production existantes en d'autres filières à plus haute valeur ajoutée. Ils concernent les agriculteurs qui pratiquent des cultures à faible valeur ajoutée dans un milieu offrant des possibilités de changement de spéculation.

Projets d'intensification

Ces projets concernent les agriculteurs pratiquant une spéculation ayant de réelles potentialités de développement et nécessitant d'intensifier l'existant.

A titre d'exemple, on peut citer les projets de réhabilitation des vergers d'amandier moyennant les opérations de taille de rajeunissement et la confection d'impluviums.

Projets de diversification

Ce type de projet est développé en vue de garantir une production additionnelle, permettant de générer un revenu complémentaire au profit des bénéficiaires et ce moyennant l'introduction de produits de niches ou le développement des produits de Terroirs.

A ce jour, **985 projets** ont été lancés (soit 108% de l'objectif 2020) au profit de **733.000 petits agriculteurs** (soit 94% de l'objectif 2020). Le budget alloué à ce jour par l'Etat à ces projets a atteint **14,5 Milliards de Dirhams**.

Les principales réalisations ont consisté en ce qui suit :

- La plantation **de 388.000 ha** (olivier, amandier, cactus, figuier…) ;
- L'installation de **417 unités** de valorisation (Trituration, concassage, séchage…) ;
- L'aménagement hydro-agricole de **84.000 ha** ;
- L'aménagement pastoral de **37.000 Ha** ;

- La distribution de **28.000 têtes d’animaux** et **73.000 ruches ;**
- La création de **793 points d’eau** pour l’abreuvement du cheptel **;**
- L’aménagement de **444 km de pistes**.

Il est à noter que l’évaluation réalisé en 2018 a montré que les projets pilier II ont contribué à la création de **66,8 millions de JT** dont 31,9 MJT durant la phase de l’investissement et 34,9 MJT durant la phase d’exploitation. Le chiffre d’affaires cumulé durant 2010-2018 issu des productions végétale et animale et des unités de valorisation est de l’ordre de **12,6 Milliards DH** et les plantations réalisées dans le cadre du pilier II, malgré leurs jeunes âges, auraient contribué à la séquestration du carbone de l’ordre de **1,9 millions de tonnes Eq CO2**.

Keywords/mots clés: Agriculture solidaire, pilier II, projets solidaires et inclusifs, projets de reconversion, projets d'intensification, projets de diversification, création d’emploi, séquestration du carbone

Adaptation du système d'irrigation californien aux conditions rurales en Afrique pour le développement de l'irrigation des petits et moyens périmètres villageoises. Expérience du Burkina Faso. *JEBBOUR Said*

Ingénieur Génie Rural à l'ORMVA du Gharb

Résumé de la présentation

Face aux effets des changements climatiques et les risques d'insécurité alimentaire qui en découlent, de nombreux pays en Afrique, sans tradition d'irrigation, se sont trouvés dans l'obligation de se tourner vers une agriculture irriguée, pour atteindre l'objectif de croissance durable de l'agriculture et de lutter contre la pauvreté rurale. Ceci, à travers des techniques performantes de mobilisation et de distribution de l'eau d'irrigation par des aménagements à la fois de faibles coûts et rentables.

Le système d'irrigation Semi-Californien répond parfaitement aux caractéristiques du milieu social et rural de nombreux pays d'Afrique notamment les pays sahéliens, en répondant le mieux aux développement de l'agriculture irriguée notamment les petites et moyennes exploitations aux niveaux des villages les plus reculés, contribuant ainsi à de nombreux projet potentiel à l'adaptation et à l'atténuation du changement climatique ainsi qu'à l'amélioration de la productivité agricole et la sécurité alimentaire.

Le système d'irrigation Semi Californien est une réadaptation du système Californien, par l'introduction d'ouvrages de répartition d'eau à ciel ouvert. Dans ce système, le transport de l'eau se fait sous pression depuis la station de pompage jusqu'à un bac de répartition. A partir de ce point, l'eau est envoyée dans le réseau de distribution en conduites. Le réseau peut se composer également, selon la taille du périmètre, de bassins de répartition secondaires et tertiaires, qui desservent les rampes enterrées comportant les prises d'alimentation des parcelles. Les bassins de répartition sont connectés entre eux par un réseau de tuyau PVC ordinaire enterrés et l'eau coule par gravité sous l'effet de la hauteur du bassin amont, suivant le principe des vases communicants. Il présente de multiples avantages au niveau des aspects exploitation du réseau, économie en eau, simplicité et rapidité de réalisation et le faible cout d'investissement.

Ce système d'irrigation a été retenu comme modèle d'aménagement largement pratiqué au Burkina Faso depuis ces dernières années. Il a été adopté au niveau de plusieurs Programmes de développement de l'irrigation, totalisant une superficie de plus de 5 000 ha (*jusqu'en 2012*) répartie dans différents villages des régions du pays. Les résultats obtenus en particulier au niveau social par l'occupation des populations en saison sèche et l'amélioration de leurs revenus ne sont pas à démontrer.

Une estimation des couts d'aménagements a été établie sur un ensemble d'exploitations classées en trois catégories de superficie exploitées dans un cadre individuel ou collectif. Les résultats obtenus montrent que le cout moyen complet à l'hectare est de 2 700 000 FCFA soit environ 4000 $. Ce cout fait du système semi californien non seulement un aménagement à faible cout, mais un aménagement répondant aux conditions rurales africaines par le recours à une technologie simple dont son matériel est disponible chez les revendeurs locaux.

Mots clés : Périmètres villageois, semi-californien- bassin de répartition- rampe de distribution et prise parcelle.

INTRODUCTION

Les résultats du Programme Spécial de sécurité alimentaire de la FAO conduit au Burkina Faso avec la coopération technique Marocaine (2000 à 2004) ont montrés les possibilités de production en saison sèche. Sur cette base le gouvernement Burkinabé a pris l'initiative de mettre en valeur les ressources en eau, à travers les aménagements hydro-agricoles simples, afin de prévenir les risques d'insécurité alimentaire. Il s'est engagé résolument dans le développement de l'agriculture irriguée, pour atteindre l'objectif de croissance durable de l'agriculture et de lutter contre la pauvreté, ainsi que la diminution de l'impact des aléas climatiques sur le taux de croissance. Cet engagement s'est traduit par la réalisation de nombreux programmes d'aménagements hydro-agricoles.

La volonté politique s'est fixée comme objectif durant la décennie de 2005 à 2015, d'aménager 60 000 ha de périmètres irrigués et bas-fonds, soit le triple de la superficie totale aménagée durant quatre décennies afin d'augmenter la production et la productivité par l'intensification et l'extension de l'irrigation à travers des techniques performantes de mobilisation et de distribution de l'eau par des aménagements de faibles coûts et rentables. Parmi ces techniques, figurent le système semi-californien qui est une adaptation du système Californien pour répond entre autre aux caractéristiques du milieu social et rural Burkinabé. Ainsi, de nombreux sites, sur la base des potentialités offertes, à la fois en ressources en eau et en terres irrigables, ont été aménagées dans différents régions par le système d'irrigation semi californien

Ce système d'irrigation a été adopté initialement au niveau des périmètres retenus dans le cadre de la phase I du Programme de développement de la petite irrigation lancé par le Ministère de l'Agriculture et été par la suite retenu au niveau de plusieurs projets et programmes de développement rural.

LE SYSTEME D'IRRIGATION SEMI CALIFORNIEN

Le système Californien tire son nom en référence à la Californie aux Etats unis où les premières expériences d'utilisation sont connues depuis les années trente pour l'irrigation surtout des vergers de la cannes à sucre. Il est désigné généralement par d'autres termes à savoir système à conduites enterrées, réseau basse pression etc. Il se définit comme étant un réseau de canalisation enterrée fonctionnant à faible charge alimenté par gravité ou par relevage, et chargé de délivrer l'eau aux parcelles sous une charge de l'ordre de 1 MCE à travers des bouches de sorties.

A petite échelle, le système Californien est le type de système d'irrigation constitué principalement de conduites d'adduction composées de conduites enterrés, depuis la station de pompage, jusqu'en tête des parcelles. Sur ces conduites, sont fixées des petites cheminées de sorties ou cannes qui alimentent les parcelles. Les cannes sont munies d'un dispositif permettant l'ouverture et la fermeture de la canne pour la desserte en eau de la parcelle.

En système semi- californien, cette continuité des conduite depuis la source jusqu'à la parcelle est interrompue par des ouvrages de répartition à ciel ouvert. Ainsi, le transport de l'eau se fait sous pression depuis la station de pompage jusqu'à un bac de répartition qui se trouve placé généralement en un point haut de la zone à aménager. A partir de ce point, l'eau est envoyée à faible charge par gravité dans le réseau de conduites distribution. Le réseau peut se composer également, selon l'importance du périmètre, de bassins de répartition secondaires et tertiaires, qui desservent les prises d'eau alimentant les parcelles. Les bassins de répartition sont connectés entre eux par un réseau de tuyau PVC enterrés et l'eau coule par gravite sous l'effet de la hauteur du bassin amont, suivant le principe des vases communicants.

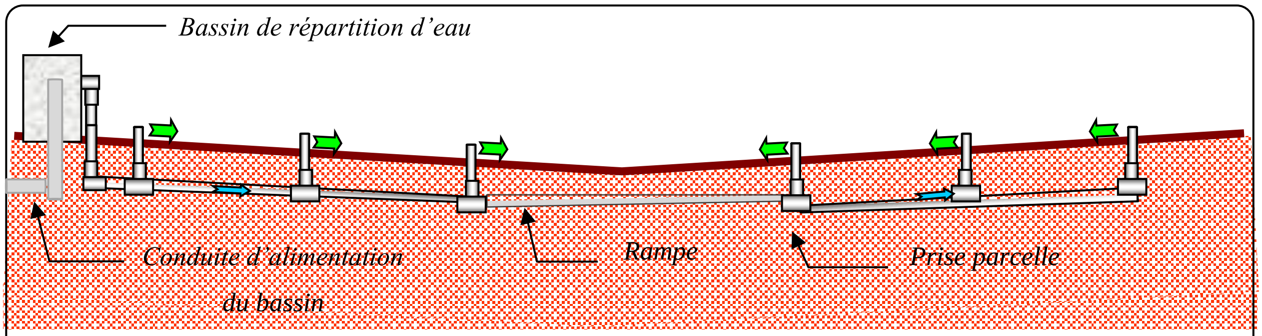

Figure n° 1 : Schéma montrant la connexion des rampes au bassin de répartition d'eau d'irrigation

Les différents ouvrages du Semi- californien

Le réseau semi californien se compose essentiellement des ouvrages suivants :

- **La station de pompage** : pour le relevage d'eau d'irrigation de la source d'eau d'alimentation du périmètre, vers le point de départ du réseau de distribution,

- **Les regards de connexion** (bassin principal) : c'est le lieu de connexion du tuyau de refoulement avec le départ de des conduites d'alimentation du réseau ; Au niveau de ce regard principal, la conduite centrale sert d'arrivée d'eau et les autres servent à la distribution d'eau dans le réseau d'irrigation.

- **Les ouvrages partiteurs** (bassins secondaires ou tertiaires) : comprend toujours un bac d'arrivée de l'eau et deux ou plusieurs bacs de dérivation selon le nombre de sorties prévues. Les déversoirs sont généralement situés à une certaine côte au-dessus de base du bassin afin de permettre la mise en charge des conduites PVC situées à l'aval de l'ouvrage et permettre la circulation de l'eau dans les conduites. Les longueurs des déversoirs, sont proportionnelles aux débits dérivés.


Photo n° 1 : bassin de répartition composé d'un bac d'arrivée et de deux bacs de dérivation


Photo n° 2 : autre forme de bassin de répartition

- **Les prises d'eau** : ce sont des dispositifs qui délivrent l'eau d'irrigation à la parcelle. Ces prises jouent le rôle de vannes, fixées à l'extrémité haute de la rehausse. Elles permettent de freiner le jet d'eau à la sortie de la rehausse par un bouchon placé sur l'orifice du tuyau. Ce bouchon est constitué d'une plaque de tôle circulaire reposant sur des rondelles de joint en caoutchouc.

Photo n° 3 : ouvrage de prise doté d'une seule sortie au niveau du bac

Photo n° 4 : ouvrage de prise sans bac et doté de deux sorties directes

Photo n° 5 : Situation du périmètre de Dagouindodou avant aménagement (Burkina Faso)

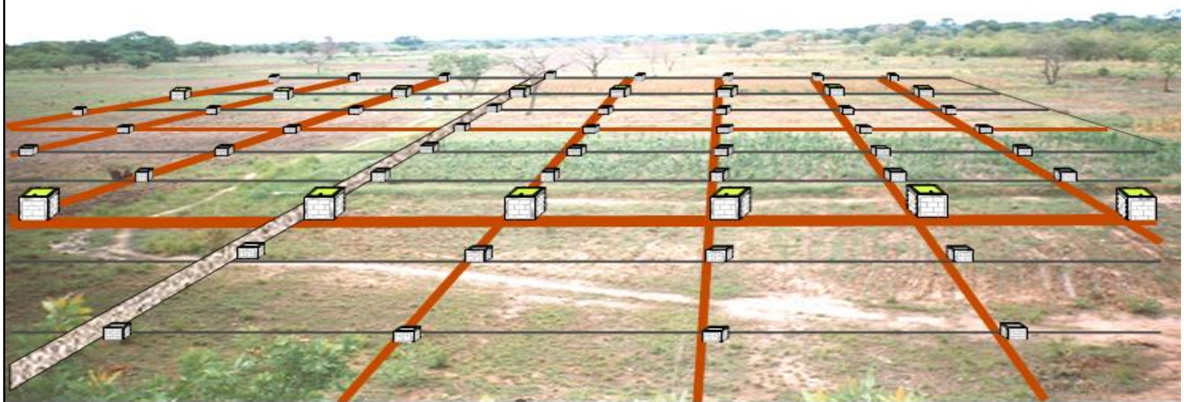

Photo n° 6 : Schéma d'aménagement en semi Californien du périmètre de Dagouindogou *(en y indiquant l'emplacement des bassins de répartition ; les prise parcelle les passage des conduite ; limite des parcelles et les pistes de circulation)*

Les avantages du système semi-californien

Le système semi californien présente de multiples avantages à savoir :

- Aspect exploitation du réseau

- ✓ Système applicable aux petites et moyennes exploitations,
- ✓ Offre une gestion simple du réseau ; individuelle et collective,
- ✓ Adaptation à tous les systèmes de cultures,
- ✓ Très bonne adaptation du système aux parcelles ayant une topographie variée et éloignées d'un point d'eau.

- Aspect économie d'eau

- ✓ Absence de pertes par évaporation,
- ✓ Absence de pertes d'eau par infiltration lors du transport d'eau d'irrigation et de la distribution,

- Aspect économique

- ✓ Coût inférieur à une installation sous pression,
- ✓ Se bases sur du matériel simple et disponible chez les revendeurs locaux,

- Aspect réalisation

- ✓ Ne présente aucune gêne pour les travaux agricoles,
- ✓ Simplicité de réalisation des ouvrages (bassins de répartition) et le montage, des conduites en PVC ordinaire,
- ✓ Simplicité d'entretien puisqu'il ne nécessite pas d'interventions particulières,

- Autres facilités

- ✓ Possibilité d'extension de superficie sans avoir à reprendre des modifications au niveau des aménagements initiaux ;
- ✓ Possibilité d'appliquer d'autres modes d'irrigation notamment en tuyau souple à la sortie de la prise,

CONTRAINTES RESOLUES PAR LES AMENAGEMENTS EN SEMI CALIFORNIEN

Depuis les premiers résultats du Programme Spécial de la Sécurité Alimentaire de la FAO, la petite irrigation commençait à se développer à titre individuel. Parallèlement, dans le cadre de la consolidation des programmes de développement de l'irrigation, un vaste programme de développement durable de l'agriculture irriguée a vu le jour. Ce programme a porté sur la réalisation des travaux d'aménagement en semi californien, sur une superficie importante repartie sur les différentes régions agricoles. Ainsi, de nombreux projet de développement ont été lancés dont la composante aménagement des périmètres, représentait l'une des principales activités.

De nombreux sites favorables au développement de l'irrigation, où les agriculteurs procèdent au pompage privé et utilisant les moyens de bord pour assurer la distribution d'eau ont fait l'objet d'aménagement en système semi californien, dans un cadre collectif et privé. Ces aménagements ont permis au niveau de ces périmètres, la résolution des contraintes illustrées ci-dessous.

Suppression de la pénibilité d'installation et de mobilisation des conduites

- Suppression des efforts physiques fournis par les paysans pour les montages et le démontage quotidien des tuyaux de transport ;
- suppression de la pénibilité du transport des tuyaux entre le lieu d'utilisation et lieu de stockage et de gardiennage du matériel (photos ci-dessous),
- Réduction des difficultés de déplacements individuels et multiples vers les centres urbains qui sont souvent loin des périmètres, pour l'acquisition du gasoil pour les motopompes,

Photo n° 7 ; transport manuel des tuyaux d'irrigation

Photo n° 8 : multitude de conduites de refoulement privées pour le transport d'eau

Acquisition commune du matériel

- Suppression de la nécessite de l'acquisition individuel des tuyaux de transport, correspondant à un investissement important à l'échelle du site exploité,
- Regroupement des motopompes individuelles en une seule station réduisant ainsi les charge d'acquisition et d'entretien à titre individuel.

Photo n° 9 : multitude de motopompes privées autour d'un point d'eau

Photo n° 10 : multitude de motopompes privées autour d'un point d'eau

- Aménagement de la station de pompage dans un abri permettant à la fois son gardiennage et sa protection contre les effets du soleil, évitant ainsi les déplacements réguliers des motopompes individuelles entre le lieu de pompage et le lieu de gardiennage.

Elimination des risques de dégradations de la tuyauterie

- Suppression des dégradations des tuyaux lors des multiples transports, et les divers casses pouvant avoir lieu en étant posées sur le sol et exposées au soleil,
- suppression des risques de dégradations et de détérioration des conduites par les feux de brousse, une fois arrangés ou omis sur le terrain (photos ci-dessous),.

Photo n° 11 ; conduite de refoulement abîmée par les feux de brousse

Photo n° 12 : conduites de distribution détériorées par les feux de brousse

Amélioration des conditions d'irrigation

- Gain en temps d'irrigation puisque les opérations de montage et de démontage aussi bien de la tuyauterie et que de la motopompe ont été supprimées,
- Gain en débit d'irrigation suite aux caractéristiques de la motopompe collective, permettant d'irriguer en moins de temps et éviter les pertes par infiltration dues aux faibles débits d'irrigation initiaux dus aux petites motopompes,
- Suppression des fuites de transport ayant lieu au niveau des jonctions de la tuyauterie mobiles,

Harmonisation des parcelles irriguées,

- Facilité de création des chenaux de distribution d'eau, et des sentiers de circulation, au sein du périmètre aménagé,
- Extension des superficies irriguées par sites, suite aux tracé uniforme du réseau de conduites et aux aménagements des pistes de circulation,

Photo n° 13 : chenaux d'irrigation au niveau d'un périmètre aménagé en semi californien

Photo n° 14 : harmonisation des parcelles au niveau d'un périmètre irrigué en semi californien

BASES D'UN AMENAGEMENT EN SYSTEME SEMI CALIFORNIEN

Parcellement du périmètre

L'aménagement d'un périmètre villageois passe d'abord par le parcellement de la zone à aménager. Cette opération constitue aussi l'une des étapes la plus importante de l'ensemble des phases d'aménagement d'un périmètre. Un parcellement réussi, permet une meilleure exploitation du futur réseau d'irrigation à installer et une simplicité des conditions de distributions d'eau d'irrigation entre parcelles.

Le parcellement du périmètre est intimement lié à la morphologie de la conception du réseau d'irrigation et l'architecture d'implantation des conduites d'adduction et de distribution d'eau d'irrigation entre parcelles. Les principaux facteurs à prendre en considération lors des opérations de parcellement d'un périmètre, sont ; la topographique et les pentes du périmètre, la sectorisation du périmètre, la taille des parcelles et le réseau de circulation et d'accessibilité aux parcelles.

Objectif de la sectorisation

Au niveau des périmètres présentant des potentialités importantes, les parcellement pourra être réalisé en secteurs. Ce partage du périmètre devra être conduit de manière à avoir, dans la mesure du possible, des secteurs ayant les caractéristiques similaires ; notamment :

- la même forme, en vue de pouvoir avoir une architecture du réseau d'irrigation, de circulation et d'assainissement similaire et homogène entre les secteurs,
- la même superficie, afin d'avoir le même matériel de pompage et les conditions d'exploitation,
- la même architecture du réseau d'irrigation pour que l'ensemble des exploitants assurent un même mode de distribution et de répartition d'eau d'irrigation,
- la même superficie relativement limitée par secteur, en vue d'éviter le recours à de grosses motopompes non disponibles localement,

Différentes situations de sectorisation

Selon les potentialités en terres irrigable offertes par le site ainsi que sa topographie générale, les secteurs peuvent avoir des dispositions différentes. Les situations les plus pratiques sont :

- Disposition des secteurs en une seule rangée ; cette situation a lieu généralement quand le terrain est plat et le potentiel des terre irrigable présente une forme rectangulaire.
- Disposition des secteurs en double rangée : cette situation a lieu généralement quand le terrain est plat et le potentiel des terres irrigable présente une forme relativement carrée, ou que le site présente une forme en dos donnant une pente dans les deux sens.

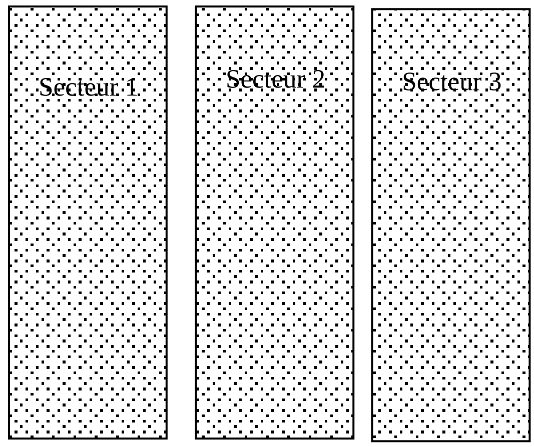

Figure n° 1 : disposition des secteurs en une seule rangée

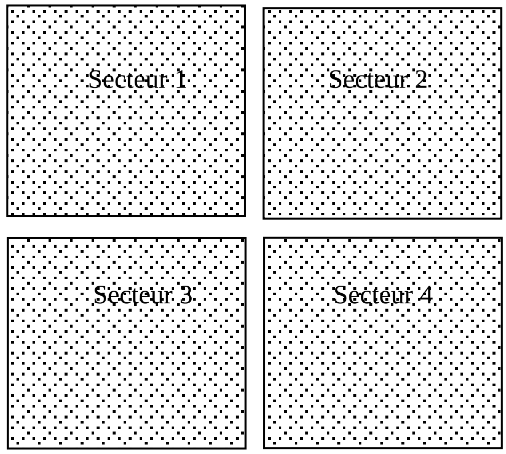

Figure n° 2 : disposition des secteurs en rangées double

Avantages de la sectorisation

La répartition du périmètre en secteurs dont chacun est desservi en eau par une motopompe, entraîne une série d'avantages au niveau des aspects suivants :

+ Gestion de la motopompe :
- Facilité de gestion de la motopompe par un nombre réduit de paysans,
- Choix de taille de la motopompe permettant la réparation des pannes simples,
- Interchangeabilité des pièces de rechanges entre les motopompes des secteurs du périmètre,

+ Gestion de l'irrigation :
- Organisation des membres du groupement du périmètre en sous-groupes autour des motopompes facilitant l'organisation du tour d'eau,
- Utilisation du même mode de distribution au niveau des secteurs pour faciliter l'exploitation du périmètre.

+ Conception des aménagements :
- Elimination de l'utilisation de la tuyauterie de grands diamètres,
- homogénéisé des caractéristiques des conduites de transport et de distribution au niveau des secteurs du même périmètre,
- réalisation de réseau d'irrigation présentant les mêmes formes,
- réalisation de réseau de servitude et de circulation bien structuré et bien adapté au réseau d'irrigation.

Taille et forme des parcelles des secteurs

Le partage des secteurs se fait en parcelles identiques et selon une même taille, qu'un simple exploitant peut facilement exploiter. Cette taille en générale est fixée à 0,25 ha. Le but de ces parcelles identiques est de pouvoir uniformiser les paramètres d'irrigation par secteur.

Les parcelles seront disposées par rangée de deux parcelles en vue de les desservir en eau d'irrigation par une seule conduite, comme le montre la figure ci-dessous. Aussi, selon la forme du secteur et le nombre de rangée de parcelle qu'il peut offrir ; les parcelles peuvent avoir une forme simple, carrée ou rectangulaire (figure 3 et 4). Les formes irrégulières sont a éviter, elles conduisent souvent à :

- disposition non alignée des bassins ainsi que les prises pour donner une forme simple et harmonieuse à l'aménagement du périmetre,
- des difficultés de mise en place des pistes de servitude à l'intérieur du périmètre,
- la création du mode de distribution spécifique à chaque unité de parcelles,

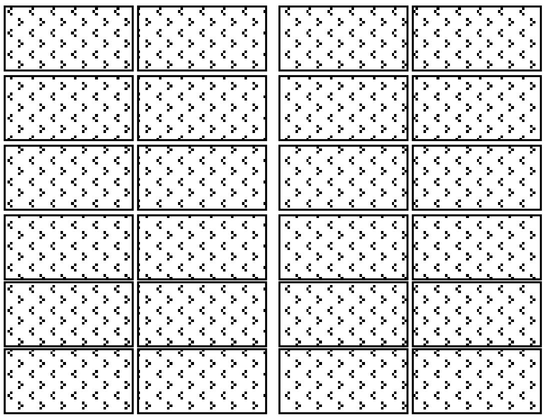

Figure n° 3 : parcelles en forme rectangulaire

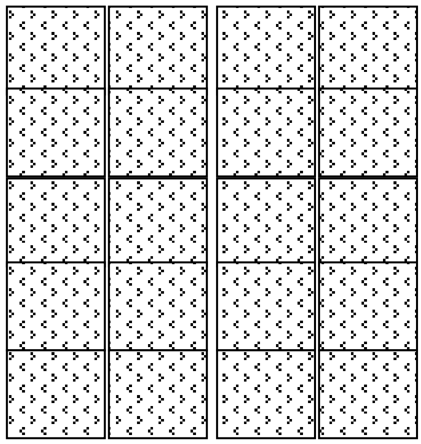

Figure n° 4 : parcelles en forme carrée

Réseau de circulation et accessibilité aux parcelles

Le réseau de circulation permet d'accéder aux parcelles et faciliter les déplacements des exploitants à l'intérieur du périmètre, il reste donc d'une utilité très importante. A cet effet, ce réseau devrait être étudié lors de la phase du parcellement, pour permettre par la suite, une meilleure implantation du réseau d'irrigation. Ainsi, le réseau de circulation se compose, selon la taille de chaque site de :

- une piste principale permettant les déplacements des exploitants entre secteurs d'irrigation pour les périmètres composés en secteurs.
- des pistes secondaires longeant les bassins secondaires,
- Pistes tertiaires situées entre les lignes de rampes de distribution et permettent un accès direct aux parcelles (figure n°5).

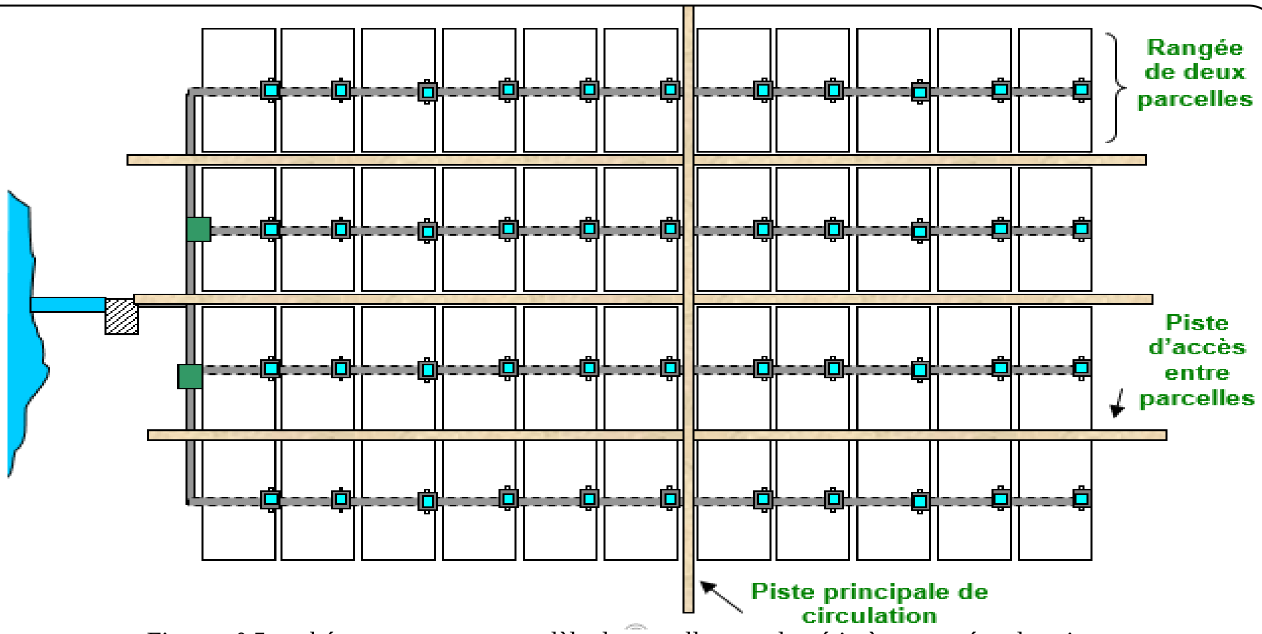

Figure n° 5 : schéma montrant un modèle de parcellement du périmètre en créant les pistes de circulation et d'accès aux parcelles à l'intérieur du périmètre

REGLES DU TRACE DU CANEVAS HYDRAULIQUE

Le tracé du canevas hydraulique ou encore l'implantation du réseau d'irrigation consiste en l'indication du passage des conduites de transport et de distribution d'eau d'irrigation, en vue de desservir les parcelles. Généralement, il existe toujours plusieurs solutions en fonction des nombre de prises à prévoir par rampe et le nombre de bassin secondaires à installer. La solution optimale consiste à faire un tracé qui respecte, à la fois, un bon fonctionnement hydraulique assurant une gestion simple entre exploitants et un coût économique de réalisation acceptable.

Paramètres d’exploitations du réseau semi californien facilitant le bon déroulement de la distribution

Utilisation d’une main d’eau unique

L’utilisation d’une main d’eau unique pour l’ensemble des prises parcelles et au niveau des bassins permet d’avoir une programmation simple de la distribution au niveau du secteur et facilite un autocontrôle entre paysans. Cette main d’eau ne devra pas être d’un débit relativement faible pour permettre des débits d’attaque permettant de réduire les infiltrations et permettre un avancement du front d’humectation au niveau de la parcelle.

Cette main d’eau se créée au niveau des bassins principaux par la répartition du débit de pompage en faction de ½,1/3 ou ¼. Aussi cette répartition peut avoir lieu au niveau des bassins secondaires généralement avec un facteur de fractionnement de ½. C’est ce facteur de répartition qui conditionne à l’avance les répartitions à retenir au niveau des bassins à construire au niveau du réseau.

Sur le terrain, la majorité des sites collectifs sont équipés de pompes de 100 m3/h ou de 200 m3/h. ceci entraine pour les débits de 100 m3/s deux mains d’eau de 14 l/s et pour les motopompes de 200 m3/s 4 main d’eau de 14 l/s.

Utilisation d’un Tour d’eau similaire au niveau des rampes

Le tour d’eau est intimement lié au mode de conception de réseau, qui lui aussi dépond des facteurs de répartition d’eau retenus au niveau des bassins principaux et secondaires. Si les répartitions ne sont pas identiques, elles entrainent l’utilisation de débits différents par rampes, entrainant donc, des tours d’eau d’irrigation spécifiques à chaque rampe et donc différents tours d’eau au sein d’un même secteur. Cette situation résulte en effet du nombre de prises qui différent d’une rampe à l’autre.

Ainsi, l’utilisation d’une main d’eau unique au niveau des rampes d’un secteur permet d’avoir un tour d’eau simple et uniforme au niveau du secteur. Cette uniformité assurera une facilité de fonctionnement de la distribution, offrant les conditions d’une facilité de son assimilation par les paysans.

Le tour d’eau devra indiquer toutes les informations de déroulement de la distribution notamment :

- le débit de chaque prise, en fonction de la répartition adaptée au niveau du bassin,
- le temps de fonctionnement des prises,

- le nombre de rampes en fonctionnement simultané,
- le nombre de prises à ouvrir par rampes,
- la durée par jour, de fonctionnement des rampes et par conséquent la durée de fonctionnement de la station de pompage.

Similitude de fonctionnement des bassins de répartition

Le mode de fonctionnement des bassins est régi directement par le nombre de prises que chaque bassin domine et du nombre de rampe en fonction de leurs tailles. Le fonctionnement du bassin permet de donner les informations suivantes ; qui pour avoir une distribution simple, devront être identiques pour l'ensemble des secteurs.

- les horaires de changement des ouvertures au niveau du bassin principal pour desservir les bassins secondaires,
- les horaires de changement des ouvertures au niveau des bassins secondaires pour desservir les rampes,
- les proportions de fractionnement et de répartition des débits entre bassin pour les bassins principaux,
- les proportions de fractionnement et de répartition des débits entre rampes d'un bassin secondaires,

Ainsi, pour faciliter ces opérations au niveau des bassins et de les rendre identiques et similaires pour l'ensemble des secteurs d'un périmètre ; le canevas hydraulique du réseau devra être conçu de manière à avoir le même nombre de prises qui fonctionne par jour avec un même débit.

Paramètres de conception aboutissant à une simple distribution d'eau entre irrigants

En phase de conception et d'implantation du réseau, les paramètres de conception aboutissant à une simple distribution devront être pris en compte, en vue d'aboutir à une distribution d'eau simple et qui, en principe, devrait tendre à être similaire à l'échelle d'un secteur et même au niveau des secteurs d'un périmètre. Ces facteurs sont comme suit :

- Symétrie de fonctionnement des rampes par rapport au bassin principal ou secondaire,
- Similitudes de fonctionnement des rampes de distribution au niveau d'un même bassin,

- Respect des même nombre de prises par rampes.

Répartition équilibrée des prises par rapport au bassin (principal ou secondaire)

Principe de base de la répartition du nombre de prises

La répartition des prises en nombre égale au niveau des bassins et rampes permet un fonctionnement des rampes avec le même débit (main d'eau) fixée initialement.

$$\Sigma P_{Dd} = \Sigma P_{Dg}$$

Avec :

- PDd : nombre total des prises parcelles sur la partie droite du bassin principal,
- PDg ; nombre total des prises parcelles sur la partie gauche du bassin principal,

Ainsi, lors du parcellement et du tracé du réseau ; le responsable des études et de conception du réseau, devra s'arranger à respecter cette condition en adoptants les arrangements suivants :

- la création de nouvelles prises vers le côté duquel les prises sont en nombre réduit,
- la suppression d'autres prises, notamment celles présentant des difficultés de dominance en eau ou nécessitant un nivellement important, au niveau du coté présentant le plus de prises,
- changer le premier tracé de manière avoir un autre permettant de satisfaire la répartition égales des prises par rapport au bassin considéré.

Autrement, les rampes fonctionneront avec des débits différents et par conséquent des temps d'arrosage différents. Dans cette situation, les déversoirs auront des largeurs différentes entrainant la réalisation de bassins différents.

Exemple de répartition équilibrée de prises par rapport au bassin

L'exemple ci-dessous présenté au niveau de la figure 6, montre la répartition équilibrée des prises par rapport au bassin principal. Ce dernier, assure le rôle de répartition d'eau d'irrigation en répartissant le débit de pompage en deux (Q/2), pour desservir les deux bassins secondaires, lesquels assurent le rôle de distribution d'eau d'irrigation entre rampes regroupant un même nombre de prises.

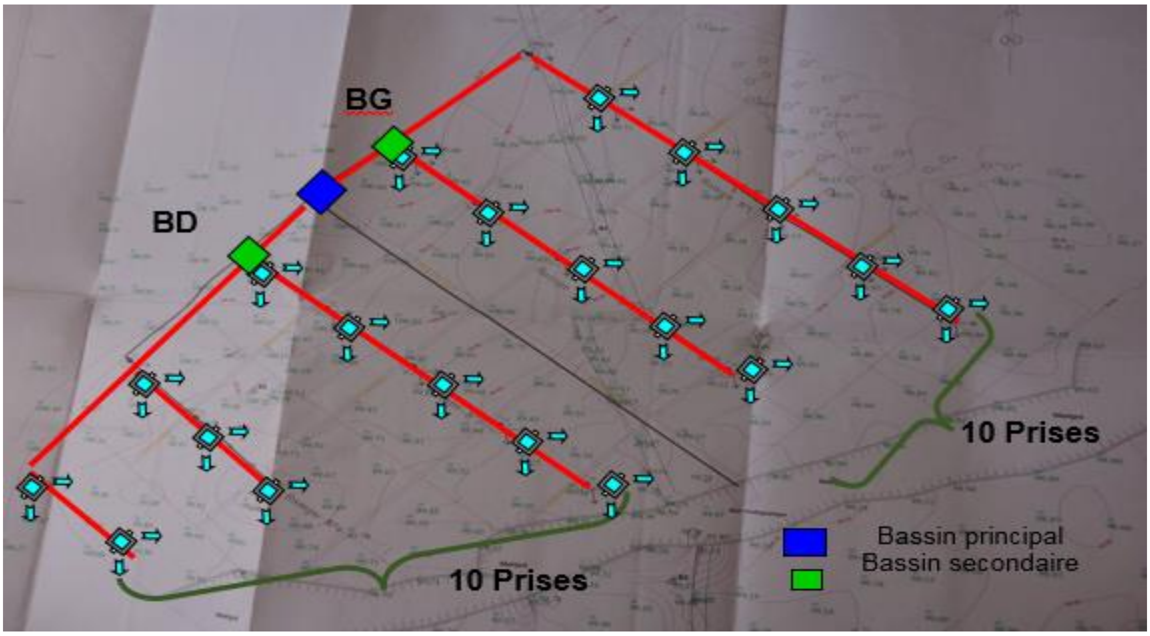

Figure n° 6 : schéma du réseau d'irrigation équilibré par rapport au bassin principal

Réduction du nombre de rangées de rampes et rationalisation des bassins secondaires

La rationalisation des effectifs des bassins secondaires et la réduction de rangées des rampes sont intimement liées et vont de pair. Plus le nombre de rangées de rampes par secteur est important, plus le réseau de distribution nécessite, soit la création de bassin supplémentaires, soit l'augmentation de déversoirs au niveau des bassins prévus. Ceci, engendre souvent des difficultés de distribution qui compliqueront le déroulement du tour d'eau entre rampes d'un secteur. A cet effet, il revient à trouver un équilibre du schéma du réseau et du nombre de bassin en réduisant le nombre de rangées de rampes, par une rationalisation du nombre de prises par rampes.

La réduction du nombre de bassins passe par le regroupement important des prises par rampe. Ce regroupement entraine une augmentation des longueurs des rampes et par conséquent une réduction de leur nombre. Cette solution offre aussi une ramification du réseau, plus simple et uniforme comme l'illustre les figures suivantes.

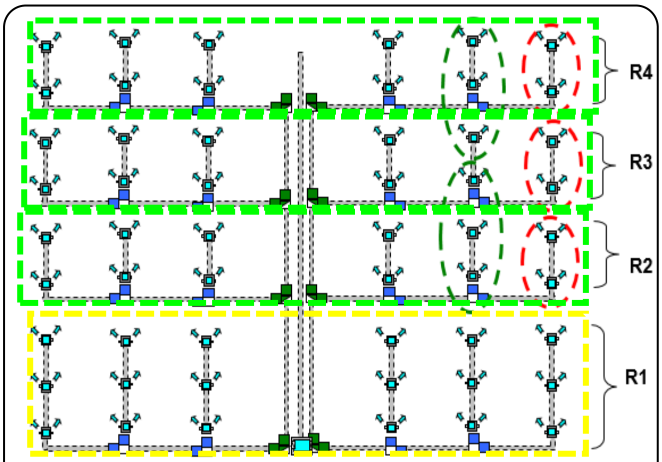

Figure n°7 : schéma existant du réseau d'irrigation en quatre rangées de rampes

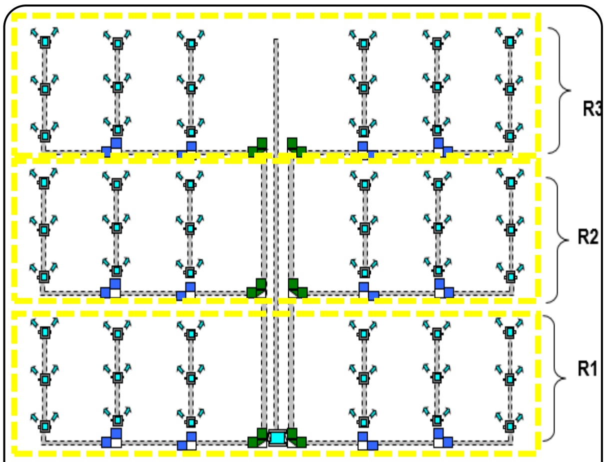

Figure n°8 : schéma en trois rangées représentant l'uniformisation du réseau d'irrigation

Equilibre du fonctionnement des bassins d'un secteur

Lors du tracé du réseau d'un secteur, on veille à respecter à la fois, un nombre identique de prises par rampe et un nombre identique de rampes par bassin. Cette règle conduit à avoir des bassins identiques en conception et en fonctionnement. Elle permet en outre une implantation des bassins sur un même alignement entre secteur, en vue d'avoir une homogénéité permettant de répondre à réseau de circulation donnant l'accès à tous les ouvrages de distribution. En outre une meilleure disposition des bassins, offre une esthétique montrant l'importance des aménagements réalisés (figure 5).

Similitude de fonctionnement des secteurs

La similitude de fonctionnement des secteurs est un paramètre de conception aussi important. Elle constitue une suite logique de la similitude de fonctionnement des bassins d'un secteur. Il est le fruit de recoupement de l'ensemble des paramètres du tracé du réseau. Le recours à ce paramètre permet un fonctionnement identique au niveau des secteurs d'un même périmètre.

La similitude de fonctionnement des secteurs d'un périmètre est une extension, dans la mesure du possible, du mode de fonctionnement des bassins d'un secteur aux autres secteurs du périmètre. En effet, on essaye que les bassins de l'ensemble des secteurs du périmètre soit identique en desservent en eau d'irrigation, les mêmes superficies.

Exemple d'un modèle du tracé du canevas hydraulique

Emplacement des rampes et tracé du réseau

Le nombre des parcelles à définir par secteurs au niveau du découpage, permet de donner la répartition des parcelles au niveau des rampes. Pour une meilleure illustration nous considérant un découpage du secteur en deux sous-secteurs ayant une rangée de rampes comportant 10 parcelles chacune. Dans cette situation nous obtenant deux rangées de rampes identiques avec une main d'eau du débit de pompage de Q/2 ou de Q/4 selon la répartition à prévoir au niveau des bassins.

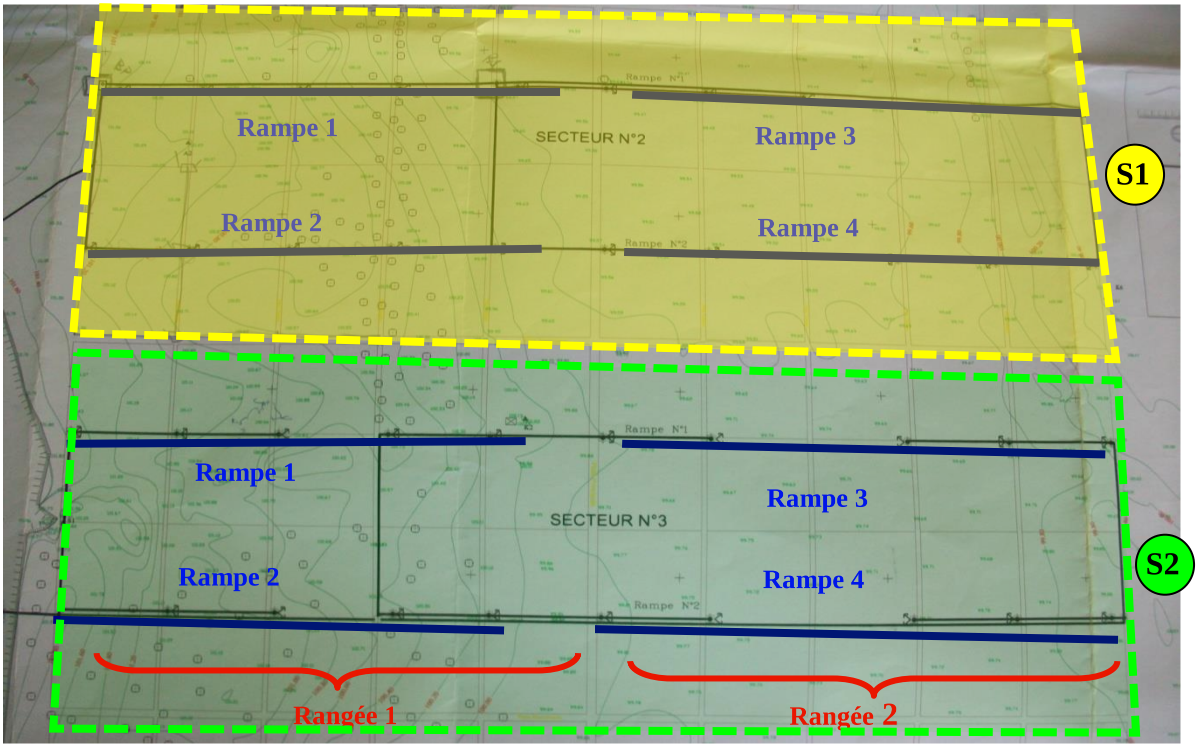

Figure n° 10 : Schéma montrant la nouvelle implantation du réseau en tenant compte des facteurs de conception et de fonctionnement (bassin unique)

Implantation des bassins et répartition d'eau

Le tracé retenu et le mode de distribution d'eau à adopter imposent souvent un canevas d'implantation des bassins. Dans le cas de l'exemple considéré ci-haut, l'implantation peut être faite des façons suivantes :

. **-Première possibilité : séparation des bassins**

Dans cette situation de séparation des bassins, les deux sous-secteurs peuvent avoir un bassin secondaire chacun desservant deux rampes (figure ci-dessous). Ce choix conduit à la création d'un bassin principal (ou que ce dernier soit jumelé au bassin secondaire du premier sous-secteur).

Sur le plan de répartition d'eau, les trois bassins auront deux déversoir identiques chacun avec les possibilités suivantes en main d'eau ;

- une main d'eau de Q/2 du débit de pompage ; ainsi, le débit refoulé est envoyé par le bassin principal en totalité vers un seul bassin secondaire. Au niveau de ce dernier, le débit de pompage (Q) et partagé en deux par les deux déversoirs pour avoir une main d'eau de Q/2 au niveau de chaque rampe.
- une main d'eau de Q/4 du débit de pompage : le débit refoulé est partagé en deux par le bassin principal et dessert les deux bassins simultanément d'un débit de Q/2 vers un seul bassin secondaire. Au niveau de ce dernier, le débit reçu (Q/2) est partagé en deux par les deux déversoirs pour avoir une main d'eau de Q/4 au niveau de chaque rampe.

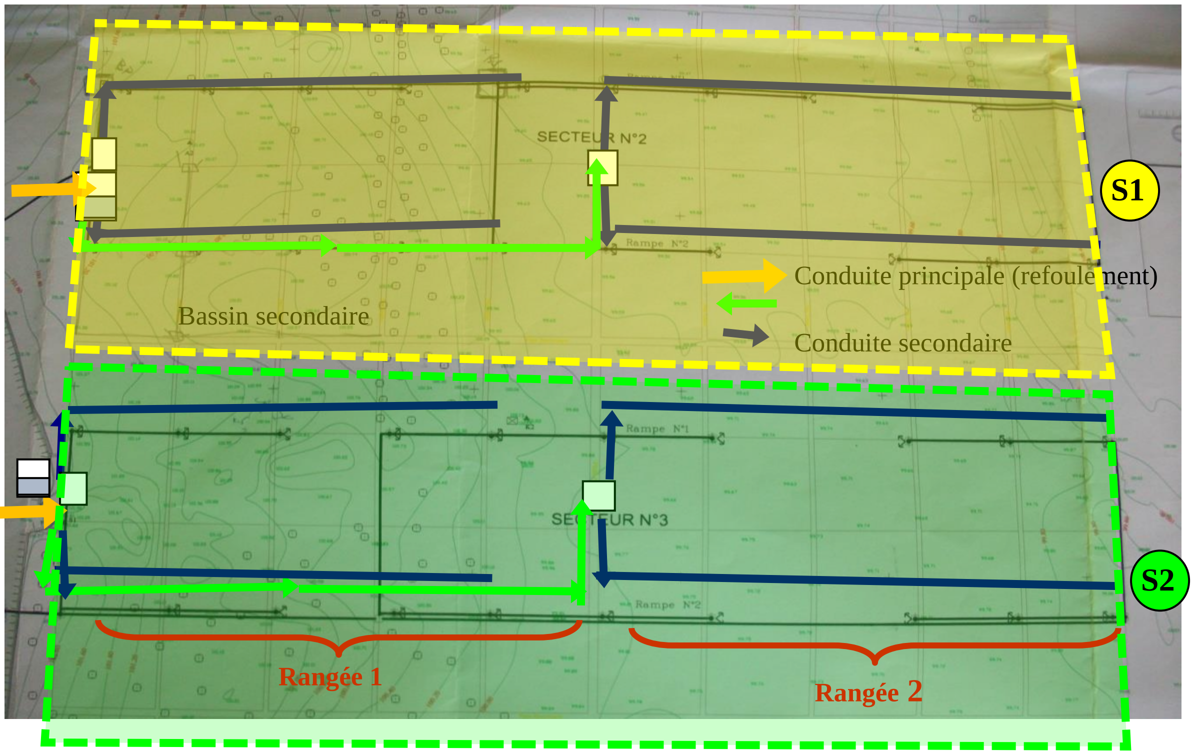

Figure n° 11 : Schéma montrant une possibilité d'implantation des bassins

-Deuxième possibilité : regroupement des bassins

Dans cette situation le bassin principal et les deux bassins secondaires des deux sous-secteurs peuvent être regroupés en un seul bassin assurant le rôle des trois bassins (bassin principal et les deux bassins secondaires des sous-secteurs). Ce choix conduit avoir un seul bassin qui sera placé au milieu du secteur. Dans cette situation, la conduite de refoulement traverse le secteur pour rejoindre le bassin.

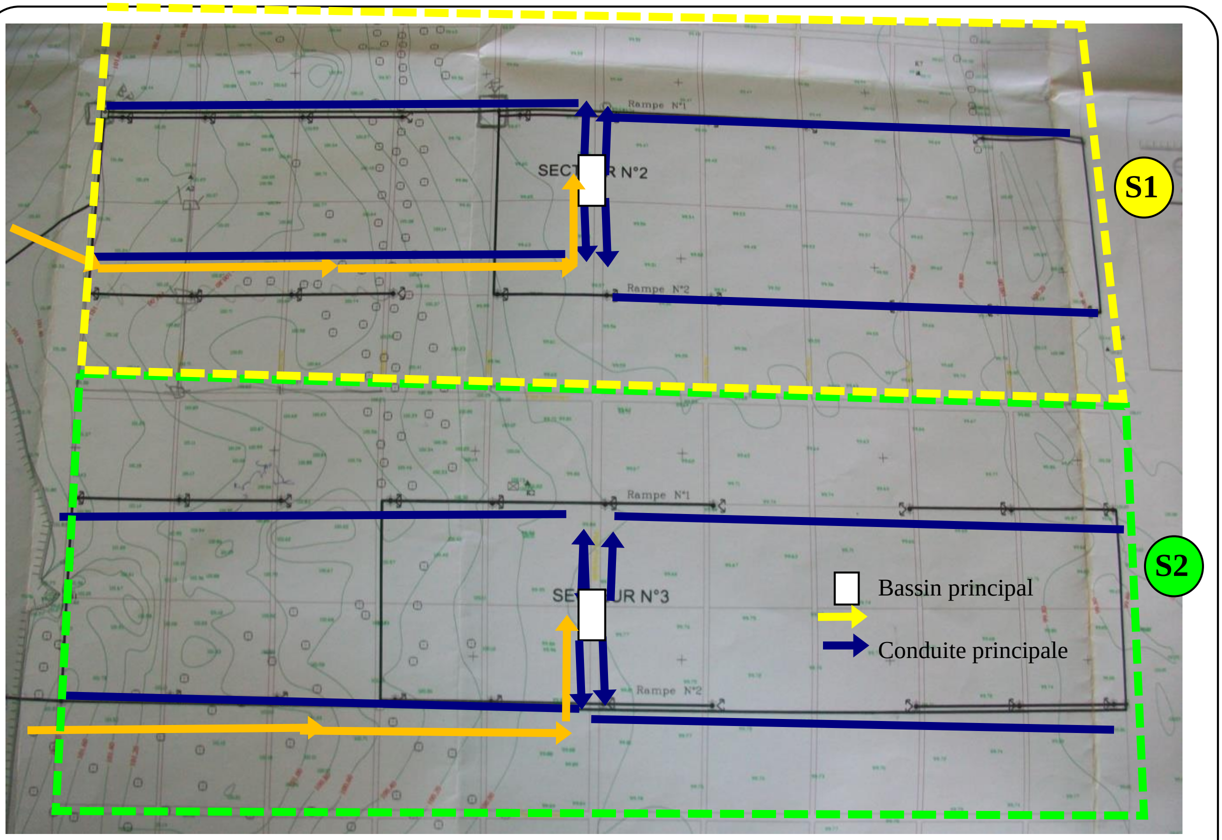

Figure n° 12 : Schéma montrant la possibilité adéquate d'implantation des bassins unique)

Cette deuxième possibilité reste la meilleure puisque elle permet ce qui suit

1- Gain en nombre de bassins à réaliser ;
2- Regroupe à un seul endroit l'ensemble des manœuvres de distribution notamment les fermetures et les ouvertures des vannelles des déversoirs ;
3- Facilite l'orientation des débits entre les quatre rampes du secteur ;
4- Réduit la charge hydraulique du sous-secteur aval, puisque le refoulement d'eau se fait jusqu'au milieu du secteur,

Dans cette solution de regroupement du rôle du bassin principal et des bassins secondaires en un seul, il est nécessaire d'adopter un nouveau modèle de bassin regroupant l'ensemble des bacs de dérivation dotés de vannettes. Ce regroupement des bassins offre de multiple avantage notamment au niveau de la répartition d'eau par les possibilités suivantes :

- ✓ Répartition du débit sur les quatre rampes,
- ✓ Répartition du débit en 3 dans le cas où une rampe présente un problème,
- ✓ Répartition du débit entre deux pour de rampes dans cette situation il présente 6 possibilités

Implantation des prises et sens d'irrigation des parcelles

L'implantation des prises à lieu à l'extrémité haute sur l'alignement de rampe desservant la parcelle. Pour l'exemple considéré, l'implantation des prises est donnée au niveau de la figure ci-dessous. On distingue bien pour certaines parcelles, le sens d'écoulement de la rampe qui diffère du sens d'irrigation des parcelles.

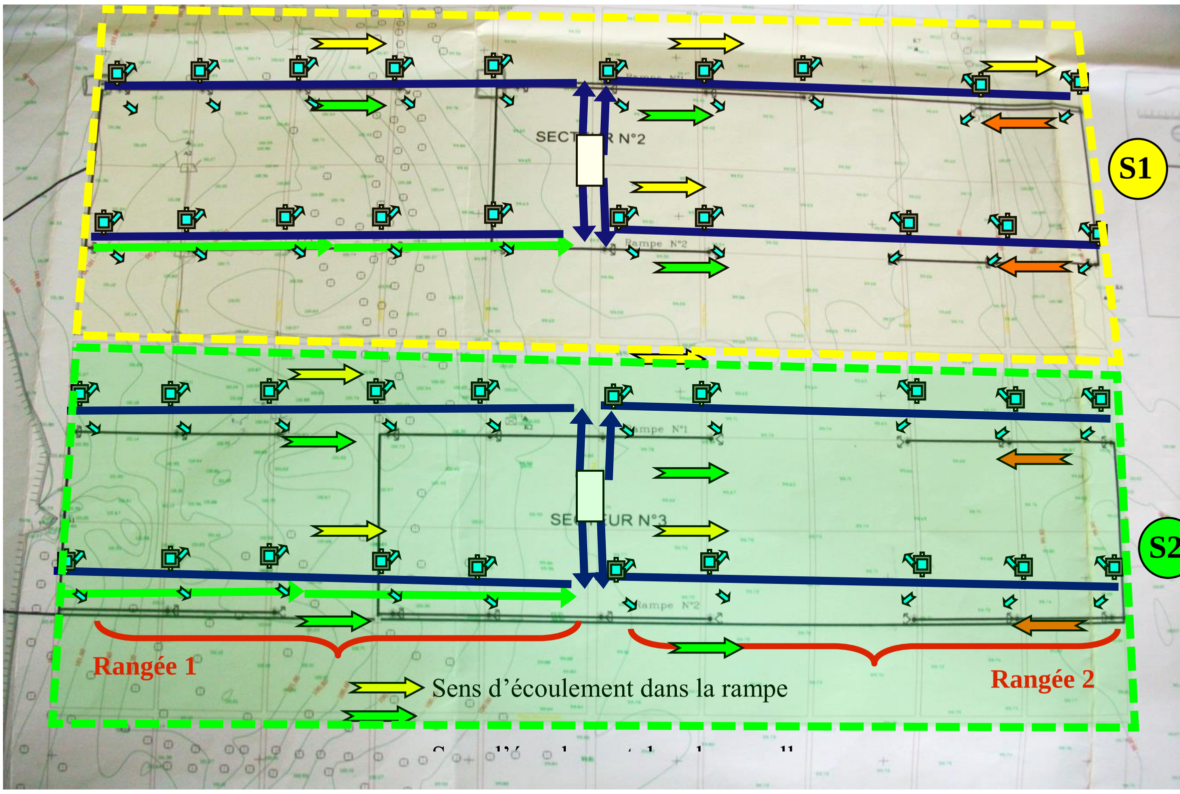

Figure n° 13 : Schéma montrant la nouvelle implantation du réseau en tenant compte des facteurs de conception et de fonctionnement (bassin unique)

Cette nouvelle implantation du réseau présenté au niveau de l'exemple considéré, permet les avantages suivants :

- rampes avec le même nombre de prises,
- similitude entre les rampes de chaque secteur,
- fonctionnement des rampes avec le même débit,
- réduction des bassins à un seul bassin principal comportant 4 déversoirs, chaque déversoir assure l'alimentation d'une rampe,
- symétrie par rapport au bassin principal, induisant une symétrie et simplicité de distribution
- similitude du réseau entre secteurs, engendrant un même tour d'eau pour les secteurs.

LES BASSINS DE REPARTITION D'EAU D'IRRIGATION

Classification des bassins

Les catégories des bassins de répartition

Les bassins de répartition d'eau d'irrigation sont classés en trois catégories : les bassins principaux, secondaires et tertiaires.

- ✓ Le bassin principal ; est celui qui reçoivent en premier lieu, l'eau refoulée par la station de pompage et la distribue aux bassins secondaires,
- ✓ Le bassin secondaire est généralement positionné entre le bassin principal et les rampes de répartition pour la majorité des sites aménagés. Il assure la répartition d'eau pour les rampes qui en dérivent.
- ✓ Les bassins tertiaires ; ils sont d'ordre 3. Ils sont prévus au niveau des périmètres de grande taille. Ils se positionnent entre les bassins secondaires et les rampes de distribution. il assure la répartition d'eau directement aux rampes.

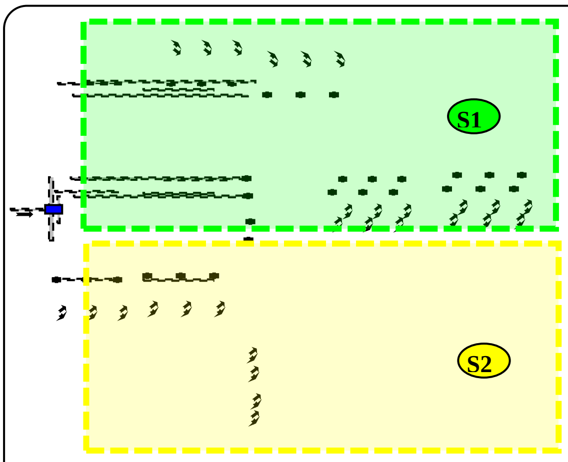

Figure n° 14 : plan du tracé des conduites des secteurs comportant un seul bassin

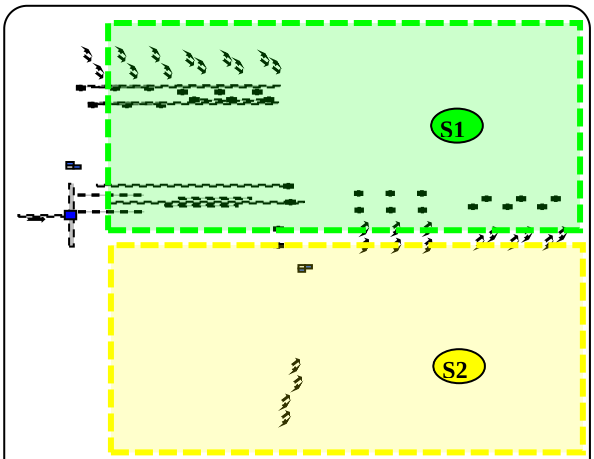

Figure n° 15 : plan du tracé des conduites des secteurs comportant un seul bassin principal et d'autres bassins secondaires

Modèle de bassin

Le bassin est composé d'un ensemble de compartiments (Bacs) dont un est le compartiment de réception lié à la conduite d'alimentation du bassin et le reste bacs sont les compartiments de répartition liés aux rampes de distribution. Un exemple du détail d'un bassin est dressé au niveau de la figure ci-dessous. Il correspond généralement aux bassins ayant une hauteur d'élévation relativement importante. Dans ce modèle, la partie inferieure constitue à la fois une protection des conduites de connexion du bassin, et un abri utile permettant le rangement du petit matériel agricole.

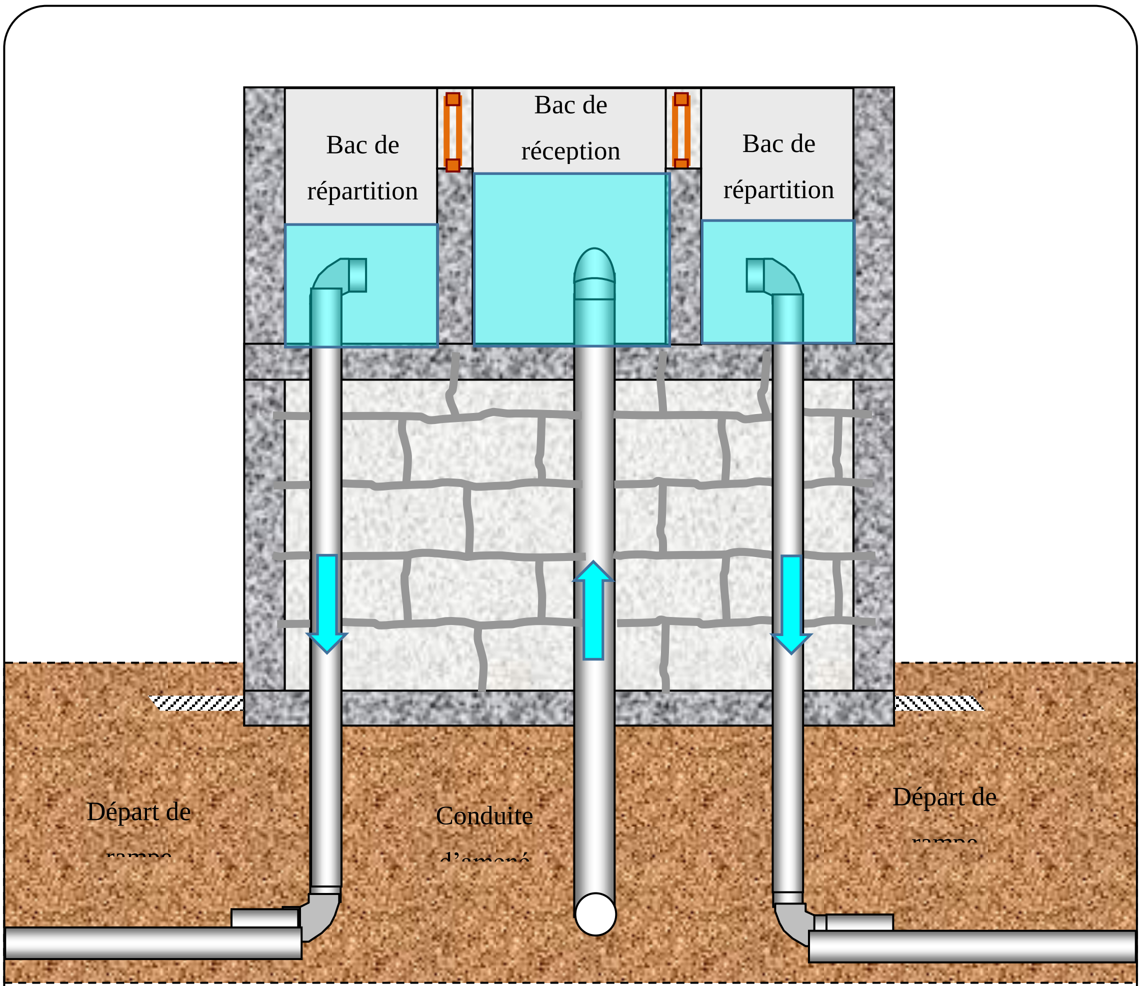

Figure n° 18 : nouveau model des bassins ou les conduites sont installées à l'intérieur des bacs du bassin

Les formes possibles à donner aux bassins

La forme du bassin est une forme simple de section rectangulaire suffisante. Cette forme dépend de son classement et du nombre de rampes ou de sous-secteur qu'il dessert. Ainsi, le bassin peut être à deux départs ou plus.

Bassins à deux départs

Cette forme est la plus répandue au niveau des certains bassins principaux et la majorité des bassins secondaires. Il s'agit de la situation dont le bassin principal dessert deux bassins secondaires ou dont le bassin secondaire dessert deux rampes. Ceci, conduit donc à la création au niveau du bassin de deux bacs de départ.

Bassins à trois départs

Cette forme à lieu au niveau des bassins assurant la desserte de trois bassins départs comme le montre la figure 19.

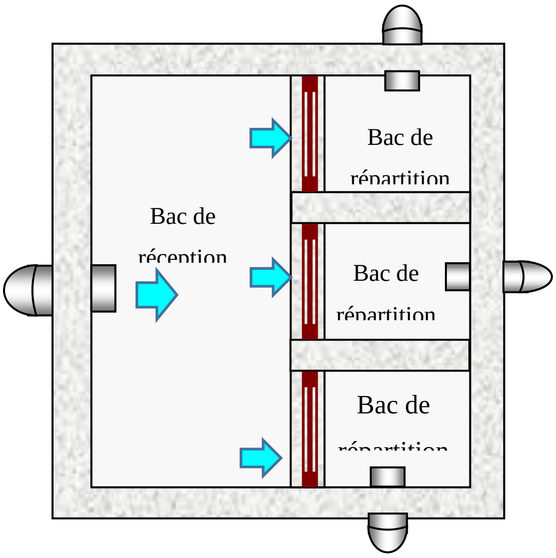

Figure n° 19 : vue en plan du bassin à trois départs

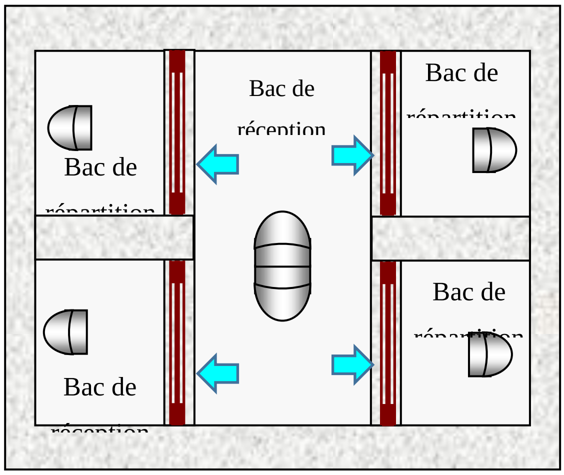

Figure n° 20 : vue en plan du bassin à 4 départs

Bassins à quatre départs

Cette forme, comme dans le cas précédent, à lieu au niveau des bassins assurant à la fois le rôle de bassin principal et secondaire ou l'ensemble des départs est regroupé au niveau du bassin principal (figure 20).

Bassins à départs multiples

Cette forme, comme dans le cas précèdent, à lieu au niveau des bassins assurant à la fois le rôle de bassin principal et secondaire ou l'ensemble des départs est regroupé au niveau du bassin principal avec des bacs de départ pouvant être de 6.

Répartition des débits entre bassins

L'eau refoulées par la station de refoulement, arrive directement au niveau du bassin principal et se reparti vers les bassins secondaires à travers des déversoirs qui y sont aménagés. Cette répartition est proportionnelle à la longueur des déversoirs. Pour une répartition égale ; les déversoirs sont dotés d'une même longueur de déversement. Ce type de répartition se fait d'une manière automatique au niveau du bassin.

Charge hydraulique de fonctionnement des prises parcelles et hauteur des bassins

La hauteur du bassin correspond à la charge hydraulique suffisante pour assurer une alimentation correcte de la prise la plus défavorisée du réseau (figure 22 et 23). Cette charge est évaluée en tenant compte des paramètres suivants :

- La vitesse de sortie d'eau exigée au niveau du diamètre de la prise pour garantir le débit de la main d'eau retenue au niveau du programme de distribution ;
- Les pertes de charge de la conduite, depuis le bassin jusqu'à la prise la plus défavorisée ; nécessitant la valeur maximale de la charge de fonctionnement à laquelle la crête du déversoir du bassin devra être calée,

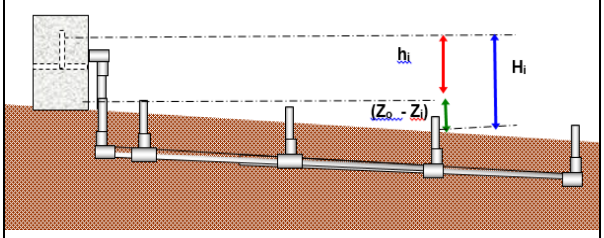

Figure n° 22 : Schéma montrant la surélévation du bassin dans un terrain en pente

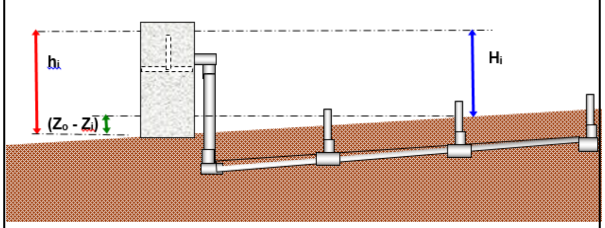

Figure n° 23 : Schéma montrant la surélévation du bassin dans un terrain en contrepente

LES OUVRAGES DE PRISES PARCELLES

Description des ouvrages de prise

Il s'agit du dernier élément du réseau semi californien. Ce sont des dispositifs qui délivrent l'eau d'irrigation à la parcelle. Ces prises jouent le rôle de vannes, fixées à l'extrémité haute de la rehausse associe à un ouvrage de génie civil pour fixation et protection. Ces ouvrages sont multiples. Le plus pratique et économique reste celui où la prise de sortie est centrée au niveau d'un bassin permettant d'amortir les eaux récupérée. La répartition d'eau d'irrigation vers les parcelles se fait moyennant des tuyaux en PVC équipés de bouchons (Photos ci-dessous).

Photo n° 17 : ouvrage à une seule prise dans les sortie sont équipées de bouchons

Photo n° 18 : ouvrage à deux prises

Emplacement des prises et choix du sens des irrigations

L'implantation des prises constitue une suite logique au tracé des conduites de distribution et des rampes. Le facteur déterminant pour l'emplacement des prises parcelle est la pente générale du terrain à aménager. Les courbes de niveau dressées sur le plan, donne les détails de l'allure de la pente au niveau de la parcelle. Cette pente permet de montrer le sens des irrigations et par la suite le positionnement des prises. Chaque prise parcelle sera placée au point le plus haut situé sur l'alignement du tronçon de la rampe longeant la parcelle. Il peut y avoir les positions suivantes :

- ❖ Une position centrale en terrain relativement plat ; avec une légère surélévation de manière à pouvoir dominer toute les partie de la parcelle ou moyennant un léger nivellement. cette position permet de positionner l'arroseur en milieu de la parcelle pour permettre d'irriguer dans les deux sens (figure 25).

❖ Une position à l'extrémité de la parcelle en terrain en pente pour dominer toute la parcelle (figure ci-dessous). Ainsi, l'analyse de la pente à l'échelle de la parcelle, par rapport au sens d'écoulement d'eau dans la rampe, permet d'indiquer l'endroit de l'emplacement de la prise. Elle sera placée selon l'une des deux situations suivantes :
  - ➢ du coté amont de la rampe traversant la parcelle, si la pente de la parcelle est dans le même sens d'écoulement d'eau dans la rampe,
  - ➢ du coté aval de la rampe si la pente de la parcelle est dans le sens contraire à l'écoulement d'eau dans la rampe.

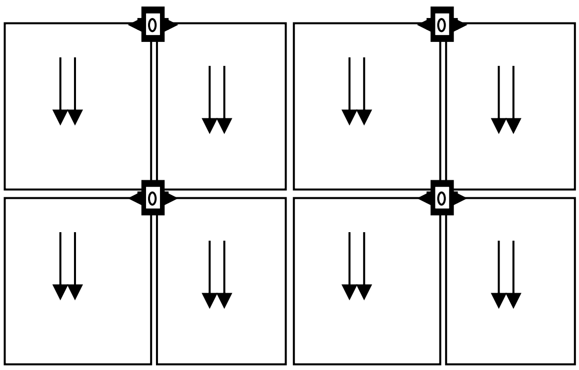

Figure n° 24 : ouvrage de prise installé à l'extrémité de la parcelle

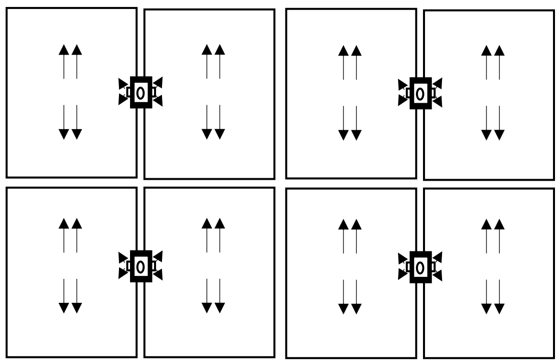

Figure n° 25 : ouvrage de prise installé au milieu de la parcelle

EVALUATION DES COUTS DES AMENAGEMENTS

Classification des périmètres

Catégorie de périmètres

Selon les données disponibles au niveau des projets et programmes d'aménagements des périmètres, l'ensemble des périmètres peut être classé en trois catégories :

- Une catégorie des périmètres de l'ordre 2 à 3 ha, destinés aux petits exploitants privés,
- Une deuxième catégorie dont la superficie des périmètres oscille autour de 5 ha,
- Une troisième catégorie de périmètres de l'ordre de 10 ha de superficie, exploités généralement dans un cadre collectif par des groupements de paysans. Cette catégorie

de périmètre correspond aux superficies des secteurs de la majorité des sites du Programme de la petite irrigation.

Model du tracé de réseau des catégories de périmètres

Sur l'ensemble des périmètres aménagés en système semi californien, certains ont été dotés d'une architecture de réseau simple et équilibrée. Les formes du réseau retenues pour chaque catégorie sont les suivantes :

-Catégorie 1 :

En raison du caractère individuel de l'exploitation et de sa taille petite (autour de 2 ha), il est prévu une seule rampe, ne nécessitant pas ainsi de distribution au niveau de bassin, d'où sa suppression. A cet effet, le schéma du réseau est donc comme suit :

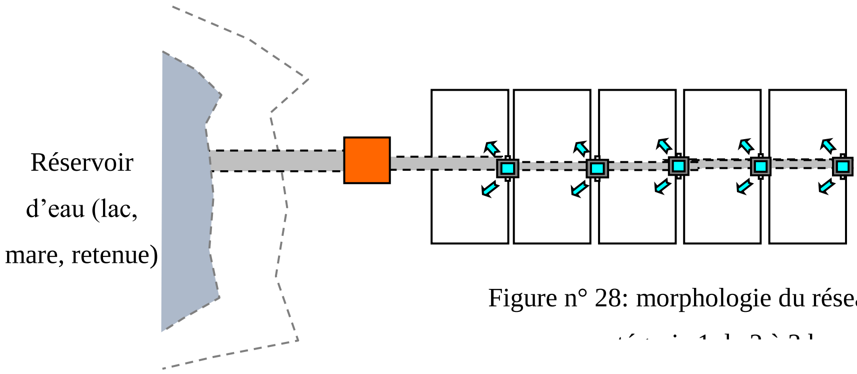

Figure n° 28: morphologie du réseau de la

-Catégorie 2 :

Pour la catégorie 2 de périmètres autour de 5 ha, le schéma du réseau de distribution est doté d'un bassin de répartition alimentant deux rampes dans la majorité des cas identiques. Il est présenté au niveau de la figure ci-dessous :

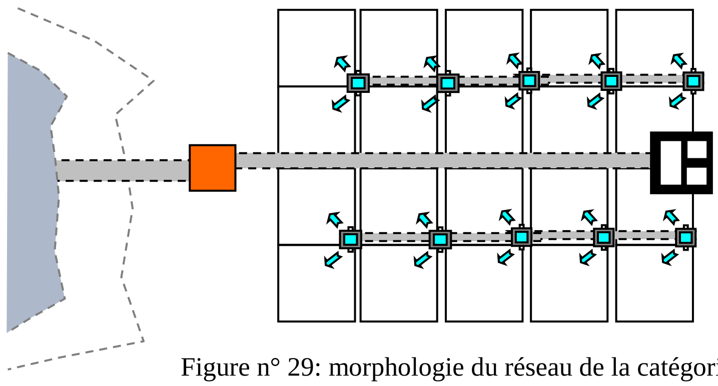

Figure n° 29: morphologie du réseau de la catégorie 2 de 5 ha

-Catégorie 3 :

Pour la catégorie 3, le schéma du réseau de distribution présenté pour l'évaluation des aménagements représente une forme simple parmi d'autres formes que peu avoir les périmètres de cette taille. Il comporte des améliorations sur le tracé et l'implantation des bassins. Il est doté d'un seul bassin de répartition alimentant quatre rampes identiques. Le schéma du réseau est présenté au niveau de la figure ci-dessous, il correspond aux situations ou le terrain est relativement plat.

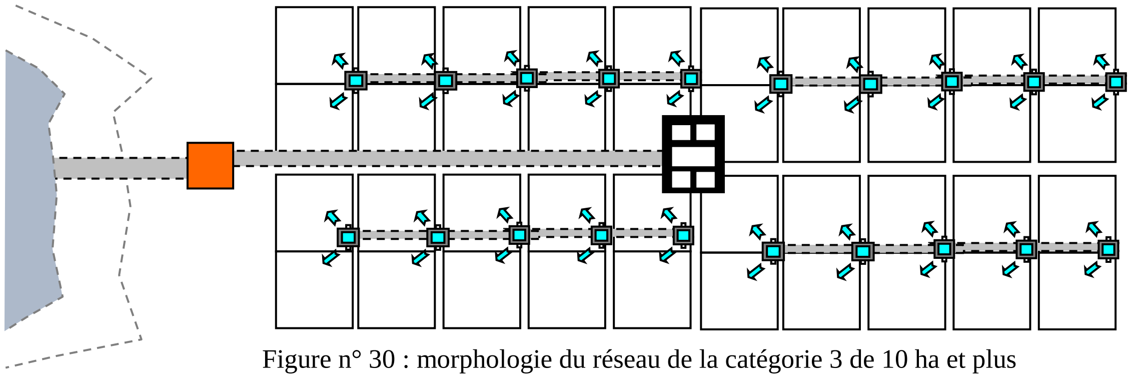

Figure n° 30 : morphologie du réseau de la catégorie 3 de 10 ha et plus

Evaluation et choix des diamètres des conduites

L'évaluation des diamètres de chaque catégorie de périmètre requiert des données de basses, à savoir les besoins en eau, superficie de catégorie de périmètres et la durée d'irrigation. Concernant les besoins en eau ; ils sont évalués à environ 3000 m3 / ha en mois de pointe pour la culture la plus exigeante en eau qui est le maraichage.

Concernant la durée d'irrigation, plusieurs paramètres conjuguent entre eux pour son évaluation, notamment la main d'eau à retenir au niveau des périmètres. Ainsi en se fixant des mains d'eau entre 10 l/s à 14 l/s, il serait judicieux de fixer à la durée d'irrigation comme suit :

- 6 h pour les périmètres privés, soit de 7 à 13 h, pour laisser le temps libre à l'agriculteur de s'occuper d'autres taches agricoles ou divers.
- 10 h, pour les périmètres collectifs de 10 ha de superficie.

L'ensemble de ces paramètres permettent de déterminer le débit de la station et la main d'eau d'irrigation à adopter au niveau du périmètre, lesquels permettent d'estimer le diamètre à donner aux conduites. L'ensemble des résultats après les itérations possibles, est présenté au niveau des tableaux ci-dessous.

La conduite de refoulement.

Pour la conduite de refoulement. L'évaluation des diamètres ne tient pas compte beaucoup de la vitesse comme dans le cas des conduites de distribution. La vitesse variera entre 1 à 1,5 m/s. Elle ne constitue pas de contrainte de dimensionnement car l'ensemble des pertes de charge seront supportées par la motopompe.

Tableau n° 1 : choix des diamètres de la conduite de refoulement

Catégorie de périmètre	Superficie (en ha)	Débit de pompage (l/s)	Diamètre (mm)	Vitesse (m/s)	PDC (en m/100 m)	observation
1	2,5	12	125	1,06	1 ,5	
2	5	24	160	1, 29	2,74	
3	10	28	160	1,5	3,15	

Les conduites de distribution

Au niveau des conduites de distribution, les diamètres à retenir sont ceux qui permettant de réduire les pertes de charge totales, de manière à ce que la hauteur du bassin soit une hauteur non haute, variant entre 1m à 2 m. le tableau ci-dessous donne les résultats obtenu après les itérations nécessaires. Le choix sera porté pout le diamètre 125 mm pour les conduite de distribution.

Tableau n° 2 : choix des diamètres des rampes de distribution

Catégorie De périmètre	Superficie (en ha)	Débit de pompage (l/s)	Main d'eau (l/s)	Diamètre (mm)	Vitesse (m/s)	PDC (en m/100 m)	Hauteur minimale calage déversoir
1	2,5	12	12	125	1,06	1,5	
2	5	24	12	125	1,06	1 ,5	
3	10	28	14	125	1,24	1 ,9	

Evaluation des couts

Rubriques des travaux

Les principales rubriques des travaux d'aménagements semi californien des périmètres sont :

- La réalisation du chenal de pompage, pour les prélèvements d'eau sur les retenues d'eau,
- La construction de l'abri de la station de pompage, qui revêt plusieurs formes selon la source de pompage,
- Acquisition de la motopompe et accessoires,
- La réalisation du réseau de distribution et ses accessoires de distribution.

Evaluation des couts de réalisation des ouvrages type

Les ouvrages modèles sont ceux où des adaptations ont été introduites pour à la fois améliorer leurs conceptions, réalisations et fonctionnements. Ce sont les ouvrages de prise et bassin de répartition.

Concernant les ouvrages des prise parcelles, ils sont évalués à environ 25 000 FCFA par ouvrage ; le modèle proposé coute moins de la moitié des ouvrages de prise très répondus au niveau des périmètres déjà aménagés. Il est prévu qu'il soit réalisé complètement en béton moyennant le moule en bois ou en acier, pour faciliter la réalisation.

Concernant les bassins, ils dépondent de leurs tailles qui correspond au nombre de bacs de répartition qu'ils comportent. Leur évaluation est présentée au niveau du tableau ci-dessous, le résultat obtenu montre une augmentation de l'ordre de 32 % par augmentation de bac de répartition.

Tableau n° 3 : Evaluation des couts de réalisation des bassins

Rubrique	Bassin à 2 bacs répartition	Bassin à 3 bacs de répartition	Bassin à 4 bacs de répartition	Bassin à 6 bacs de répartition
Cout estimé en FCFA	280 000	370 000	420 000	500 000

Evaluation des couts des aménagements des périmètres

Pour l'évaluation des couts des différentes catégories de périmètres, il a été tenu compte de certaines hypothèses, en considérant que le chenal et l'abri de la station sont presque les mêmes pour les 3 catégories de périmètres ; car la variation dans la masse des travaux est limité d'une catégorie à l'autre. La synthèse des résultats obtenus sont dressé dans le tableau ci-dessous.

Tableau n° 4 : cout des amendements en semi californien (en x 1000 FCFA)

Rubrique	Catégorie 1	Catégorie 2	Catégorie 3	Observation
Installation	530	530	530	
Chenal	2 950	2 950	2 950	
Abri de la station	1 200	1 200	1 200	
Motopompe accessoire	678	1570	1770	
Réseau d'irrigation	1 550	11500	14950	
Cout total	693	17770	21400	
Cout moyen à l'ha	2 770	3550	2140	

Les résultats obtenus montrent que le cout à l'hectare augmente quand la superficie diminue ceci est du cout du chenal et de l'abri de la station qui ne subissent de grande variation par catégorie de périmètres.

L'évaluation de chaque pourcentage rubrique au sein cout des aménagements montre que pour les petits périmètres le chenal représente une part importante du cout d'aménagement. Le réseau reprendre en moyenne 60 % du cout à l'hectare pour les aménagements de superficies de 5 Ha. A cet effet, il est recommandé que la superficie minimale d'aménagement soit supérieure à 5 ha.

Tableau n° 5 : pourcentage de répartition des rubriques d'aménagement :

Rubrique	Catégorie 1	Catégorie 1	Catégorie 1	
Installation du chantier	2	3	8	
Chenal	14	17	43	
Abri de la station	6	7	18	
Motopompe accessoire	8	9	10	
Réseau d'irrigation	70	65	22	

CONCLUSION

Les aménagements réalisés au niveau des différentes sites ont permis de comprendre le mode de conception et de fonctionnement des périmètres aménagés en semi californien et d'en relever les différences, à l'origine des difficultés de fonctionnement des réseaux de distribution. Sur cette base des propositions de modèle d'ouvrages ont été faites pour les futurs aménagements. Ces propositions ont portés sur l'ensemble des composants du réseau semi californien (bassins, déversoir, ouvrage de prises et les vannes des prises).

Concernant le réseau, les hypothèses et paramètres de base d'une meilleure conception aboutissant à un réseau d'une morphologie simple et une exploitation facile ont été développés. Un ensemble de détails et d'exemples garantissant la maitrise des facteurs de réussite d'un aménagement ont été illustrés, en indiquent toutes les règles à adoptées au niveau des aménagements de périmètre villageois en semi californien.

D'une manière globale, un ensemble de conseils pratiques pouvant être considérés à la fois comme recommandations et éclaircissements sur les techniques de conception et de gestion des réseaux d'irrigation en semi californien ont été formulées pour éviter les difficultés vécues au niveau des périmètres aménagés et de mettre à la disposition des paysans, des réseaux simples, et faciles à être gérés à la fois individuellement au niveau des exploitations privé et collectivement au niveau des groupements d'exploitants.

Les estimation des couts d'aménagements entreprise sur l'ensemble des périmètres ayant été classés en trois catégories ; la première destinés aux petits exploitants privés, une deuxième dont la superficie du périmètre oscille autour de 5 ha, une troisième catégorie de périmètres dépassant les 10 ha, exploités généralement par des groupements de paysans. Les résultats obtenus montrent que le cout moyen complet à l'hectare est de 2 700 000 FCFA soit environ 4000 $. Ce cout ; fait du système d'irrigation semi californien non seulement un aménagement à faible cout, mais un aménagement répondant aux conditions villageoises par le recours à une technologie simple dont son matériel est disponible chez les revendeurs locaux garantissant sa disponibilité et par conséquent la longévité des ouvrages et du projet.

The development of agricultural mechanization in sub-Saharan agriculture: the FEDERUNACOMA project. *Marco Pezzini*

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Regional Meeting on Advancing the Operationalization of the Framework for SAMA

About FederUnacoma / CEMA

The Italian Agricultural Machinery Manufacturers Federation brings together, and represents in Italy and abroad, the associations of Italian manufacturers implements (**Assomao**), self-propelled machines (**Assomase**), tractors (**Assotrattori**), components (**Comacomp**) and gardening machinery (**Comagarden**). FederUnacoma's associates account for 80% of Italian production, with exports accounting for 60% of this production.

FederUnacoma is a member of CEMA, the association representing the European agricultural machinery industry. With 11 national member associations, the CEMA network represents both large multinational companies and numerous European SMEs active in this sector. The industry comprises about 7,000 manufacturers, producing more than 450 different types of machines with an annual turnover of about EUR 40 billion (EU 28 -2016) and 150,000 direct employees.

Both FederUnacoma and CEMA are part of the AGRIEVOLUTION Alliance, i.e., the global voice for agriculture equipment manufacturers. Made up of 15 agriculture equipment manufacturing worldwide associations and organizations, AGRIEVOLUTION's mission is to support our collective agriculture equipment manufacturing members around the globe, working to promote the benefits of mechanization in global sustainable agriculture.

CEMA-FAO alignment

- Since the early 2000s, several drivers, such as the rise in global food prices, the emergence of new suppliers of agricultural machinery, the demographic trends in Africa with increased urbanisation, in particular of youth and men, the increased investment by many African governments in agricultural productions and agri-food processing, have contributed to a renewed interest in agricultural mechanisation in Africa.
- Against this backdrop, while keeping in mind the need to seriously rethink the transformation of agriculture and sustainable mechanisation in Africa at all governance levels, FAO and the European Agricultural Machinery Industry Association (CEMA), forged a partnership in 2015 that aims to promote wider use of sustainable agricultural mechanization in developing countries.
- CEMA and FAO are working together to manage and disseminate knowledge on sustainable approaches to agricultural mechanization. The aim is also to jointly develop technical programmes to support innovation in mechanization and facilitate the implementation of sustainable mechanization initiatives at the field level.
- Tailored, inclusive, and integrated approaches to agricultural mechanization can make a real difference in increasing the welfare of farm households and create positive dynamics and opportunities for economic growth in rural areas.
- One the main focuses of the partnership is on capacity building activities in Africa, where human muscle remains the most important power source for smallholder farmers. For example, in sub-Saharan Africa, humans provide 65 percent of the power required for land preparation compared to 40 percent in East Asia, 30 percent in South Asia and 25 percent in Latin America and the Caribbean.
- Furthermore, since the early 2000s, FEDERUNACOMA actively launched and supported the idea behind the creation of a worldwide alliance in the agricultural machinery industry. In 2008, FEDERUNACOMA holds the inaugural AGRIEVOLUTION Summit in Rome. AGRIEVOLUTION is the global alliance of agriculture equipment manufacturers. Made up of 15 agriculture equipment manufacturing worldwide associations and organizations, AGRIEVOLUTION's mission is to support our collective agriculture equipment manufacturing members around the globe, working to promote the benefits of mechanization in global sustainable agriculture. The idea of an international coalition of associations has been

designed to share information and collaborate globally throughout the year. It was launched on the shared belief that in today's global agricultural economy, it is crucial that current issues and future challenges be viewed from a global perspective and be addressed on a global basis.

Main gaps and Enabling factors

Despite its potentiality, the agronomic yields in Africa remain low if compared with other regions of the world, and the gaps are widening.

Main Gaps	Most farmers are smallholders, many of whom are poor. Africa has about 51 million farms of which 80% (or 41 million) are smaller than 2 ha in size (Lowder, Skoet, & Raney, 2016), and their numbers are still increasing in most countries (Headey, 2016; Jirström et al., 2011).
	A significant lack of the infrastructural and skills for the agricultural use of water although the availability of the water resource.
	A significant lack of training in good agricultural practices able to reach the yield per hectare of some areas less advantaged from a geo-climatic point of view.
	A significant lack of know-how for harvest, post-harvest, and adequate storage facilities in order to reduce food losses especially with regard to challenges due to climate change
	A significant lack of know-how for a transformation able to increase the added value.
	A significant lack of funds for the production, which creates deficiencies in the whole agri-food chain and increases the uncultivated marginal lands
	Gender disparities, typically women are disproportionately concentrated in 'lower skill' and lower paid positions.
	The Governance is not able to attend in training and directing the actors involved in the logistics, to link national, regional and international markets.

Food security is actually one of the main concerns. This is due to several causes:

- One of the main drivers of the surge in consumers' demand in Africa is the continent's growing population.
- **37% of the African population is urbanized**, and the UN foresees that by 2050 the urban population share will reach 56% (UN, 2014).

- African countries and public authorities should consider to measures to mitigate potential food shortages or food distribution system disruptions in case rural and urban population suffering from natural and human-made disasters.

How mechanisation can support sustainable agriculture

The European Agricultural Machinery industry is aware of the challenges we're facing today, with an unprecedented critical convergence of population growth, dwindling natural resources and the impacts of climate change.

What we know right now is that there is a pressing need to increase global food production to feed the growing, and increasingly urban, global population. We know that agricultural production must increase by 70% by 2050 at a global level, according to FAO's figures. At the same time, the planet is suffering from a continuing degradation of the natural resource base, with soil and water resources which are jeopardized by conventional agricultural practices involving intensive and excessive soil tillage. Especially in developing countries, this leads to low productivity on family farms resulting in low family income and an inability to invest in appropriate agricultural mechanization inputs. This means that doing "business as usual" is not an option on the table if we want to avoid widespread food shortages.

In the last decades, the growing interest in conservation agriculture has been leading the agricultural machinery industry to line up.

(*Conservation Agriculture is a complementary set of three general principles which are adapted locally to become compatible with the location specific environment. These general principles are minimal soil disturbance, maintaining a permanent organic soil cover, maintaining biodiversity in crop production*)

The implementation of the Conservation Agriculture involves the adoption of specific equipment. It means an uptake of specific technologies dealing with the reduction of tillage, appropriate sowing and fertilizer delivery practices.

The use of CA mechanization allows the reduction of significant amount of energy consumption compared to the technology used for tillage-based agriculture - approximately half the energy is expended.

Mechanization in its broadest sense has great potential to increase productivity and improve livelihoods along the all agri-food value chain. This will include post-harvest operations such as storage and processing. It can also include food processing from simple packing of fresh produce for supermarket chains to more industrial type processing.

For sustainable mechanization initiatives to work, complimentary action on two levels is needed: national (/regional) and local are important:

a) At the macro-level, the objective is to enhance food security of the countries, in terms of food availability levels, i.e. volume, but also in terms of differentiation, infrastructure or support need-ed to enable national food security policies in the countries involved;

b) On the other hand, at the micro or local levels of intervention, the national policies should meet the potential (both agricultural and human) and the needs of communities at local level.

Discussing the solution: the dual approach

Such components will define an overall framework in which macro, meso and micro levels of intervention can be designed, converging to a series of complementary objectives:

Top-down

– Review Food Security targets, plans and policies for each country involved (these are the responsibilities of African Governments), in light of the smallholder farm sector demand for appropriate mechanization, not only for crop production, but also for processing and along the entire value chain. This also means that the public authorities should consider the more appropriate agronomic and mechanisation measures to meet primary food security objectives.

– Formulate an inclusive policy connecting of all the stakeholders to bring about the enabling factors in terms of development. These factors are.:

- **Agricultural potential** (sustainable and productive agriculture), unleashing the potential of sustainable intensification for each country or region,
- **Human potential** (active population in the primary sector or related sectors), mobilisation universities, extension services, African Farmers Unions (PAFO and regional/national farmers' associations, AGRA, - ACT, local public and private organizations) to foster access to education, training, tangible or intangible resources (knowledge, processes, tools, etc.); Define an access to innovation strategy to endow

local communities and businesses with the appropriate tools to realize their potential within the national or regional food security framework;

- **Financial framework:** financial support should be sought and provided by institutions such as the World Bank, IFAD, the FMI, EU, EIB, or AfDB, in order to set appropriate measure to foster investments in the enabling factors. Entrepreneurs will need to have access to the correct equipment, and this should involve facilitating their access to financial credit.

Bottom-up

The dual approach suggests the need to take stock of the current practices and actual requirements of the farmers. This should be done on the basis of an evidence-based to identify the best options to match country-specific mechanization needs, in line with the overall objectives of Food Security Plans and the perceived needs of local communities. Therefore, a series of investigations prior to action are needed to:

- Collect baseline data on the current knowledge, attitude, and practices,
- Define widely accepted agricultural sustainability and productivity metrics,
- Identify and assess the readiness and potential of local communities to contribute to the objectives,
- **Take into account current agricultural practices along the food value chain** (types of cultivations, storage and agri-food processing, levels of food security met, margins of improvement towards sustainability, productivity, and reduction of post-harvest food loss),
- **Consider current available equipment and asset management** (instruments and machines used, structure of ownership, maintenance and management capacities, acquisition, or commissioning practices, etc.)

For mechanization to work on the ground, the involvement of local communities is of fundamental importance. This bottom up approach would define the critical training needs to reach the minimum level of competence.

We believe that the dual approach ("top-down and bottom-up") will answer to specific and different kinds of requests of mechanization, but the major result will be the level of food security for the country involved and the concrete development of economic units (small farm, village…). These will be able to produce the sufficient agricultural good for themselves, bring to the market the extra production and start their own viable economic development.

Reaching these two goals will require on the one hand training from the local institutions (Ministries of Agriculture) in defining Sustainable Agricultural Mechanization Strategies and how to implement them; and, on the other hand, the involvement of local agricultural universities for the necessary agronomic practice as well as the engagement of a larger range of stakeholders to encourage growth not only in terms of mechanization, but also of management.

The conservation of natural capital (especially soil, water and forests) requires a renewed focus on sustainable land management. Supply chains for sustainable mechanization options need to be strengthened to encourage increased demand. Because of rural-urban migration and the impact of pandemic diseases, female-headed farm families are becoming more prevalent, especially in SSA.

Improving women's access to farm power through the provision of suitably designed equipment needs to be addressed by the actors in the farm power provision supply chains.

Promoting mechanization in agriculture means that more tasks can be completed at the right time, more efficiently and saving labour and energy. However, the equipment has to be compatible with the social, economic and environmental conditions in which it will work, in order to achieve sustainable crop production intensification.

An example of this type of equipment that can easily adapt to the context of developing countries is the range of low-cost smaller horsepower tractors. This type of tractor can be attached to planters designed to operate on soils under zero tillage regimes by depositing seeds directly into the soil with minimal disturbance.

Compared to traditional tillage-based practices, direct seeding is far more energy efficient and less time consuming. It also reduces input losses and drudgery and, over time, achieves better crop yields when combined with adequate conservation agriculture practices. The effect on the environment is also very positive as soil erosion and compaction are eliminated and biodiversity is enhanced.

Direct planters are also well suited to animal traction which can also be used to pull small carts for transporting people and of goods. Low horsepower tractors, and indeed stationary engines, can also be used by smallholders to power other agricultural equipment, such as pumps, threshers and mills, improving farming conditions and productivity and coping with problems such as labour shortage and inadequate processing times.

Other examples of hand operated equipment that have a huge impact on labour efficiency are improved maize shellers or pumps for water lifting.

Conclusions

Mechanization is to be viewed as a means to achieve two main objectives: sustainability and food security. The mechanizations of the agricultural processes can and should be adapted to the specific needs of the local communities and of entire regions, depending on the policy goals set by the Public Authorities. This suggests that high-level stakeholders should take in great account the need to apply a dual approach to address the challenges ahead. Sustainable mechanization involves the application of different forms of skills, power sources (from manual to engine), equipment, along the agri-food value chain. As a result, mechanization must meet farmers’ needs effectively while improving productivity and competitiveness. The recommended dual approach brings with it a significant value since it considers economic, financial, social, environmental and cultural issues at stake. It recognizes that mechanization can be provided to smallholders in a number of different ways if both the public and private sectors work together to nurture an attractive environment where the private sector can do business and provide the necessary financial and appropriate training support.

Rainwater Harvesting and Water Conservation as veritable impetus for Food Security.

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ABSTRACT

Food security is one of indicators of assessing gross domestic Product (GDP) which promotes national security of a country. It depends on food availability, accessibility, utilization and stability. Water is considered as the most critical resource for sustainable agricultural development worldwide which plays important role in promoting food security. Climate change and recurrent drought in many of world's dry places continue to inspire a search for economically attractive measures to conserve water. The term "water conservation" encompasses the policies, strategies and activities made to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future human demand, population, household size, and growth. Water conservation through re-use and harvesting is extremely important in fragile ecosystems and arid environments as it reduces energy use and can even save households money. Rainwater harvesting is one of the methods of water conservation. The term "rainwater harvesting" can be defined as an innovative technique utilized to harvest rainwater from roofs and other above surfaces to be stored for later use. It gives a helping hand in the effort to attain the global targets, related to access to water, food and environmental protection in the Millennium Development Goals. This paper seeks to illuminate the potential of review of literatures on food security, water conservation and water harvesting. Relationship between water conservation and rainwater harvesting were examined. Nexus between water harvesting and food security and its adaptive strategy were highlighted

Keywords : Adaptive strategy, climate change, food security, interrelationship, water conservation, rainwater harvesting,

1. INTRODUCTION

Food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food. Food security is one of indicators of assessing gross domestic Product (GDP) and also has impacts on human well-being outcomes; it depends on food availability, food access, food utilization and stability. Reducing pressures of climate change on food security is one of the major challenges of the 21st century. According to Lobell et al. (2011), Creighton et al. (2015) and Herrero et al. (2015) that impacts of climate changes on agriculture which has being given the serious threats to food security and national security. The intergovernmental panel on Climate change (IPCC, 2007) highlighted that there is growing global recognition of the urgent need to identify and implement strategies that make food systems more resilient in the face of increasing climate variability. The effects of climate change are more pronounce in Sub-Sahara Africa (SSA), because most Africans' livelihoods and agri-food systems rely on rainfed farming. Africa is one of the world's most vulnerable regions to climate change (FAO, 2009, FAO, 2010). This climate change has created uncertainties on level of agricultural production globally; because not knowing exact shape of future climates or even next season, and these uncertainties are unlikely go away in the next decade (Heal and Millner, 2014). The (IPCC) has listed rainwater harvesting as a key strategy for a planned adaptation in the water sector. There's no doubt that climate change has got us thinking about water conservation again, especially with the supply companies beginning to put their prices up. The general consensus is that letting all that rainwater go to waste is no longer acceptable. It can be collected and that can help reduce water bills. In other words, is not only a good idea ecologically, it makes sense financially.

About half of the people in developing countries lack access to safe drinking water (UN, 2003). An attractive solution for resolving water scarcity in various parts of the world is the use of water harvesting systems for runoff water collection and storage (Oweis and Hachum, 2006, Frot, 2008). Ngigi (2003) defined rainwater harvesting as collection and concentration of runoff, but Mati (2012) defined rainwater harvesting as rainwater collection and storage only. Sonbol (2006) described rainwater harvesting as a sub-category of water harvesting (collection of surface water in the lakes and rivers and groundwater in aquifers) and rivers and one of three major water harvesting types, along with overland flow and groundwater harvesting. The major outstanding advantage of it is that it is additional source of water which can relieve the burden on the convectional sources such as lakes, rivers and groundwater aquifers

Rainwater harvesting (RWH) is the method by which rainwater that falls upon a roof surface is collected and routed to a storage facility for later use. It is not a new concept in practice and also in water resources management, as its use has been documented in ancient Greek and Roman civilizations (Phoca and Valavanis, 1999). It has been in existence for a long period of time before the advent of large scale public water systems. Traditionally, it has been implemented in regions with limited access to water resources.

Lee et al. (2000), Radhakrishna (2003) and Abdulla and Al-Shareef (2009) reported that rainwater harvesting has being practicing since 1900s in some places include India, Jordan, parts of Asia, Italy, South America and Africa. Several researches such as Hermann and Hasse (1997), Coombes and Barry (2007), Zhang et al. (2009) and Mendez et al. (011) highlighted that RWH systems acceptability became prominence as alternative water supply in many areas including Australia, Germany, China and the United States due to increase in population growth, climate change and increasing water supply shortages. It is being encouraged and promoted in some countries include China, Brazil, Australia, and India. In New Delhi and Chennai, India, according to UN-HABITAT (2005) that it is mandatory to have a rainwater harvesting system for a building plan in order to secure approval from the local authority. It has been reported to promote potable water savings in buildings (Hermann and Schimda, 1999; Fewkes, 1999, Zaizen et al, 1999, Chilton et al, 1999, Hills et al, 2001, UNEP, 2002 and Handia et al, 2003). The benefits of rainwater harvesting are enormous (Krishna, 2005). It provide a source of free water with only storage and treatment costs, augment limited quantities of groundwater and reduce storm water runoff. It gives a helping hand in the effort to attain the global targets, related to access to water, food and environmental protection in the Millennium Development Goals. Rainwater can also be used to minimize water loss and to augment water supply in any watershed systems (Sekar and Randhir, 2007).It can be considered realistic to mainstream rainwater harvesting in the integrated water resources management (Zhang et al., 2009). Another perspective is that integrated water management (which includes rainwater harvesting) is economically efficient from a societal view point because of non-market values and an inefficient distribution of costs and benefits (Vesely et al, 2005, Kettle, 2009, Wilson et al, 2010). One of the major challenges of the RWH lack of knowledge regarding the quality of harvested rainwater has prevented widespread use of this practice (Lye 2009, lee et al., 2012).

1.2. Objectives

The content of the study is set out in the terms of reference as follows: This document presents a concept of food security, rainwater harvesting and water conservation. Reasons and benefits of rainwater harvesting and water conservation were highlighted. Nexus between rainwater harvesting and food security and its adaptive strategy for food security was examined

2. METHODS

The report was based on

- A review of literature
- Personal observation and group discussion

2.1 **Food security**: It is defined by the United Nations' Committee on World Food Security, is the condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 1996). Food Agricultural Organization (FAO, 2011) highlighted that "food security depends more on socio-economic conditions than on agroclimatic ones, and on access to food rather than the production or physical availability of food". Food security is built on four pillars: availability, access, utilization and stability.

Food availability: It refers to the existence of sufficient quantities of food with appropriate quality, and supplied through domestic production or import (Thompson et al., 2010). Food availability is probably most frequently used as a measure of food security and it has a channel with climate change which directly affects food security (Oyija et al., 2011). The major direct impact of climate change is expected to have on food security is through food availability component due to changes in agricultural productivity (Wlokas, 2008).

Food accessibility: Access to food refers to the ability of individuals, communities and countries to purchase food in sufficient quantities and quality (Ludi, 2009). Accessibility depends on the transport infrastructure; fewer roads mean reduced food access.

Food utilization: It depends on how food is used, whether food has sufficient nutrients and whether diet can be maintained. Food utilization refers to the individual or household capacity to consume and benefit from the food (FAO, 2011). Although food availability and access are necessary conditions for food utilization, they are not sufficient conditions to reduce malnutrition.

Food system stability: The concept of stability can therefore refer to both the availability and access dimensions of food security.

2.2 Water Conservation

Over the years rising populations, growing industrialization, and expanding agriculture have pushed up the demand for water. Efforts have been made by government at both federal and states levels to make water available to its citizenry by building dams and reservoirs and digging wells; some countries have also tried to recycle and desalinate (remove salts) water. Water conservation (WC) has become the need of the day. The idea of ground water recharging by harvesting rainwater is gaining importance in many cities. Despite massive investment on water supply system in most developing countries both rural and urban centres by government or individual people, large numbers of people still do not have access to adequate water supplies**.** Sanitation provision is even worse. Some of the major causes of supply system failures according to Well (2008) as follows:

(a) Physical constraints not properly addressed during planning which is attributed to poor aquifer with limited storage and potential competition with other uses, especially irrigation, not addressed

(b) Engineering shortcomings: It dues to reticulation systems that are too expensive to operate and maintain

(c) Institutional/ management failure: This is caused by illegal connections to water supply systems and consequent problems in tail-end villages, overexploitation of groundwater under conditions of open access, poor cost recovery leading to lack of investment/maintenance, lack of maintenance e.g. hand pumps, poor institutional organisation for the operation and maintenance of communal facilities

(d) Corruption: Attitude of people to make profit from water shortages e.g. vendors, tanker operators, kick-backs associated with large engineering contracts

(e) Rising demands: This may arise due to increasing population, incentives to use water inefficiently especially for irrigation, changing patterns of water use with changes to lifestyles

Water conservation encompasses the policies, strategies and activities made to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future human demand, population, household size, and growth and affluence all affect how much water is used. Schaible and Aillery (2003) defined water conservation (WC) as all the policies, strategies and activities to sustainably manage the natural resource of fresh water, to protect the hydrosphere, and to meet the current and future human demand. The Environmental Engineering Dictionary defines water conservation as “the physical control, protection, management, and use of water resources in such a way as to maintain crop, grazing, and forest lands, vegetation cover, wildlife, and wildlife habitat for maximum sustained benefits of people, agriculture, industry, commerce and other segments of the national economy”. In summary, WC is an attempt to reduce water usage in household, agricultural and industrial water use to harvesting rainwater.

Benefits of Water Conservation

Some of the benefits of water conservation according to Schaible and Aillery (2003) and Sadler et al. (2005) as follow:

It minimizes the effects of drought and water shortages. Even though our need for fresh water sources is always increasing because of population and industry growth, the supply we have stays constant. Even though water eventually returns to Earth through the water cycle, it's not always returned to the same spot, or in the same quantity and quality. By reducing the amount of water we use, we can better protect against future drought years.

It guards against rising costs and political conflict. Failing to conserve water can eventually lead to a lack of an adequate water supply, which can have drastic consequences. These include rising costs, reduced food supplies, health hazards, and political conflict.

It helps to preserve our environment. Reducing our water usages reduces the energy required to process and deliver it to homes, businesses, farms, and communities, which, in turn, helps to reduce pollution and conserve fuel resources.

It makes water available for recreational purposes. It's not just swimming pools, spas, and golf courses that we have to think about. Much of our freshwater resources are also used for beautifying our surroundings, watering lawns, trees, flowers, and vegetable gardens, as well as washing cars and filling public fountains at parks. Failing to conserve water now can mean losing out on such uses later on.

It builds safe and beautiful communities: Fire fighters, hospitals, gas stations, street cleaners, health clubs, gyms, and restaurants all require large amounts of water to provide services to the community. Reducing our usage of water now means that these services can continue to be provided.

2.3 Rainwater Harvesting

Rainwater harvesting (RWH) is a process or technique of collecting, filtering, storing and using rainwater for irrigation and for various other purposes. It is the process of collection of rainwater from surfaces on which rain falls, filtering it and storing it for multiple uses, it is an innovative technique utilized to harvest rainwater from roofs and other above surfaces to be stored for later use. It is best and cheapest alternative to the traditional water supply systems and is economically viable in the areas that experiencing high amounts of rainfall. It serves as soil conservation and also one of the methods of water conservation which allows cities and regions to plan for more efficient use of the water resources in the future. It is one of general methods of water conservation and it falls in the second category of water conservation along with desalination and wastewater reuse. To reduce the consumption of groundwater, many people around the world are using rainwater harvesting systems. Till today, rainwater is used as a primarily source of drinking water in several rural areas. The best thing about rainwater is that it is free man-made contaminants. In areas where there is excess rainfall, the surplus rainwater can be used recharge ground water through artificial recharge techniques. The roofs our homes are the best catchment areas, provided they are large enough to harvest daily water needs which most refers to as notable system. Other than that, large bowls and tarps can also fulfil the function. Notable systems are systems for runoff rainwater and rooftop rainwater harvesting system. The type used depends greatly on the purpose (domestic or industrial use) and to some extent also on economics and physical and human considerations. Other one is called non-table system in which water harvested in catchment or depression area and is usually for non-potable uses.

Benefits of non-potable water and rainwater collection according to Oweis and Hachum (2006) and Bunguma et al. (2010) as follows

Benefits of non-potable water use as follows:

(1) It uses include washing pots, clothes, or bathing the children and making of bricks.
(2) It uses in mixing local clay for the resurfacing of homes
(3) For large natural depressions: it serves for irrigation purposes,
(4) It serves as drinking water for animals and source of food for birds
(5) Depressions serve as fish farms and also recreation area

Benefits of Rainwater Collection:

1. When used in conjunction with a Gutter Helmet, gutter guard system that filters out leaves and debris, rainwater is clean and ready to use for any non-potable need.
2. The water is free.
3. Water is conserved, reducing the demand on local wells and municipal supplies.
4. Your use of stored water cannot be restricted by your town or city.
5. Rainwater harvesting can be an excellent back-up source of water in emergencies.
6. Rainwater collection systems can be set up in urban, suburban or rural areas.
7. Collection systems can be easily set up, expanded, reconfigured or relocated, when necessary..
8. Rainwater harvesting reduces storm water runoff that can cause erosion and water pollution.
9. Rainwater collection may solve drainage problems on your property

Environmental Benefits of Rainwater Harvesting

Rainwater Harvesting System serves as climate change mitigation in two ways, namely:
It serves alternatives water source during a drought, and provides adaptation actions to reduce flooding.
Rainwater harvesting is vital to environment in following ways (Rockstrom, 2002, UN-HABITAT, 2006, Bonbol, 2006):

(1) Utilize recycled materials
(2) Protect local watershed
(3) Drought-proof, flood-proof, *and* fire-proof your garden;
(4) Restore the hydrologic cycle
(5) Recharge groundwater
(6) Reduce your carbon footprint
(7) Maintain healthy soils
(8) Keep your garden lush and healthy
(9) Lessen the effects of wet and dry spells
(10) Mitigate impacts of climate change

Advantages and Disadvantages of Rainwater Harvesting

Some of the major benefits of water conservation according to UN-HABITAT (2005, 2006) and Zhang et al. (2009, 2010) as follows

Advantages of Rainwater Harvesting

1. Easy to Maintain: Utilizing the rainwater harvesting system provides certain advantages to the community. It implores simple technology.

2. Reducing Water Bills: Water collected in the rainwater harvesting system can be put to use for several non-drinking functions as well.

3. Suitable for Irrigation: As such, there is little requirement for building new infrastructure for the rainwater harvesting system. Most rooftops act as a workable catchment area, which can be linked to the harvesting system. This also lessens the impact on the environment by reducing use of fuel based machines.

4. Reduces Demand on Ground Water: With increase in population, the demand for water is also continuously increasing. The end result is that many residential colonies and industries are extracting ground water to fulfil their daily demands. This has led to depletion of ground water which has gone to significant low level in some areas where there is huge water scarcity.

5. Reduces Floods and Soil Erosion: During rainy season, rainwater is collected in large storage tanks which also help in reducing floods in some low lying areas. Apart from this, it also helps in reducing soil erosion and contamination of surface water with pesticides and fertilizers from rainwater run-off which results in cleaner lakes and ponds.

6. **Can be used for several non-drinking purposes**: It can be used for several non-drinking functions including flushing toilets, washing clothes, watering a garden, washing cars etc.

7. Water and Energy Conservation: It helps you to conserve water and save energy that is needed to maintain centralized water system.

8. Prevention of sea water ingress in coastal areas.

9. It promotes and enhances traditional and localized water harvesting techniques.

Disadvantages of Rainwater Harvesting

1. Unpredictable Rainfall: Rainfall is difficult to predict and sometimes little or no rainfall can limit the supply of rainwater. Rainwater harvesting is suitable in those areas that receive plenty of rainfall
2. Initial High Cost: It depends on the system's size and technology level, a rainwater harvesting system requires high cost and its benefit cannot be derived until it is ready for use
3. Regular Maintenance: It require regular maintenance as they may get prone to corrosion and animal attack
4. Storage Limits: The collection and storage facilities may impose kind of restriction as to how much rainwater you can use.

2.4 Nexus between Rainwater harvesting and Food security

Food security components are the accessibility, availability and utilization and all the components affected by effects of climate change (effects of climate change such as drought, flooding, erosion, rising in water level, high temperature). The effects of climate change can be reduced by adaptation of rainwater harvesting which is one of the methods of water conservation. The food security outcomes are the impacts of food security components such as food availability (production, distribution and exchange), food accessibility (affordability, allocation and preference which depends on income and prices) and food utilization (nutritional value, food safety and social value which depends on food quality). The benefits of RWH and its impacts on food security outcomes are presented in Table 1. Nexus rainwater harvesting and food security is presented in Fig. 1

Table1. Impacts of Rainwater harvesting on Food Security

S/N	Rainwater Harvesting	Food Security
1	Reduction of Flood, Drought and Erosion	Increased food production, increased income from farm, reduced water borne diseases, improved transportation and storage facilities (reduced in prices), increased food distribution, improved food safety and nutritional value (quality)

2	Supply alternative source for portable water	Improved social value and improved food quality
3	Reduce political power	Improved food allocation

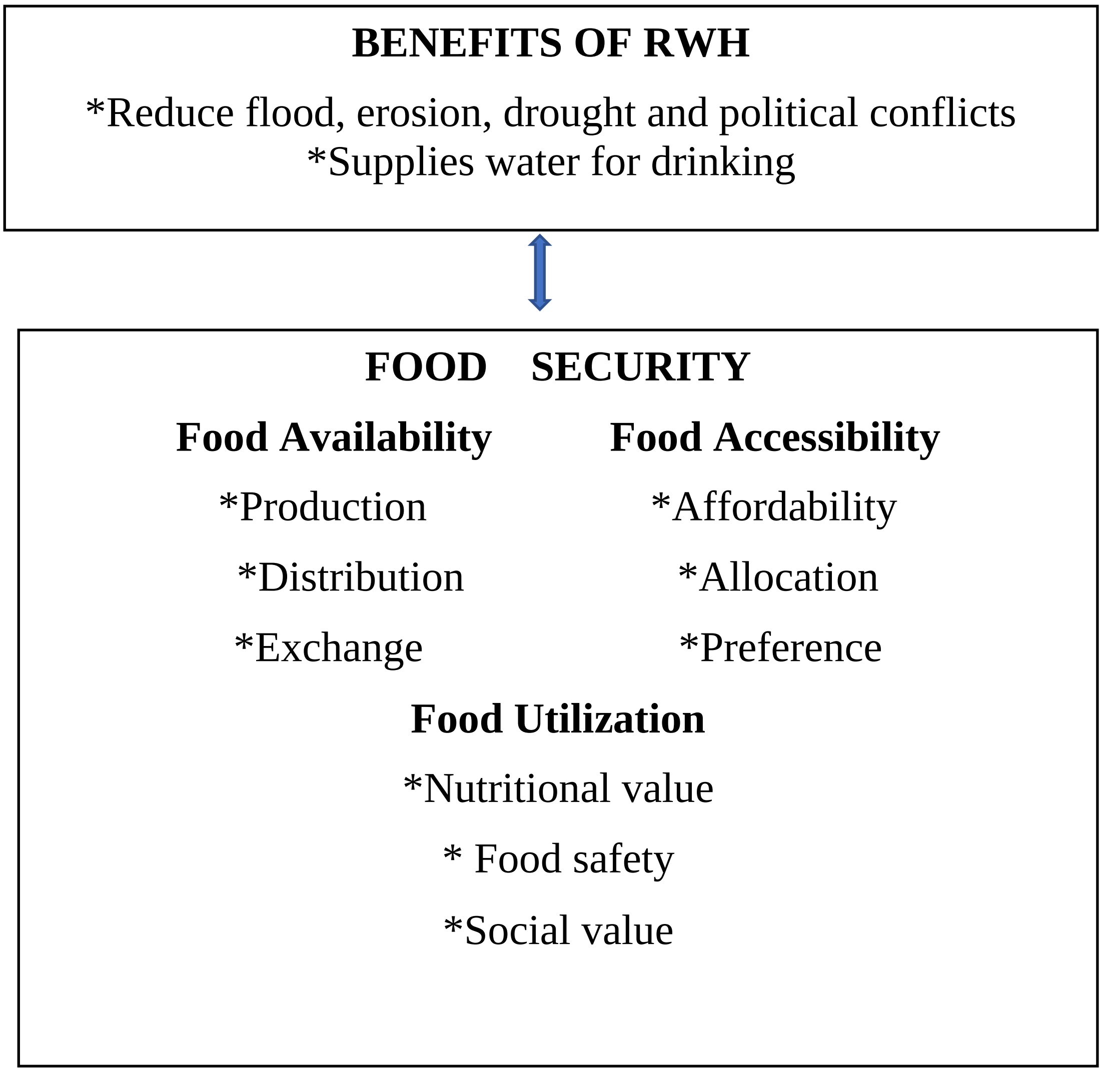

Fig. 1: Nexus rainwater harvesting and food security

2.5 Rainwater Harvesting for food security Adaptive Strategy

(1) Buildings containing a specific garden area must require installing RWH system
(2) Public education and enlightenment on benefits of RWH
(3) Development of risk management frames
(4) New investment in flood embankments and wind resistant technologies on new and existing structures
(5) Development and dissemination of more flood-tolerant varieties and species.
(6) Effective water management policies and water use regulations

(7) Use of moisture-retaining land management practices

(8) Use of recycled runoff harvesting (wastewater) for irrigation

(10) Construction of water retaining structures such as micro-dam, ponds, etc

(11) Permaculture: An agricultural philosophy that combines several agricultural principals, including agroforestry, intercropping, mulching, and rainwater catchment

3 Conclusions and Recommendations

Conclusions

The concept of food security, RWH systems and water conservation have been studied

Food security is affected by climate change. Both rainwater harvesting and water conservation have great potential in terms of climate change mitigation and enhancing food security.

Recommendations

- Government should provide Policies that support RWH and also invest on research, innovation and rural infrastructural development
- Government should ensure that food security as integral to its national security
- Relocating buildings and roads that have experienced repeated flooding can reduce future risk.
- RWH must be part of water emergency plan Government should establishment rainwater harvesting acts to make rainwater harvesting mandatory for every building at all levels of government as part of buildings laws.
- Formation of rainwater harvesting association (RHA) at all levels of government
- RWH must be made as one of the food security and poverty reduction strategies and inclusion as a research and academic agenda in tertiary institutions.
- Government should establishment rainwater harvesting acts to make rainwater harvesting mandatory for every farmer as part of farm building structures
- It must be made as one of the soil conservation strategy plan
- Financial benefits of using RWH should be investigated
- There should be integration of public education, engineering and public health research on RWH
- Quality of harvested rainwater should be examined

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Moisture Dependent Mechanical Properties of Moringa oleifera seeds.

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Abstract

The mechanical properties of *Moringa oleifera* seeds were determined with respect to moisture content varying from 7.8 – 17.8% dry basis. The mechanical properties of the seeds were determined using Instron testing machine at compression loading speeds of 5mmmin^{-1}. The seeds were conditioned to the required moisture content and kept inside the refrigerator at 4^{0}C until when needed. The behaviour of the seeds to the compressive load was analyzed by using the software 'TEXTURE ANALIZER'. All the mechanical parameters such as compressive force, rupture force, deformation, yield stress, and Young's modulus were obtained from the result of the 'texture analiser'. The mechanical properties are Compressive force, 23 – 30N; Rupture force, 26 – 33N; deformation, 1.13 – 2.91mm; yield stress, 10.5 – 24.35Nmm^{-2}; and Young's Modulus, 232.1 – 462.0 Nmm^{-2}. The properties varied non linearly with increase in moisture content. These properties can be used as a database for designing agroprocessing machines for *Moringa oleifera* seed size reduction as a prerequisite for oil processing and water purification attributes of the seed.

Keywords: Moringa, Mechanical Properties, Texture Analizer, Deformation

Introduction

Moringa oleifera is a pan tropical plant specie that is known by regional names as horse radish, drum stick, *Kelor moringe* in India, *ewe ile*, *ikwe oyibo* and *Baganruear maka* in Nigeria (Fuglie, 2001: Adejumo, Sule and Mbatyelevde, 2010). It belongs to the *Moringaceae* family which is a single genius family with fourteen known species of which *Moringa* *oleifera* is the most widely cultivated specie of this monogeneric family (John, 1986: Fahey, 2005). Adejumo *et al*. (2010) reported that the powdered seeds of this plant can be used for oil extraction, purification of turbid water, honey clarifier and fertilizer. Gates and Dobraszezyk, (2004) stated that the knowledge of mechanical treatment is needed in the processing of agricultural crops to flour or fine particle sizes. The mechanical properties are needed in the design of equipment for size reduction or milling and oil extraction. There are documented evidence in the literature on the effect of moisture on the mechanical properties of some agricultural crops or their products such as Roselle seed, Wheat, *Jatropha curcas* and Safflower seed and Wheat endosperm (Bamgboye and Adejumo, 2011; Kang, Spillman, Steele and Chung, 1992; Bamgboye and Adebayo, 2012; Aklas, Celen and Durgut, 2006; Oloyede, Aviara and Shittu, 2015; Haddad et al., 2001). Some of the works done on Moringa oleifera seed has been on the physical and thermal properties (Adejumo and Abayomi, 2012; Adesina, Asiru, Omotade and Samuel, 2013 Adejumo, Sule and Mbatyelevde, 2010, Adejumo and Daramola, 2014). Work done on the mechanical properties of *Moringa oleifera* seeds has been limited to the determination of these properties at a single moisture content. Ajav and Faayode (2013) determined these properties at 7.31% moisture content (wet basis) as a pre-requisite for the efficient design of an oil expeller. These properties were also determined for the husked and dehusked Moringa seeds to ascertain the type of correlation relationship existing between the seed types (Olayanju, Osueke, Dahunsi, Okonkwo, Adekunle, Olanrewaju and Oludare 2018). Nothing has been done on the effect of moisture content on these properties. Hence this work is investigating the effect of moisture content on the mechanical properties of *Moringa oleifera* seeds as a database for size reduction and a requirement in oil processing and water purification technologies.

Materials and Methods

Five kilogrammes of *Moringa oleifera* seeds was obtained from the Moringa plantation at theTeaching and Research Farm of the Agricultural and Bioenvironmental Engineering Department of the Federal Polytechnic, Bida, Nigeria and kept in a low density polyethylene bag. The seeds were cleaned by both mechanical and manual methods to remove foreign materials (plant parts, dirt and dust), broken and immature seeds and those damaged by insects. The initial moisture content of the seed was determined by using the ASAE standard S352.2 (ASAE 2003). Compression tests were carried out on the seed samples at five different moisture levels in the range of 7.8 to 17.8% dry basis. Conditioning of the seeds to the required moisture content was done by the method reported by Adejumo and Daramola (2014). The method used by Bamgboye and Adejumo (2011) for Roselle seed was adopted for the tests. A uniaxial compression assay using ASAE Standards (2003) was used to determine the resistance of the *Moringa oleifera* seed to compression. The standard involved submitting individual seed within the sample to compression in their natural resting position using a Universal Testing Machine (UTM) 'Texture Analizer' manufactured Testometric Co. Limited, England, model Testometric AX connected to a computer.

A seed at the required moisture content was dropped at a height of 100mm from a flat surface to allow the seed to fall and rest in its natural resting position which was used as the loading surface. The seed was loaded between two flat parallel plates at compression speed of 15mm min^{-1}. The behaviour of the seed to compression was analysed by using the software 'TEXTURE ANALIZER'. The software graphic interface produced the force-deformation curves for the various treatments and showed the collapse of the seeds with the variation of force during deformation. The height of the seed when loaded in the machine was taken as the thickness of the seed used in the course of the experiment. This was measured with a vernier calliper. The mechanical properties obtained from the result of the Texture analizer are the Compressive force, rupture force, deformation, rupture stress and Young's Modulus.

Each property was replicated ten times for all the moisture content level and loading rate considered. The mean values of the measurements were presented and analysed using regression analysis.

Results and Discussions

The mechanical properties of *Moringa oleifera* seeds that were determined are presented in Table 1. These properties were obtained at a loading rate of $15mmmin^{-1}$. The yield stress determines the degree of toughness of agricultural materials to compressive loading.

Table 1: Mechanical Properties of Moringa oleifera seed

Property	Unit of Measurement	Moisture Content in % Dry Basis				
		7.8	10.3	12.8	15.3	17.8

Yield Stress	Nmm^{-2}	24.350 (1.14)	20.000 (1.20)	15.65 (1.16)	16.0 (1.25)	10.5 (1.21)
Deformation	mm	1.13 (0.064)	2.91 (0.170)	1.36 (0.233)	2.34 (0.047).	2.47 (0.541)
Young's Modulus	Nmm^{-2}	327.1 (55.600)	232.1 (19.200)	269.0 (32.180)	321.0 (53.725)	462.0 (50)
Compressive Force	N	28 (4.000)	23 (5.324)	30 (2.500)	27 (3.102)	27 (2.100)
Rupture Force	N	32 (3.240)	33 (2.270)	28 (3.010)	30 (2.481)	26 (4.200)

The values in the parentheses are the standard deviations

The mean values of this property had a decreasing trend but the values ranged between 10.5 to 24.35 Nmm^{-2} within the moisture content considered. At the $15mmmin^{-1}$ loading rate it had a polynomial trend with the moisture content. The varying trend of yield stress indicated that the toughness of the seed decreased as the moisture content increases up to 12.8% beyond which the toughness increased by about 2.24% at 15.3 %. The same trend were observed by (Haddad *et al*., 2001; Olayanju *et al*., 2018) in their works on mechanical properties of wheat kernels and undehusked and dehusked *Moringa oleifera* seeds. Reverse trend was observed by (Bamgboye and Adejumo, 2011) in their work on Roselle seeds. This could be due to the variation in the cellular arrangement of the genes of these seeds. Bamgboye and Adejumo (2011) reported values that are close to the mean values recorded in this work. The regression equation showing the relationship between the yield stress and moisture content is shown in equation 1 with a high value of coefficient of determination (R^2 = 1). The trend of variation is graphically shown in Figure 1.

$$\text{Yield Stress} = -0.0163M^4 + 0.8017M^3 - 14.315M^2 + 108.29M - 269.57 \qquad R^2 = 1 \qquad (1)$$

The deformation which is a measure of change in shape of the seed increased from 1.13 to 2.91mm as the moisture content increases. This could be attributed to the suppleness of the seed and the fact that the molecules becomes softer. This parameter showed a nonlinear relationship with moisture content. Aviara *et al.*, (2015) reported mean values that are close to those reported in this work. The regression equation for the relationship between the deformation and moisture content is shown in equation 2. The moisture content has a significant effect ($p<0.05$) on the deformation of the seed and it has a sigmoidal shape as shown in Figure 2.

$$\text{Deformation} = -0.0099M^4 + 0.5179M^3 - 9.9327M^2 - 245.18 \qquad R^2 = 1 \qquad (2)$$

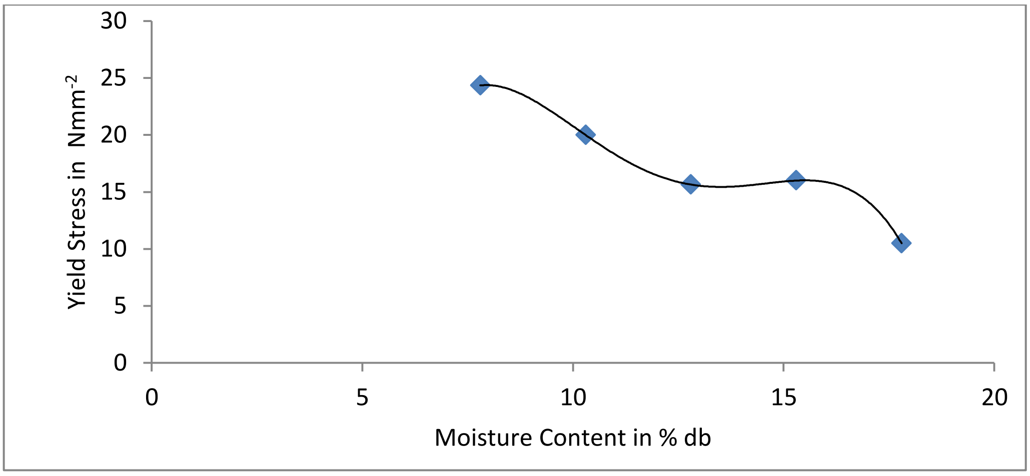

Figure 1: Graph showing the effect of Moisture Content on the Yield Stress of *Moringa oleifera seed*

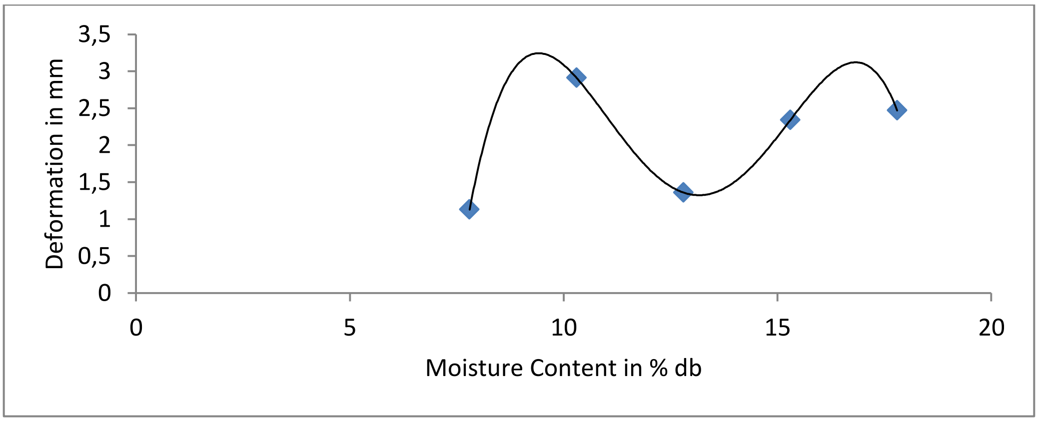

Figure 2: Graph showing the effect of Moisture Content on the Deformation of Moringa oleifera seed.

The mean values of the Young's Modulus increased from 232.1 to 462.0Nmm^{-2} within the range of moisture content considered in this study. The value decreased by about 29% at 10.3% moisture content beyond which the mean values of the young's modulus rose steadily from this moisture to 17.8%. This trend could be due to the flexibility and visco-elasticity of the seed at high moisture content. Haddad *et al*., (2001) observed a similar increasing trend in their work. The regression equation relating the young's modulus with the moisture content is as shown in equation 3. This property showed a good correlation with moisture content.

$$\text{Young's Modulus} = -0.2288M^3 + 14.353M^2 - 235.76M + 1398.7 \qquad R^2 = 0.983 \qquad (3)$$

The compressive force is a measure of the hardness of the seed. The mean values of this property varied from 23.0 to 30 N. It was observed that the compressive force was at its peak when the moisture content was 12.8%. It showed that at moisture content beyond this, the seed molecules become more mobile and consequently softer as they enter the rubbery stage thus making them ductile and flow thus the low values obtained at higher moisture contents. This property has a polynomial relationship with moisture content and the high value of the coefficient of determination obtained from regression equation in equation 4 showed that moisture content has a great influence on the hardness of the *Moringa oleifera* seed.

$$\text{Compressive Force} = 0.0373M^4 - 1.959M^3 + 37.51M^2 - 309.21M + 949.44 \qquad R^2 = 1 \quad (4)$$

The mean values of the rupture force decreased from the initial moisture content of 7.8 to 12.8% beyond which it rose by about 7.142% before it started decreasing again. This type of variation was reported for *Moringa oleifera* pods (Oloyede *et al*., 2015). Roos (1995) attributed this trend to the fact that at low moisture content the macromolecules of agricultural and food materials are in amorphous state which makes them to be hard, brittle and are said to be in the glassy state thus making the molecules to become mobile and consequently softer as the moisture content increases. This makes the material to enter in to rubbery stage thereby making them ductile and flow. The variation of this property has a high level of coefficient of determination as shown in the regression equation 5. This indicates that the moisture content has significant effect on this property

$$\text{Rupture Force} = -0.0028M^4 + 0.142M^3 - 2.653M^2 + 21.327M - 58.863 \qquad R^2 = 1 \qquad (5).$$

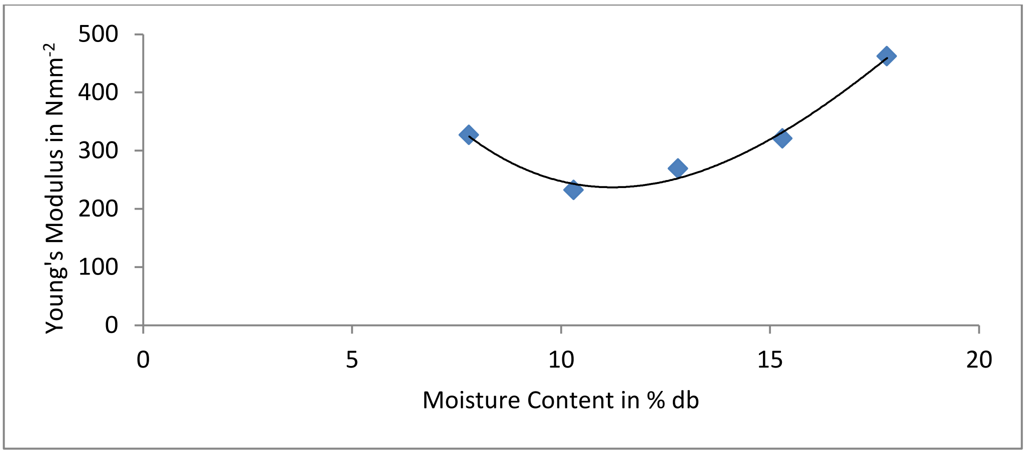

Figure 3: Graph showing the effect of Moisture Content on the Young's Modulus of *Moringa* oleifera seed

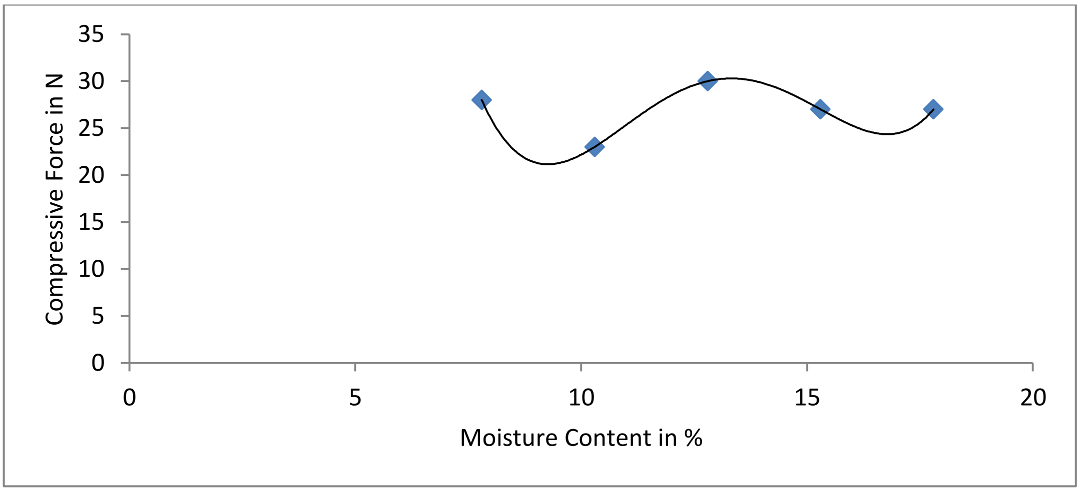

Figure 4: Graph showing the effect of Moisture content on the Compressive Force of *Moringa* oleifera seed.

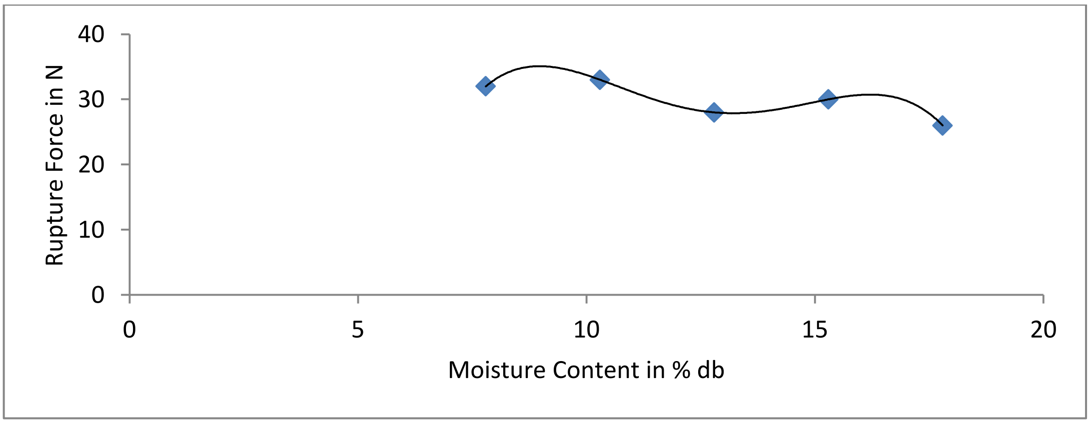

Figure 5: Graph showing the effect of Moisture Content on the Rupture Stress of Moringa oleifera seed

Conclusions

The moisture dependent mechanical properties of *Moringa oleifera* determined at 15mmmin^{-1} varied significantly with moisture content. These properties have polynomial relationship with increase in moisture content. The high value of the coefficient of determination of the regression equations showed a good correlation between the moisture content and these properties. These properties showed that size reduction of *Moringa oleifera* seed should be done at a moisture content ranging between 10.3 to 12.8% dry basis.

Acknowledgement

The authors acknowledge the provision of fund for the sponsorship of the presentation of this paper at the combined Conference of the CIGR First Section 5th Interregional Conference on the Challenges of Water Mobilization and Soil Conservation in better Adapting to Climate Change and 2nd Conference of the Pan African Society for Agricultural Engineering (PASAE-AfroAgEng) on the Role of Agricultural Engineering in meeting the Challenges of Global Food Security which was held at IAV, Rabat, Morocco, between September 10 – 13, 2019.

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Design, Fabrication and Testing of a Manual and Motorized Ginger Size Reduction Machine.

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ABSTRACT

This research work was carried out to design, fabricate and test the performance of a manual and motorized ginger size reduction machine in order for the ginger to be dried easily for storage. This concept also aimed at reducing the processing cost, drudgery and time involved in drying ginger. The machine was designed to have a capacity of 900kg per day. The machine consists of hopper, cutting unit, press, cutting blade, frame, an electric motor, manually operated pulley and crank arm. The machine was designed and fabricated using locally sourced material of stainless steel for all part that made contact with the ginger. Three ginger cutting orifices size blades of 2.5 x 2.5cm, 2.0 x 2.0cm and 1.5 x 1.5cm were used in the design so as to enable testing to be carried out to ascertain the orifice size that achieved efficient drying. The machine was tested for its efficiency and capacity using varying speeds and blade sizes. Results show an increase in the cutting efficiency with increase in speed and blade size as the highest cutting efficiency of 93.3% was obtained at a speed of 80rpm and blade size of 2.5cm. Also machine capacity increases with increase in the speed of the machine and increase in blade size as the highest machine capacity of 28kg/h was recorded at a speed of 80rpm and a blade size of 2.5cm. The percentage uncut increased with decrease in speed and blade size as the highest percentage uncut of 28.3% was obtained at a speed of 40rpm and a blades size of 1.5cm. Conclusively the set aim and objectives of this project work were duly achieved and the equipment can be easily dismantled for ease of transportation and maintenance and reassembled when needed.

Keywords : Design, fabricate, size reduction, ginger

1. INTRODUCTION

Ginger (*Zingiber officinale*) is a flowering herbaceous perennial crop, grown as an annual crop for its spicy underground rhizomes, ginger root or simply ginger. It is scientifically known as *Zingiber officinale* and likely originated as ground flora of tropicallowland forests in regions from the Indian subcontinent to southern Asia (Ravindran and Nirmal, 2005).It is a perennial reed-like plant with annual leafy stems, about a meter (3 to 4 feet) tall. The young gingerrhizomes are juicy and fleshy with a mild taste. Traditionally, the rhizome is gathered when the stalk withers; it is immediately scalded, or washed and scraped, to kill it and prevent sprouting. Raw ginger is composed of79% water, 18% carbohydrates,2% protein, and 1% fat. In 100wgrams. it supplies Calories and contains moderate amounts of vitamin B6, dietary minerals, magnesium and manganese, but otherwise is low in nutrient content.

Averagely it takes about nine months from ginger planting to mature. If fresh ginger is required, it is harvested six months after planting. If mature ginger is required, it is harvested nine months after planting. The rhizomes can also be left in the ground for two years for propagation. Ginger harvesting starts from October until May, manually by hand or with machines. It is usually available in three different forms; fresh (green)ginger, preserved ginger in brine or syrup and dried ginger spice

Ginger is valued for its essential oils, mainly oleoresin and ginger ol, used in pharmaceutical, bakery and soft drink beverage industries as well as culinary and cosmetic preparation. The percentage composition of volatile oil and non volatile extract of ginger from Nigeria was given as 2.5% and 6.5% respectively (Akhila and Tewari,1984; Ravindran and Nirmal, 2005) which accounts for the high demand for Nigerian ginger in international market

Nigeria is one of the largest producers and exporters of ginger in the world, especially the split-dried ginger. Nigeria produced 156,000wMT of ginger in 2012, accounting for 7% in the world and ranking 4th globally. Ginger cultivation in Nigeria started in 1927 in the then southern Zaria (now Southern Kaduna) Plateau Gombe, Benue, Nassarawa, etc. Ginger farmed in Nigeria especially the type farmed in Kaduna, is the best and in demand throughout the world. In Nigeria, ginger is found in almost all the local markets across the country. Ginger is used as flavoring for recipes such as ginger bread, ginger biscuits, sweets, and ginger tea, ginger ale and ginger beer. It is used as a spice in much local cuisine, and also acts a constituent of herbal medicines. Ginger is an important export product which plays a major role in the total contribution of the agricultural sector to Nigeria economy. Freshly harvested ginger cannot last for a long period of time in its freshly harvested state, therefore there is need for further processing of the harvested ginger before it can be exported, the bulk of Nigerian ginger is marketed internationally in split-dried form, where the importing countries further process it into industrial products mainly ginger powder, essential oils, oleoresin and ginger ale concentrates. The amount of foreign exchange earned by exporting dry ginger is how ever very insignificant when compared with the amount spent on importing processed ginger products thereby substantiating the need for industrial processing of the Nigerian ginger within Nigeria (Yiljep et al., 2005).

Nigerian ginger is mostly cultivated by peasant farmers and processed by them as whole dry or split dry ginger. Splitting facilitates the drying process. Farmers traditionally use manual method of splitting ginger using a knife, which is slow and labour-intensive, not suitable for large-scale production. Splitting machine is scarce and cutting machine is not attractive.

Size reduction of ginger is an important unit operation in the dry ginger processing because it reduces the time consumption for drying and energy requirement. Cutting and dicing are the two main pulverizing types which has been practiced for ginger rhizomes. If the ginger is cut, only 5 to 6 hours are needed to dry in a cross-flow drier, compared to 16 to 18 hours for drying scraped whole ginger using the same equipment and conditions. Most of the time dried cut ginger is produced for the export market because there is a big demand in the international market for such value added products. Mechanization of cutting procedure is important due to the problems of labor shortage in the industry. Although various types of vegetable slicers are available in the market, due to some drawbacks, those machines cannot be introduced for the ginger cutting(Jayashree&Visvanathan2011). While considering the morphological characteristics of a ringer rhizomes, long and strong fibers can be found in the flesh which can withstand the cutting forces. Some machines have also been made to solve this problem of ginger cutting an example of which is turmeric slicer for ginger cutting. The turmeric slicer developed by All India Coordinated Research Project on Post-Harvest Engineering and Technology was tested for cutting of ginger. The machine/process parameters were optimized for better cutting efficiency. But these machines are not available to local farmers. They commonly make use of normal kitchen knives which cause injuries due to the hazardous cutting equipment and practices. Also the productivity and the efficiency of the cutting procedure is not at its optimum level. The quality of final products also not uniform due to this manual cutting practices. Mechanical cutting of ginger can solve the problems associated with the manual labour and transform into commercial production. This study is undertaken to design and develop a cost effective and efficient mechanical solution to slice the fresh ginger with high quality output.

2. METHODS

2.1 Machine Description

i. Hopper

This is where the ginger is feed into it is has the shape of a cone frustum.. It is designed in a way that it allows easy feeding of the material into the cutting chamber. The hopper was made of stainless steel because of its high strength, high resistance to corrosion and easy machinability.

ii. Cutting blade

Ginger in the base drum is being pushed forward against the cutting blade which slices the gingers as it is being pushed out. The cutting blades are made of straight knife crossed over each other to from smaller square unit and mounted on a hollow cylindrical frame. The blades and the blade frame were made of stainless steel due to its strength, resistance to corrosion and easy machinability

iii. Base drum (cutting unit)

This is where ginger from the hopper is fed the ginger is collected here before the press presses it against the cutting blade. The base drum is a hollow cylindrical structure made of stainless steel due to its ability to resist corrosion, ease of machining, and local availability.

iv. Press

This pushes the ginger collected in the base drum towards the cutting blade and eventually out of the machine the press consists of a cylindrical plate attached to a shaft. The press was made of stainless steel due to its high strength, corrosion resistance and machinability.

v. Crank arm

This is made of shaft bent at 90^{O} to form a cam. It converts the circular motion of the pulley to reciprocating motion delivered to the press to enable it push the material in the base frame a shaft made of mild steel was used because it can withstand the bending and shearing force, it is easily machined and it is relatively cheap

vi. Frame

This supports the whole machine and provides rigidity to the machine was made of mild steel due to its high load bearing capacity and it is cheap.

vii. Belt and pulley system

This is the machine part that transmits torque from the electric motor to the crank arm by means of belt attached to both the electric motor pulley and the shaft pulley.

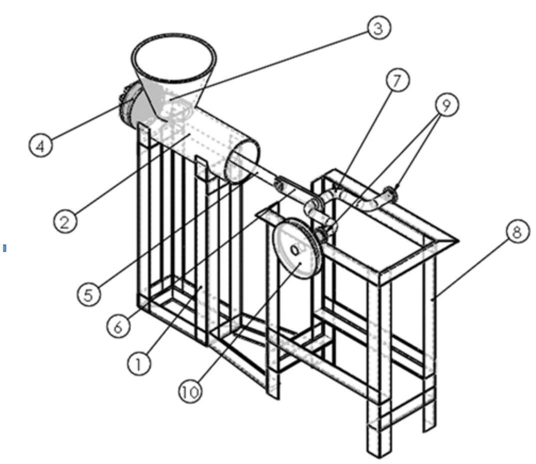

Fig. 1: Isometric view

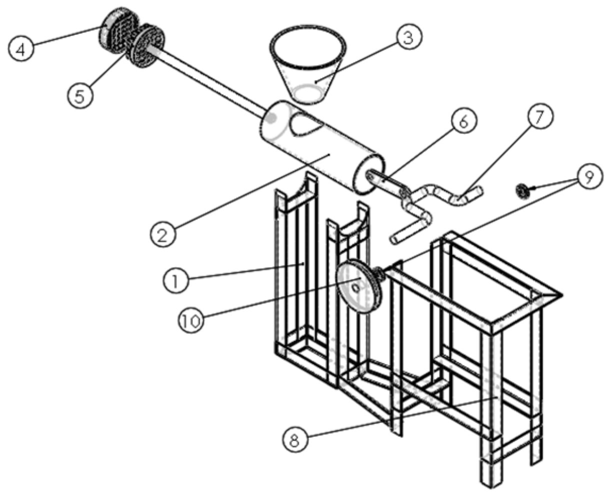

Fig. 2: Exploded view

LEGEND	
Key	**Name of parts**
1	Main frame
2	Cutting unit (Base drum)
3	Hopper
4	Cutting Blade
5	Press
6	Extension Arm
7	Crank Arm
8	Pulley Arrangement Support Frame
9	Bearing
10	Pulley

2.2 Working mode of the machine

Ginger is fed into the machine through the hopper and slides down into the cutting unit where the press being move by the rotation of the electric motor through the crank arm pushes the ginger out of the machine through the cutting blades to where it is being collected.

2.3 Design of the major parts of machine

The following are the parameters and assumed parameters used for the design of the major parts of the machine. These parameters and assumed values made the design calculations possible as well as the fabrication. The implement was designed mainly for ginger size reduction machine.

i. Determination of the volume of the hopper

The volume of the hopper was calculated in order to determine the weight of the hopper.

$$V_h = \left(\frac{1}{3}\pi h_1\left(r_1^2 - r_2^2\right)\right) - \left(\frac{1}{3}\pi h_2\left(r_3^2 - r_4^2\right)\right) \quad (1)$$

Where, V_h is volume of the hopper (m), h_1 is the height of bigger cone (m), h_2 is the height of smaller cone (m), r_1 is the outer radius of bigger cone (m), r_2 is the inner radius of bigger cone, r_3 is the outer radius of smaller cone (m), r_4 is the inner radius of smaller cone (m).

ii. Determination of weight of the hopper

The weight of the hopper was calculated to know the total weight of the machine it is given by

$$\mathbf{W = \rho \times V \times g} \quad (2)$$

Where W is the weight of the hopper (N), $\boldsymbol{\rho}$ is the density of mild steel (Kg/m^3), V is volume of the hopper (m^3), g is the acceleration due to gravity.

iii. Determination of machine capacity

The machine capacity was obtained as follows

$$\mathbf{M_c = M \times w} \quad (3)$$

Where $\mathbf{M_c}$the machine capacity (kg/h), M is is the mass of ginger expelled (kg), w is the angular speed (rpm)

iv. Determination of force required to reduce the size of ginger.

This is done to know the force required to reduce the size of ginger to be able to determine the power required to reduce the size of ginger. It was obtained using the equation reported by Khurmi and Gupta (2005)

$$\mathbf{F = f \times N} \quad (4)$$

$$\mathbf{N = \frac{M}{m}} \quad (5)$$

Where F is total force required to cut the whole ginger (N), f is force required to cut 1 ginger (N), N is the total number of cut ginger, M is the total mass of ginger (kg), m is unit mass of ginger (kg).

v. Determination of required power to reduce the size of ginger

The power required to reduce the size of ginger was calculated to be able to determine the power requirement of the electric motor that can be used to drive the machine. The power required to reduce the size of ginger can be determined using the formula reported by Khurmi and Gupta (2005)

$$\mathbf{P = \frac{2\pi N\tau}{60}} \quad (6)$$

Where Where, P is the power required by the machine (watt), $\boldsymbol{\tau}$ is the torque generated (Nm), N is the speed (rpm), $\boldsymbol{\pi}$ is constant

vi. Determination of volume of the press

The volume of the press was calculated and used to determine the weight of the press and is given as

$$\mathbf{V_p = \pi r_1^2 h_1 + \pi r_2^2 h_2} \quad (7)$$

Where $\mathbf{V_p}$ is volume of press (m^3), $\boldsymbol{r_1}$ is radius of the shaft (m), $\boldsymbol{r_2}$ is radius of cylindrical steel plate (m), $\boldsymbol{h_1}$ is length of the shaft (m), $\boldsymbol{h_2}$ is thickness of cylindrical steel plate (m).

vii. Determination of weight of the press

The weight of the press was determined to be able to determine the total power required to carry the press. The weight of the press can be calculated using the formula

$$\mathbf{W = \rho \times V \times g} \quad (8)$$

Where W is the weight of the press (N), $\boldsymbol{\rho}$ is the density of stainless steel material (Kg/m^3), V is volume of the press (m^3), g is the acceleration due to gravity.

viii. Determination of linear velocity of the press

The linear velocity of the press was calculated to know the power required to drive the shaft. It was determined as reported by reported by Khurmi and Gupta (2005), and is give as

$$\mathbf{V = \frac{2\pi r\omega}{60}} \quad (9)$$

Where V is linear velocity, r is radius of the pulley and ω is angular velocity in rpm

ix. Determination of power required to drive the shaft

The power required to drive the shaft was calculated to know the overall power requirement of the electric motor required to power the machine. It was determined as reported by reported by Khurmi and Gupta (2005), and is give as

$$\mathbf{P = FV} \quad (10)$$

Where P is the power, F is force (weight) and V is the linear velocity.

x. Determination of Gear Output Speed

This is done in order to know the speed reduction by the gear system. It was determined as reported by reported by Khurmi and Gupta (2005), and is give as

$$N_1 = \frac{N_2}{V.R} \qquad (11)$$

Where N_1 is the output speed of the gear, N_2 is speed of the electric motor, V.R is the velocity ratio

xi. Determination of pulley diameter

The pulley diameter was determined to know the appropriate pulley to be selected for the fabrication of the machine. The pulley diameter was calculated as reported by reported by Khurmi and Gupta (2005), and is give as follows

$$D_2 = \frac{N_1 D_1}{N_2} \qquad (12)$$

Where N_1 is speed of driving (gear) pulley, N_2 is speed of driven (machine) pulley, D_1 = diameter of driving (motor) pulley and D_2 is the diameter of driven (machine) pulley

xii. Determination of center distance

The center distance is the distance between the center of the driving and the driven pulley. It was calculated to know the minimum distance between the electric motor and the machine pulley. The center distance (x) is given as reported by Khurmi and Gupta (2005), and is given as

$$X = \frac{D_2 + D_1}{2} + D_1 \qquad (13)$$

Where D_1 is diameter of driving (motor) pulley, D_2 is the diameter of driven (machine) pulley

xiii. Determination of length of belt

The length of the belt was calculated to be able to select the appropriate belt for the machine to function efficiently.The length of the belt can be obtained as reported by Khurmi and Gupta (2005), and is given as

$$\text{Length of belt } (L_b) = \frac{\pi}{2}(D_1 + D_2) + 2x + \frac{D_1 - D_2}{4x}$$

Where D_1 is diameter of driving (motor) pulley, D_2 is the diameter of driven (machine) pulley, X = center distance between pulleys

xiv. Determination of belt velocity

The velocity of the belt can be calculated using the formula reported by Khurmi and Gupta (2005), and is given as

$V_b = \frac{\pi D_1 N_1}{60}$ (15)

Where V_b is the velocity of the belt, D_1 is diameter of driving (motor) pulley, N_1 is speed of driving (gear) pulley.

xv. Determination of the angle of contact between the belt and pulley

The angle of wrap is the angle of contact between the belt and the pulley.The angle of wrap of the belt is given as reported by Khurmi and Gupta (2005), and is given as

Angle of wrap $(\theta) = (180^0 - 2\propto) \times \frac{\pi}{180}$ (16)

Where $\propto = \sin^{-1} \frac{r_2 - r_1}{x}$ (17)

Where $r_1$is radius of driving (motor) pulley, r_2 is radius of driven (machine) pulley, X is center distance between pulleys.

xvi. Determination of belt tension

The tension developed in the belt was evaluated in order to know the power transmitted by the electric motor. It was determined as follows as reported by Khurmi and Gupta (2005), and is given as

$K = 2.3 \log \frac{T_1}{T_2} = \mu \times \theta \times cosec\beta$ **(18)**

Where,$T_1$is tension in the tight side of the belt in N, T_2 is the tension in the slack side of the belt in N, β is average groove angle of the shaft pulley, θ is angle of constant or lap between the two pulleys, μ is coefficient of friction between the belt and the pulleys

xvii. Determination of torque generated in pulley

The torque generated in the pulley was determined as reported by Khurmi and Gupta (2005), and is given as

$\tau = (T_1 - T_2)r$ (19)

Where τ is the torque generated (Nm), T_1 is the tight side tension, T_2 is slack side tension, r is radius of pulley

xviii. Determination of power transmitted by the belt

This is done in order to know the amount of energy transmitted. Power transmitted by the belt was determined as reported by Khurmi and Gupta (2005), and is given as

$$\boldsymbol{P} = (\boldsymbol{T_1} - \boldsymbol{T_2}) \times \boldsymbol{V} \qquad (20)$$

Where, P is power transmitted by the belt, $\boldsymbol{T_1}$ is the tight side tension, $\boldsymbol{T_2}$ is slack side tension in N, V = velocity of the belt in m/s.

xivx. Determination of shaft diameter

This was evaluated to know the shaft that is appropriate for the design this was calculated using the equation reported by Khurmi and Gupta (2005), and is given as

$$d^3 = \frac{16 \times T}{\pi \times \tau} \qquad (21)$$

$$\mathrm{T} = \frac{P \times 60}{2\pi N_1} \qquad (22)$$

Where, T is the torque in N.mm, P is the power transmitted to the shaft in Watts, N_1 is speed of shaft in rpm, τ is shear stress of the shaft in N/mm^2, d is the shaft diameter in mm

xx. Critical speed of the shaft

Critical speed is the speed at which the unbalanced mass of the rotating object causes deflection that will create resonant vibration. The critical speed was calculated to avoid issued such as noise and vibration. For machine efficiency the critical speed of the shaft is to be determined. It was determined as reported by reported by Khurmi and Gupta (2005), and is give as

$$\boldsymbol{\omega_S} = \sqrt{\frac{\mathbf{48\varepsilon I}}{\boldsymbol{ML}}} \qquad \mathbf{(23)}$$

where $\boldsymbol{\omega_S}$is the critical speed of the shaft, ε is the modulus of elasticity of steel, M is the mass of the shaft, L is ength of the shaft.

xxi. Torsional deflection of the shaft

To know the angle of deviation of the shaft in degrees and to make sure this angle of deviation is at its minimum. It was determined as reported by reported by Khurmi and Gupta (2005), and is give as

Thus,

$$\boldsymbol{\alpha} = \frac{\mathbf{584}\boldsymbol{\tau L}}{\boldsymbol{D^4 G}} \qquad \mathbf{(24)}$$

where, α is the angular shaft deflection in degrees, L is Length of the shaft, G is modulus of elasticity of steel, D = 2.26×4√τ

xxii. Determination of Maximum Working Stress of the Shaft

This is done in order to know the strength of the shaft and it behavior under working condition. It is determined as follows as was reported by reported by Khurmi and Gupta (2005), and is give as

$$\boldsymbol{\sigma = \frac{16Ts}{\pi d^3}} \qquad (25)$$

Where σ is maximum permissible working stress, d is the shaft diameter, Ts is the torque of the shaft

2.3 Testing of the Machine

Fresh ginger of 54 kg was bought from farmers, washed and shared into equal parts of 2kg each for testing the fabricated machine. The machine was first run under no load condition to ascertain the parts are moving freely. This parts weighing 2kg were fed into the hopper while the machine was put on to run using a machine speed of 40rpm and a blade size of 1.5cm. This process was then replicated three times to get the average and the whole process was repeated for a blade of size 2cm and 2.5cm and speed of 60rpm and 80rpm. With this the ginger were cut to the size of the blade. The weight of the cut and uncut sample were recorded and the following parameter were calculated

i. Cutting efficiency: This is the effectiveness with which the machine cut the ginger to predetermined size according to the sizes of the blades. This was calculated using the formula below

$$\text{Cutting efficiency} = \frac{W-W_U}{W} \times 100 \qquad (26)$$

Where W is the initial weight of ginger, $\boldsymbol{W_U}$ is weight of uncut ginger

ii. Percentage uncut ginger: The percent uncut ginger is the percentage of ginger that escaped being cut by the machine during the process of its operation. It was computed by the equation below

$$\text{Percentage uncut} = \frac{W_U}{W} \times 100 \qquad (27)$$

Where W is initial weight of sample, $\boldsymbol{W_U}$ is the weight of uncut ginger

iii. Machine capacity: This is the average quantity of ginger that was cut by the machine in an hour. The quantity of ginger cut in an hour can then be obtained using the expression be

$$\boldsymbol{M_c = \frac{W - W_U}{t} \times 60} \qquad (28)$$

Where W= initial weight of sample, WU= weight of uncut ginger, t = time of cutting the sample in min

3. RESULTS AND DISCUSSION

The result of testing of the machine using 2 kg of ginger at various speed of 40, 60 and 80 rpm is presented in Table 1. The cutting efficiency ranges from 71.67 to 93.33 %. The highest value 93.33 % was obtained from interaction between blade size of 2.5 cm and speed 40 rpm. The least value of cutting efficiency of 71.67 % was obtained from interaction between blade size of 1.5 cm and speed 40 rpm. The machine capacity ranges from 8.93 kg/h to 28 kgh. The highest value 28 kg/h was obtained from interaction between blade size of 2.5 cm and speed of 80 rpm. The least value of cutting efficiency of 8.93 kg/h was obtained from interaction between blade size of 1.5 cm and speed 40 rpm.

Table 1: Effects of Blade Size and Speed on Machine Efficiency and Capacity when 2 kg of Ginger was processed

Speed (rpm)	Blade size (cm)	Weight of cut ginger (kg)	Weight of uncut ginger (kg)	Time of cutting (min)	Percentage uncut (%)	Cutting efficiency (%)	Machine capacity (kg/h)
80	1.5	1.7	0.3	6.67	15	85	15.43
	2	1.80	0.2	4.67	10	90	24.16
	2.5	1.87	0.13	4	6.67	93.33	28.0
60	1.5	1.57	0.43	9.33	21.67	78.33	10.09
	2	1.73	0.27	8	13.33	86.67	13.12
	2.5	1.8	0.2	6.33	10	90	17.13
40	1.5	1.43	0.57	9.67	28.33	71.67	8.93
	2	1.57	0.43	9	21.67	74.33	10.51
	2.5	1.53	0.47	8.33	20.33	76.67	11.11

3.1 Machine capacity

From Figure 3, the highest values of machine capacity were obtained with blade size of 2.5 cm, while blade size of 1.5 cm produced the least machine capacity for all the speed. The machine capacity increases with increase in blade size for all the speed. This could be as result of more area of contact between the blade of 2.5 cm with the ginger. This resulted to more cutting of the ginger with that blade compared to the other blade with least size. The increase in the size of the blade also played a role as the bigger the blade sizes the less the resisting force that might be experienced when cutting the ginger. On the other hand machine capacity increases with increase with speed. This could be as result of more centrifugal force associated with higher speed which causes more segregation of the ginger with higher speed of cutting. Also at higher speed the strokes of the press are more which leads to increase in the machine capacity.

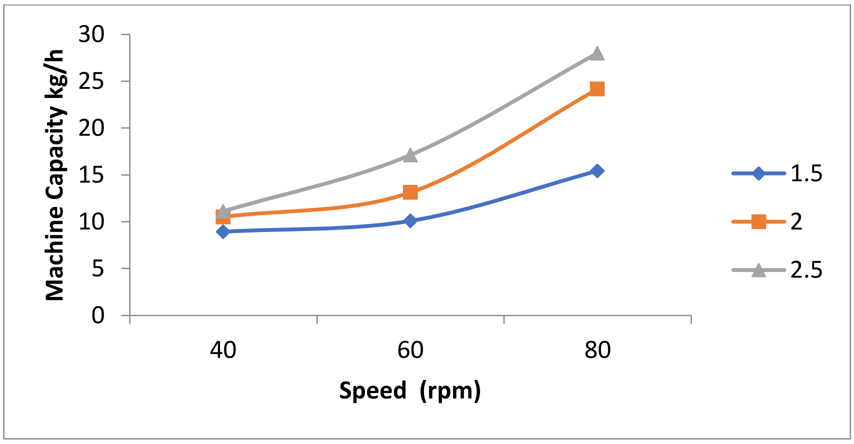

Figure 3: Effects of Speed and Blade Size on Machine Capacity

3.2 Effects of cutting speed and blade size on cutting efficiency

The effect of speed on cutting efficiency of the various blade sizes is presented in fig. 4. Cutting efficiency of the machine increased significantly with increasing speed from 40 rpm to 80 rpm but was almost constant at speeds of 60 rpm to 80 rpm for 2 cm and 2.5 cm blade sizes. However, cutting the ginger with speed of 80 r.p.m using 2.5 cm blade size had the highest cutting efficiency of 93.33 % while cutting at a speed of 40 r.p.m produced the least cutting efficiency of 71.67 % with blade size of 1.5 cm.

Generally, all the speeds produced their highest efficiency (85% to 93.33) with blade size of 2.5 cm while their least efficiency (71.67% to 76.67%) were obtained with blade size of 1.5 cm. Therefore, the machine cutting efficiency increased with increase in blade size. The high cutting efficiency observed with speed of 80 rpm could be as result of increased in centrifugal force which results to high shear force, more number of impacts, greater number of beating and cutting effect of ginger by the blade. This agreed with results of an earlier study by Jayesh (2009) were speed of cutting was reported to have a significant effect on size reduction of solid materials. Higher speed of cutting resulted to more yield of the material than lower speed of cutting. The higher efficiency observed with blade with greater size could be as result of increased in contact between the blade and the ginger with increased in size. This result agreed with the result of an earlier finding by Rachel (2007) where blade design was found to affect size reduction of materials. Both the blade size and cutting speed have significant effects ($p \leq 0.05$) on cutting efficiency of the machine.

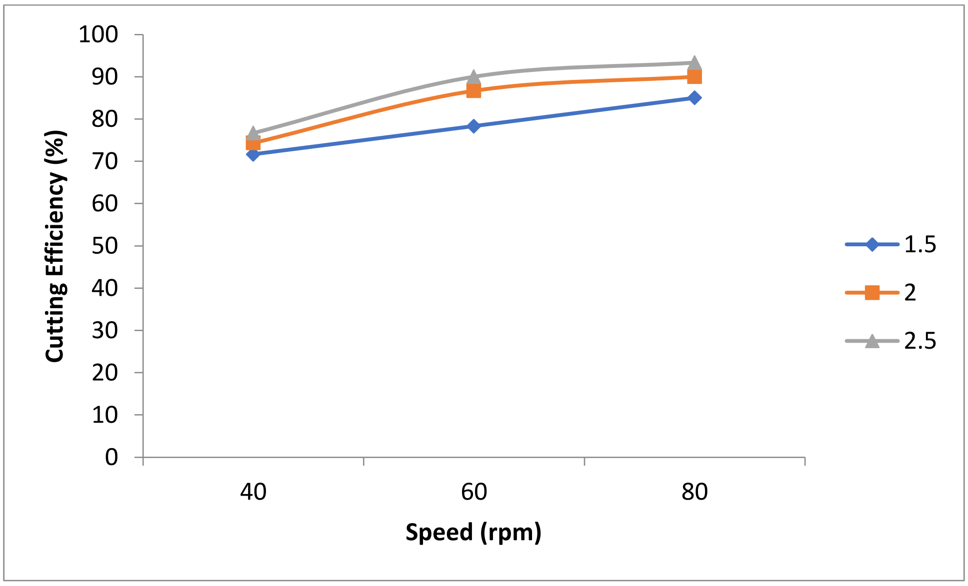

Figure 4: Effect of cutting speed and blade size on cutting efficiency

3.3 Effects of cutting speed and blade size on percentage uncut

The effects of cutting speed and blade size on percentage uncut presented in Figure 5. The percentage of the uncut ginger using blade size of 2.5 decreased from 23.33 % to 6.67 % with increased in speed of cutting 40 rpm to 80. This could be due to increase in impact, cutting and shearing actions of the blade with increased in speed of cutting which resulted to decrease in uncut ginger. This agreed with the findings report by Jayesh (2009) where rotational speed was found to be a key factor to size reduction of solid materials. Where, higher speed of cutting resulted to more segregation of materials than the lower speed. On the order hand the percentage of uncut ginger using speed of 80 rpm decreased from 15 % to 6.67 % with increased in blade size from 1.5 cm to 2.5 cm. This could be as result of increased in contact between the blade and the ginger with increased in size which caused more segregation of the materials. This result agreed with the result of an earlier finding by Gbabo et al. (2012) where blade design was found to affect segregation of materials.

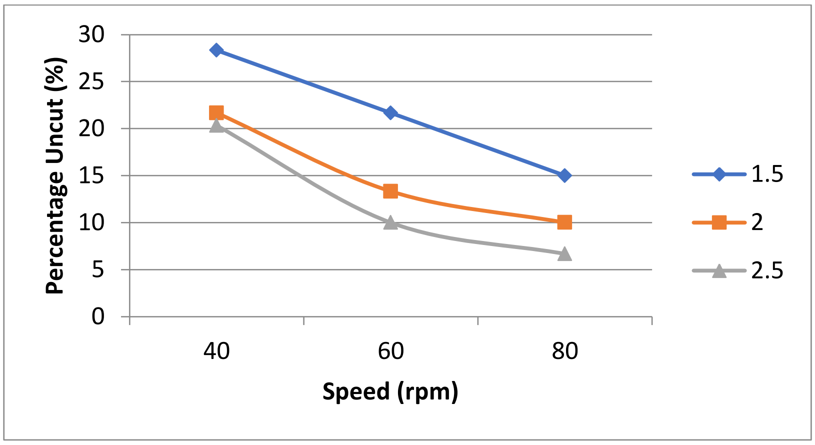

Figure 5: Effect of cutting speed and blade size on cutting efficiency

4. CONCLUSIONS

After the successive design, fabrication and testing of the equipment, it was concluded that the machine capacity increases with increase in speed from 40 to 80 rpm as well as increase in blade sizes from 1.5 to 2.5 cm. The machine cutting efficiency followed similar trend. On the other hand the percentage of uncut ginger increases with reduction in the speed and blade size and reduces with increase in speed and blade size. The developed machine will go along way in increasing processing and utilization of ginger

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The role of land husbandry practices in achieving food safety. *UMUHOZA, Ernestine; MUNYESHYAKA, Jean Damascene.*

ABSTRACT

Food safety is a major challenge in Africa, whereas most of countries are hilly with steep slopes over 30%; this leads to the lack of sufficient food for people in Africa due to soil degradation caused mostly by soil erosion and/or drought at some areas. To address the issue, it would be better to adopt best agricultural practices such as land husbandry technics which will help to address lack of sufficient soil moisture during the growth period of the crops and/or that of excess water during storm period through application of water retention measures in the soil and xappropriation measures of water from the area receiving excess water as compared to the soil saturation for reuse I other places with scarce soil moisture.

The purpose of this paper is to provide technical recommendations for soil and water conservation for irrigated and rain fed catchments to address the problem of water availability and soil degradation in Africa to adapt to the challenge of climate change and hence ensure food security and/or safety for Africans.

RESUME

When thinking about preparing this kind of paper, I was aware about the problem of climate change all over the world as a professional working in and doing studies related to this domain and who knows its implications on food safety and/or security.

The roles of key features of any landscape in determining potentials for erosional losses are considered from an agro-ecological viewpoint. In this light, the effectiveness of past commonly-accepted approaches to soil and water conservation are often found to have been inadequate. In many cases they have tackled symptoms of land degradation without appreciating fully the background causes, which often relate to inadequate matching of land-use/land-management with features of the landscape. Application of good land husbandry practices will improve land productivity and protect environment and hence ensure beneficial rain fed agriculture. In particular, an ecologically based approach to better land husbandry helps to foresee potential problems in some detail, so that appropriate forward planning can be undertaken to avoid them. This paper will show how application of comprehensive land husbandry can help in climate change mitigation and hence ensure food security/ safety.

It will also briefly show the impact of land husbandry on general people's wealth and how countries can work together and protect their lands and environment, mitigate climate change and hence ensure food safety/ security.

The purpose of this paper is to provide technical recommendations for soil and water conservation for irrigated and rain fed catchments to address the problem of water availability and soil degradation in Africa to adapt to the challenge of climate change and hence ensure food safety and/or security for Africans.

During this study we have tried to find out examples of how land husbandry can reduce land degradation and boost agriculture production and hence ensure food safety and/or security.

In this paper, we don't talk about food safety but also food security because one should not target food safety without food security: one there is food security that is ensured, economic growth is ensured and the capacity to make food safe is consequently achieved.

The challenge of food security is to assure that all people have access to enough food to lead productive lives, but a large part of food security is assuring the food is safe from a chemical, physical or biological aspect.

Introduction

The productive capacity of many areas of land now in use has already been compromised by damage to soils, following inappropriate matching of preferred systems of land use, and of their management, with the characteristics of the land on to which they have been imposed. because development puts additional pressure on ecosystems, and rich populations continue to multiply destructive resource exploitation, the agenda for the planet is shifting from *food* supply constraints to sustainability themes.

To address the problem of environment degradation which aggravate global warming and hence worsen climate change issue as well as food security and/or safety, modern agricultural practices such as comprehensive land husbandry technologies should be adopted by the hall African continent and wherever needed on this globe. Existing uses or management may need to be changed so as to halt rapid *degradation* and to return the land to a condition where good husbandry can have fullest effect.

To better show the effect of land husbandry in climate change mitigation, soil degradation control and ensuring food safety and/or security, we will part from the experience learned from Rwanda as one of the African country that has adopted land husbandry technologies and has success stories from it in about the matter even if the way is still long and the country is keeping on trying and trying. This will help other countries facing the same challenges to see how to overcome and/or reduce the impacts.

The main objective of this paper is to show the role of land husbandry in mitigating the problem of global warming causing climate change and hence lack and safety of food for many people in the world.

The specific objective is as follows:

- Show how land husbandry can be utilized to reduce global warming
- Show how land husbandry is a climate smart agricultural practice
- To show the relationship between climate change and food availability
- To show how land husbandry affect crop production and hence food safety and/or security
- To show what can be done for the countries to adopt land husbandry practices in sustained manner
- To show the role of land husbandry in SDGs achievement

The methodology that was used to prepare this paper is collection of the data related to land husbandry adoption in different places in Rwanda about the impact on agricultural production and the response by some few Rwandan farmers from where land husbandry has been implemented.

Can land husbandry affect climate change? Is climate change affecting food safety? What can be done for land husbandry be adopted by as many countries to address the issues? All these questions will be answered in the following paragraphs of this paper.

Land husbandry and global warming

Restoring the soil and improve productivity of the agricultural land is the overall goal of land husbandry. Investing in land husbandry increases resilience to climate change, reduces water erosion and soil loss, halts land degradation, and increases land productivity. Land management techniques include soil bunds, terraces, cut-off drains land husbandry practices for both rain-fed and irrigated agriculture for higher crop production.

Rwanda’s climate change vulnerability originates in the mountainous character of the country with an inherent susceptibility to soil erosion, combined with a strong reliance on rain-fed agriculture representing 34% of Rwanda’s GDP (2014) and employing 90% of its inhabitants (both directly and indirectly). This leaves the country in a challenging position with regard to climate change adaptation. As the temperature increases, Rwanda's historically predictable rainy seasons are becoming increasingly unreliable and short, resulting in more frequent droughts and higher intensity rains with the potential of causing progressively significant economic damage to crop yields and infrastructure.

Climate smart agriculture (CSA) is an integrative approach to address these interlinked challenges of food security and climate change that explicitly aims for three objectives:

A: Sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and development.

B. Adapting and building resilience of agricultural and food security systems to climate change at multiple levels; and

C. Reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries).

Climate smart agriculture approaches are mainly covered under the term 'conservation agriculture' (CA)

Land husbandry implementation recall for application of different soil and water conservation measures like terraces, ditches, grass and tree plantation, drainage system design and construction, application of lime and compost where required, green manure application, pitting,…

Among these different technologies. Forest are rehabilitated and/or newly planted, what is reducing greenhouse gases concentration in the atmosphere through photosynthesis phenomenon and hence mitigating and/or adapting to climate change.

In addition to trees plantation, land husbandry will help in increasing the vegetative cover through grass planting, crop growing and hence increasing carbon uptake and temperature reduction and that is in this way land husbandry will positively affect climate change(it will reduce global warming somehow).

Land husbandry, a climate smart agriculture practice

Abandoning unsustainable practices and moving to better land husbandry can provide a sound foundation for sustainable land use and thereby crop production. Good land husbandry considers management of soil, water, and vegetation in an integrated approach rather than trying to manage each natural resource separately. This management takes place at a variety of scales, from the field to the landscape, end embraces land under planted crops, pastures and plantations, and under native vegetation.

Land husbandry will help in increasing the capacity of water to infiltrate the soil body as the later has been softened during terracing, cultivation, compost and lime application, in improvement of soil aggregation in general thus increasing water holding capacity and delaying wilting point and hence allowing crops to grow and produce even during periods of low rain; during the periods of storm, excess water is drained through constructed drainage system toward streams and/or rivers and this avoid crops damages.

The benefits of this approach with regards to climate resilience are:

1. Stable yields: Increased average yields in the long term due to the water and soil conserving effects of CA, which help to stabilize the crops against weather extremes;
2. Drought buffering: The approach increases soil water content through increased infiltration and a reduction of runoff and evaporation. Increased infiltration improves water use efficiency and buffers crops against drought;
3. Reduced field preparation costs: CA allows for timelier planting that supports successful harvest due to the reduction in effort associated with tillage;
4. Reduced soil erosion: Reducing tillage and maintaining soil cover with crop residues can reduce erosion by up to 80%. CA also generally increases soil organic matter in the top soil, along with an increase in soil biological activity and biodiversity;
5. Climate change mitigation: Under certain conditions, CA may contribute to climate change mitigation through carbon sequestration and reduced Green House Gas (GHG) emissions.

Relationship between climate change and food availability and safety

Climate change and agriculture are deeply interconnected. Globally, the agricultural sector is responsible for approximately 21 percent of greenhouse gas emissions. Agriculture is also incredibly vulnerable to the effects of climate change, as it is so dependent on temperature and precipitation patterns. While some regions may benefit from improved growing conditions, the negative effects worldwide are expected to far outweigh the positives. Global food security will be severely affected at a time when population is rapidly expanding.

Climate change is very likely to affect food security at the global, regional, and local level. Climate change can disrupt food availability, reduce access to food, and affect food quality. For example, projected increases in temperatures, changes in precipitation patterns, changes in extreme weather events, and reductions in water availability may all result in reduced agricultural productivity. Increases in the frequency and severity extreme weather events can also interrupt food delivery, and resulting spikes in food prices after extreme events are expected to be more frequent in the future. Increasing temperatures can contribute to spoilage and contamination.

Internationally, these effects of climate change on agriculture and food supply are likely to be similar to those seen in the United States. However, other stressors such as population growth may magnify the effects of climate change on food security. In developing countries, adaptation options like changes in crop-management or ranching practices, or improvements to irrigation are more limited than in the United States and other industrialized nations.

Increasing the Risk of Hunger

Climate change exacerbates the risks of hunger and under nutrition through:

- **Extreme weather events**
  Climate change increases the frequency and intensity of some disasters such as droughts, floods and storms. This has an adverse impact on livelihoods and food security. Climate-related disasters have the potential to destroy crops, critical infrastructure, and key community assets, therefore deteriorating livelihoods and exacerbating poverty.
- **Long-term and gradual climate risks**
  Sea-level will rise as a result of climate change, affecting livelihoods in coastal areas and river deltas. Accelerated glacial melt will also affect the quantity and reliability of water available and change patterns of flooding and drought.

Food Security and Nutrition

Climate change affects all dimensions of food security and nutrition:

- **Food availability:** Changes in climatic conditions have already affected the production of some staple crops, and future climate change threatens to exacerbate this. Higher temperatures will have an impact on yields while changes in rainfall could affect both crop quality and quantity.
- **Food access:** Climate change could increase the prices of major crops in some regions. For the most vulnerable people, lower agricultural output means lower incomes. Under these conditions, the poorest people — who already use most of their income on food — sacrifice additional income and other assets to meet their nutritional requirements, or resort to poor coping strategies.
- **Food utilization:** Climate-related risks affect calorie intake, particularly in areas where chronic food insecurity is already a significant problem. Changing climatic conditions could also create a vicious cycle of disease and hunger. Nutrition is likely to be affected by climate change through related impacts on food security, dietary diversity, care practices and health.
- **Food stability:** The climatic variability produced by more frequent and intense weather events can upset the stability of individuals' and government food security strategies, creating fluctuations in food availability, access and utilization.

Climate change and food safety

Climate change is likely to have considerable impacts on food safety, both direct and indirect, placing public health at risk. With changing rainfall patterns and increases in extreme weather events and the annual average temperature we will begin to face the impacts of climate change. These impacts will affect the persistence and occurrence of bacteria, viruses, parasites, harmful algae, fungi and their vectors, and the patterns of their corresponding foodborne diseases and risk of toxic contamination. Alongside these impacts, chemical residues of pesticides and veterinary medicines in plant and animal products will be affected by changes in pest pressure. The risk of food contamination with heavy metals and persistent organic pollutants following changes in crop varieties cultivated, cultivation methods, soils, redistribution of sediments and long-range atmospheric transport, is increased because of climate changes. Climate sensitive risk factors and illnesses will be among the largest contributors to the global burden of food-related disease and mortality, including under-nutrition, communicable, non-communicable, and diarrheal- and vector borne diseases. The impact of climate change will not be even across different food systems. Some regions are projected to have an increase in food production; however, generally the projected climate change is foreseen to have a negative impact on food security, especially in developing countries. The effects of climate change on food security and consequently nutrition are closely linked to effects on food safety and public health and must be considered together. WHO, together with agriculture, environment and other relevant sectors must be ready to support national authorities, particularly in developing countries and countries most affected, to prepare and respond to these effects.

- **Climate change** is expected to lead to modified bacterial, viral and pathogenic contamination of water and food by altering the features of survival and transmission patterns through changing weather characteristics, such as temperature and humidity.
- **Climate-dependent** temperature and moisture, fungal growth and formation of mycotoxins will lead to changes in occurrence patterns. Mycotoxins are produced by certain fungi (moulds) on crops and can cause both acute toxic effects and chronic health problems (including cancer) in humans and livestock.
- Climate change has also been described as a 'catalyst for the global expansion' of algal blooms in oceans and lakes, interacting with nutrient loading from fertilizer run-off into water bodies.
- This high risk of emerging zoonoses, changes in the survival of pathogens, and alterations of vector-borne diseases and parasites in animals, may necessitate the increased use of veterinary drugs, possibly resulting in increased residue levels of veterinary drugs in foods of animal origin. This poses not only acute and chronic risks to human health, but is directly linked to an increase in antimicrobial resistance (AMR) in human and animal pathogens.
- The application of pesticides, and the subsequent residues in food, is an ongoing concern that is expected to become more prevalent due to climatic changes, with shifts in farming systems and farmers' behaviour to adapt to the changing climate.
- The increased frequency of inland floods linked to climate change will impact environmental contamination and chemical hazards in foods through the remobilization of contaminated river sediments and subsequent contamination of agricultural and pastureland soil contaminants.
- Climate change increases the frequency and severity of extreme weather events which impacts food security. Where food supplies are insecure, people tend to shift to less healthy diets and consume more "unsafe foods" – in which chemical, microbiological and other hazards pose health risks and which contribute to increased malnutrition.

Extreme weather events and natural disasters

Climate change increases the frequency and severity of extreme weather events, including; more common extreme temperatures, heavy precipitation, intense tropical cyclones and expanded areas affected by drought and floods – for example, by 2080, 2 to 7 million more people per year, will be affected by coastal flooding2 . During and after a natural disaster such as a flood or tsunami, food safety risks are heightened, as in many cases, proper storing and cooking of food may be impossible due to the lack of facilities or fuel. Poor sanitation can then compound the risks, leading to increases in foodborne diseases including hepatitis A, typhoid fever and diarrhea diseases, such as cholera and dysentery. Persons suffering from the direct effects of the disaster may already be at risk of malnutrition, therefore it becomes essential that the food they consume is safe. By 2020, between 75 and 250 million people are projected to suffer increased water stress in sub-Saharan Africa2 , however droughts also pose a nutritional risk to the population through the increased hazard of water contamination of food and crops, as farmers struggle to find fresh water to irrigate, resorting to unsafe or recycled water.

Africa overview of climate change impact on food security

The 2018 Africa Regional Overview of Food Security and Nutrition was co-published for the very first time with the United Nations Economic Commission for Africa. This new collaboration provides opportunities to broaden the technical scope, promote a wider dialogue and visibility of the findings and policy implications, and continue FAO's efforts to achieve closer collaboration on its flagship publications with the relevant UN agencies.

In 2017, FAO reported that the prevalence of hunger was on the rise in Africa, after many years of decline.

The latest data, presented in this years' Regional Overview, confirms that this trend continues, with Central and Western Africa faring the worst. Today, a fifth of Africans are undernourished, representing a staggering 257 million individuals.

The worsening trend in Africa is due to difficult global economic and worsening environmental conditions and, in many countries, conflict and climate variability and extremes, sometimes combined. Economic growth slowed in 2016 due to weak commodity prices, in particular for oil and minerals. Food insecurity has worsened in countries affected by conflict, often exacerbated by drought or floods. For example, in Southern and Eastern Africa, many countries suffered from drought.

The deterioration of the food security situation and the lack of progress towards the WHO global nutrition targets make it imperative for countries to step up their efforts, if they are to achieve a world without hunger and malnutrition by 2030. The call for greater action remains true even as the economic and climatic situation improves, offering hope of renewed progress in reducing food insecurity and malnutrition on the continent.

The need for greater efforts also emerges clearly from the findings of the inaugural biennial review of progress in implementing the goals of the Malabo Declaration. The evidence presented in the review indicates that countries committed to the values and principles of the Comprehensive Africa Agriculture Development Programme (CAADP), and that implement their National Agriculture Investment Plans, perform better. It is therefore imperative to strengthen commitments to the CAADP goals and to accelerate efforts toward formulating and implementing National and Regional Agricultural Investment Plans.

This year's Regional Overview also presents evidence from a number of countries that have successfully reduced food insecurity and malnutrition. Their experience shows that policies, when appropriately designed, and effectively coordinated and implemented, are important drivers of progress towards Sustainable Development Goal 2, i.e. end all forms of hunger and malnutrition by 2030. In addition to specific food security and nutrition policies, this year's report reviews four important cross-cutting topics, namely, youth employment, remittances, intraregional trade, and climate change. It highlights their interplay with the food system and their role in food security and nutrition.

Youth employment is a fundamental challenge across the continent and agriculture and the rural economy must play a key role in creating jobs to absorb the 10 to 12 million youth joining the labor market each year. However, the quality of jobs is equally important as most youth currently work in the informal economy and 67 percent of young workers live in poverty in sub-Saharan Africa. Rising incomes, urbanization and changing lifestyles pose challenges but also represent opportunities for the private sector to generate the growth and employment needed to provide decent jobs for our youth. Governments must step up efforts to help youth acquire skills, resources and the opportunity to participate in decision-making and policy dialogue.

International and internal migration affects millions of Africans, many of whom are youth, each year. The remittances they send home play an important role in reducing poverty and hunger as well as stimulating productive investments. International remittances amount to nearly USD 70 billion, about 3 percent of Africa's GDP, and present an opportunity for national development that governments should endeavor to strengthen. At the same time governments must promote decent employment, inclusive growth and strengthened household resilience to avoid involuntary migration.

The signing of the African Continental Free Trade Area agreement is an opportunity to accelerate growth and sustainable development by increasing investment and trade, including trade in agricultural products.

Although agricultural intra-African exports rose from USD 2 billion in 2000 to USD 13.7 billion in 2013, they remain relatively modest and often informal. Considerably higher trade flows are expected once the barriers to investment and trade are removed. Opening trade of food also carries risks to consumer and producer welfare, and governments should avoid using trade policy for multiple objectives but rather combine trade reform with additional instruments, such as safety nets and risk–mitigating programmes, to achieve food security and nutrition goals.

Climate variability and extremes, in part due to climate change, is a present and growing threat to food security and nutrition in Africa and is a particularly severe threat to countries relying heavily on agriculture.

The effects of climate change, reduced precipitation and higher temperatures are already seen on the yields of staple food crops. Without climate change adaptation and mitigation, by 2050 an estimated additional 71 million people will be food insecure in the world, over half of whom will be in sub-Saharan Africa.

The 2017 edition of the Africa Regional Overview of Food Security and Nutrition reported that in many countries adverse climate conditions were among the reasons for rising levels of hunger. It is, therefore, timely that this year's edition's special focus is on presenting a broader evidence-based assessment of the threat posed by climate variability and extremes to food and nutrition security in the region. Many countries in Africa are at great risk to climate-related disasters and suffer from them frequently. Over the last ten years climate-related disasters affected on average 16 million people and caused USD 0.67 billion in damages across the continent each year. Greater efforts are needed to support rapidly growing insurance markets and establish strategic regional grain reserves to contain food price volatility and prevent food crises.

Greater urgency in building resilience of households, communities and countries to climate variability and extremes is needed. A myriad of challenges must be faced to building institutional capacity in designing, coordinating and scaling-up actions for risk monitoring and early warning systems, emergency preparedness and response, vulnerability reduction measures, shock-responsive social protection, and planning and implementing resilience building measures.

Strategies towards climate change adaptation and disaster risk reduction must be aligned as well as coordinated with interventions in nutrition and food systems across sectors.

Effects of land husbandry on crop production and food safety and/or security

During land husbandry technologies implementation, different land husbandry technologies including mechanical and biological measures of soil and water conservation.

Among mechanical measures applied in land husbandry, terraces, soil bunds and conservation ditches supplemented with drainage system are designed and constructed and then used to protect soil from erosion, to increase available moisture conservation into the soil in case there is no sufficient rain and/or there is a challenge of irregular rain that can accelerate wilting point of the crops if soil moisture is not well conserved and ensure climate smart agriculture. In dry and moist agro climatic zones, these structures are level along the contours to just avoid loss of useful water that would be conserved and used during growth period of cultivated crops while in wet zones, they are made graded to favor xappropriation of excess water for reuse in other places where it may be required.

Biological measures of soil and water conservation are mainly grass strips alternated with trash lines where slope gradient allows, forest plantation, lime and compost application, green manuring.

All of the above mentioned measures are used for soil and water conservation, for soil physical and chemical quality improvement like aggregation and fertility that are the main issues once resolved may help n boosting crop production and hence food security.

During land husbandry implementation, trees are planted, environment is made more green due to soil moisture conservation and soil fertility improvement and this help in climate change impact adaptation and/or mitigation which also in turn may reduce and/or avoid those pests and diseases that may be caused by climate change and lack of water to the plant and hence increase food safety.

Table1. Data on annual sediment load measured at ten different LWH sites and soil erosion reduction rates measured using RUSLE[1]

Site name	Sediment load (t^{-1} ha^{-1} yr^{-1})						Soil Erosion reduction rate	
	2011	2012	2013	2014	2015	2016	Before LH interventions (Baseline - %)**	After LH interventions - from 2011* (%)
Gatsibo – 8	38	7	4	1.2	0.5	0.2	96	98
Karongi – 12	68	35	18	8.7	5.8	3.2	54	79
Karongi – 13	57	23	18	9.2	6.3	4.3	50	78
Nyanza – 23	53	15	13	7.5	4.1	2.7	67	83
Average	**54**	**20**	**13**	**7**	**4**	**2.6**	**67**	**84**

** Sediment load during construction of radical terraces; ** Baseline taken from these sites during Project Phase 1A (i.e. from 2010 to 2016)*

[1] Ibid

Table 2. Average crop productivity at in Rwanda with land husbandry interventions

Crop	Baseline productivity (T/ha) (2009 A)	Productivity (T/ha) (B2017)	End-line Productivity* (T/ha) (2017A)
Maize	1.55	4.0	2.6
Soybean	0.6	1.5	2.5
Bush beans	0.6	1.5	2.5
Climbing beans	0.8	2.7	3.5
Irish potato	3	18	25
Wheat	0.4	3.0	7.5

Source: LWH Project Progress Reports

***Source: LWH End-line Survey (May, 2018)**

From the table above, it can be realized that due to land husbandry production has been increased from 2.6 to 25 times as compared to the baseline.

Intersection between food safety and security

Food security and food safety are both public health issues. Both aim to protect and promote health Food security includes food safety Food insecurity is a serious health issue: CCHS: Moderate = quality and/or quality compromised | Severe = reduced intake and disrupted eating patterns -Child nutrition and health has impacts now on school performance and learning + social/health effects later in life -Higher prevalence of diabetes, cardiovascular, dental, psychosocial outcomes, obesity – may be related to food insecurity or to socioeconomic conditions Affects diverse range of people: First Nations, immigrants, EI or social assistance recipients, working poor, single parent families, children.

The Food Security Continuum is often used to describe a range of actions intended to promote food security, moving from meeting immediate needs to changing the system to be more food secure for all people. Food safety can be viewed in a similar way, moving from actions to remove immediate health hazards, to helping operators become more food safe, and ultimately creating safe food environments.

African countries to adopt land husbandry practices in sustained manner

African land and water resources in some areas are seriously threatened through overuse although per capita availability is one of the highest in the world. This is a direct result of the increasing needs of a growing population, combined, often, with inappropriate land management practices. Thus, on the one hand, the African population is growing at over two percent a year (FAO, 2008), requiring a doubling of food production by 2030 to keep pace with demand; on the other hand, productivity of natural resources is in general in decline. Additionally, the number of natural disasters has increased and climate change is already taking its toll. A new system of management and governance of land resources is urgently needed; one that is able to respond in a systematic and integrated manner to this key development challenge. Sustainable land management (SLM) is a comprehensive approach, with the potential of making very significant and lasting differences in the near future, and over the long-term

Focus on Sustainable Land Management in Africa

Africa is particularly vulnerable to threats of natural resource degradation and poverty. This is due to various factors including a high population growth rate and increasing population pressure, reliance on agriculture that is vulnerable to environmental change, fragile natural resources and ecosystems, high rates of erosion and land degradation, and both low yields and high post-harvest yield losses. On top of this can be added sensitivity to climate variability and long-term climate change.

SLM seeks to increase production through both traditional and innovative systems, and to improve resilience to the various environmental threats.

Principles for best SLM practices increased land productivity In order to increase production from the land, water use efficiency and productivity need to be improved. This can be achieved by reducing high water loss through runoff and unperceived evaporation from unprotected soil, harvesting water, improving infiltration, maximizing water storage - as well as by upgrading irrigation and managing surplus water. The first priority must be given to improving water use efficiency in rainfed agriculture; here lies the greatest potential for improved yields with all the associated benefits. For irrigated agriculture, conveyance and distribution efficiency are key water-saving strategies.

Soil fertility decline due to unproductive nutrient losses (through leaching, erosion, loss to the atmosphere) and 'nutrient mining' is a major problem in Arica. An improvement to the current imbalance between removal and supply of nutrients can be achieved through various means. These include cover improvement, crop rotation, fallow and intercropping, application of animal and green manure, and compost through integrated crop-livestock systems, appropriate supplementation with inorganic fertilizer and trapping sediments and nutrients.

Improved livelihoods

The implementation of sustainable land management practices creates jobs n rural areas and increase crop production and hence improve people's livelihoods.

Improved ecosystems: being environmentally friendly

Practices, to be truly sustainable, must be environmentally friendly, reduce current land degradation, improve biodiversity and increase resilience to climate variation and change. Given the current state of land in Africa, SLM interventions are vital to prevent, mitigate and rehabilitate land degradation. The main efforts should address the problems of water scarcity, low soil fertility, organic matter and reduced biodiversity. Priority should be given to low-input agronomic and vegetative measures, and only then consider the application of more demanding structural measures. Combinations of measures that lead to integrated soil and water, crop-livestock, fertility and pest management are promising. Spreading of local successes in combating degradation leads to compound impacts – the whole being greater than the sum of the parts - at the watershed, landscape and global levels.

Adoption and decision support for up scaling best practices

Despite continuous efforts to spread SLM practices adoption is still alarmingly low. Investments in spreading SLM practices in Africa have great scope and can provide multiple benefits not only locally, but also regionally nationally and globally. Consolidated action towards better use of valuable knowledge at all levels is needed and will be beneficial in the future, as it can be anticipated that change will be even more pronounced with respect to global markets, climate change, demands on ecosystem services, etc. In short, investment in SLM and a sound knowledge management shold pay now - and continue to do in the future.

To achieve this, Africans should work together in mobilizing funds and make country schools where land husbandry has been applied and learn from success stories from the countries so that every country can be aware and access the application of these best practices to adapt to the challenge of climate change.

The role of land husbandry in SDGs achievement

Maintaining and restoring land resources can play a vital role in tackling climate change, securing biodiversity and maintaining crucial ecosystem services, while ensuring shared prosperity and well-being. Healthy and productive land can play an unparalleled role as an engine of economic growth and a source of livelihood for billions worldwide, including the most vulnerable populations. Achieving land degradation neutrality (LDN) can become an accelerator of achieving SDGs across the board. Below are some of the global goals for sustainable development, which can be achieved by investing in the future of the land:

Opportunities for all:

Our future economic growth, prosperity and well-being depend on protecting and restoring working landscapes. Two billon hectares of degraded land are available to kick-start green economy and develop opportunities for employment, learning and poverty reduction.

It is also necessary to recognize the role of women as agents of positive change. Evidence shows that when women are given equal opportunities and access to resources and decision-making, communities become more prosperous and more peaceful. Women’s transformative potential can become the cornerstone for achieving LDN and fulfilling the 2030 Agenda for Sustainable Development.

Doing more and better with less:

Estimates show that 795 million people worldwide are chronically undernourished, often as a direct consequence of land degradation, declining soil fertility, unsustainable water use, drought and loss of biodiversity. The sustainable land management (SLM) and restoration of terrestrial resources are vital to enhancing agricultural productivity especially for small-scale food producers. SLM ensures sustainable food production and resilient agricultural practices, as well as the efficient use of natural resources, thus contributing to human well-being.

Blue lifelines:

Water scarcity affects more than 40 per cent of the global population and is projected to increase. SLM practices that improve water efficiency and quality in a cost-effective way, as well as the restoration of water-related ecosystems, are essential to mitigating water scarcity. This is an important precondition to achieving access to adequate and equitable sanitation and hygiene for all.

Fuel for life:

Climate change requires a rethink and a bold move towards renewable energy sources. By 2030, nearly three billion people will rely on biomass for cooking and heating. The sustainable management of land and water is pivotal to ensure a reliable, affordable and sustainable energy supply for all.

Working with nature:

By 2030, almost 60 per cent of the world's population will live in urban areas. It is critical to promote integrated spatial development planning approaches to optimize the allocation of resources, on which human settlements in urban and peri-urban areas rely. Health benefits and disaster prevention are additional advantages that sustainable land use planning can provide.

Land matters for climate:

Without proper consideration of the land sector, we cannot get to a 2° C stabilization pathway and deliver climate-change resilient landscapes. Improved land use and management, such as low-emissions agriculture, agro-forestry and ecosystem conservation and restoration could close the remaining emissions gap by up to 25 per cent, while reducing the risks posed by climate change and developing the resilience of key sectors.

Invitation:

UNCCD extends a warm invitation to those who are like-minded to join the Convention in achieving LDN by 2030. By protecting the land, we can protect the life on Earth.

Conclusion

Based on the above mentioned findings, land husbandry is a must to overcome the challenge of food safety. As we have seen, land husbandry application is crucial to mitigate and/or adapt to climate change, hence taken as climate smart agriculture practice, which helps in ensuring food security, safety included.

It is in this frame that we are advising countries to adopt the practice so as to ensure food safety which much depends on climate, where new pests and diseases may be born from irregular rains, dryness and/or excess humidity due to climate change.

Countries have to help each other in terms of targeting food safety/security, every country in what it can in order to achieve that goal as well as SDGs.

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Extension Services and Promotional of Climate Smart Agriculture in West African. *Michael Adedotun Oke*

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KEYWORDS: extension, smart, Agriculture, technology, farmers, Nigeria**.**

Introduction

For a profitable climate smart Agriculture in African Country, there is a need for a well define and quick win extension services with the promotional of climate smart Agriculture. The important is that it will increase farming activities among the peasant farmers, reduce the stress of land cultivation; some of the agricultural problems like the destruction of some arable crops will be averted, which occurs because of the climate change and it will profit the average farmers, if the different smart Agricultural technologies are extended to them and the different relevant information that will help them to embark in smart Agricultural farming and in each region to promote partnership and develop a pilot projects, to compare and learn from each other's.

The needed structure is quite germane for serious extensions services, which will help the farmers to acquire the various technologies that will address the agricultural problem's such as the various constraints of harvesting, post harvesting, processing, cultivation, storage, marketing, research issues, low production etc. In addition when planning the different climate programs there is need for the country to have a guided strategic activities, projects that will integrates farmers practices, technologies', different information about the weather for a sustainable agricultural systems.

Climate smart agriculture and smart farming technologies, are the easy pathway for the world to embrace in order to achieve food sufficiency through massive adoption of improved technologies to the farmers. Precision agriculture is also known as a smart farming which includes the promotion of crop yields, soil mapping, fertilizers applications, weather information, data collection, machineries development and animal health.

In some of the African country some farmers are into soil mapping, using different seedlings that are drought tolerant e.g. Maize. Simple Yam multiplications technology, improvement and management of dairy, intensive farming of catfish, and restoration crop fields, practicing different technology on waste-reduction on rice, new agricultural machineries that support smart farming and receiving rainfall information forecast and practicing different low-carbon agricultural activities.

While the various problems associated with the low farming productivity as to do with the various land degradation of the natural resources and the effect of the climate change, low innovational technology among the farmers , until this problems is solve the African country will find it difficult to make food available for the growing population and will not able to have enough yields.

Having study the simple practices of smart Agriculture in other countries. West African country may have some problems of the uptake of the smart agriculture technology, due to the Illiteracy of the farmers, poor management of the farms, poor technology, in adequate improved seedlings and machineries, all this should be addressed for the successfully implementation of the smart Agriculture in West African.

The various important of climate smart Agriculture is also stressed in the areas of development of high crop varieties, improvement in the Animal breeds and species, it increase economy activities, conserves natural resources and biodiversity, income generations, improves the livelihoods and food security, it also aids in planting, crop rotations, mixed cropping, strip cropping, shifting cultivation, fallowing, cover cropping, aids in the application of manure, mulching, reduced of zero tillage, agroforestry management, aids irrigational practices, water harvesting, terrace, mounds, diversion of ditches and drainages, contours.

For the effective extension services delivering of the smart agriculture in West African, the issues of low adoption of simple technology should be taken into consideration, the introduction of a simple technology, with less cost, the review of guided smart technology policy, the longevity of such technology, availability of the machineries and easy management of the simple passage of the technology and replication of the processes, sustainability of such smart technology etc.

The various research institute’s and the Extension Agent most work together to find a lasting solution to this various issues just as the International Institute for Tropical Agriculture said there are ongoing research on yam mini sett technology that encourage yam mass propagation, multiplication that will advance yam cultivation in the country.

Kick starting the various climate smart agriculture projects and farming activities will be a plus, if it will lead into farmers productivities, reduce the stress of an average farmers, help in solving the different Agricultural problems, such as the current problems of fighting between the cattle herdsmen and of the farmers. E.g. A Yam farmers in Nigeria said that farmers were yet to recover from the farmers-herders crises, which have affected severally yam production in Nigeria.

Well from the field survey we discovered that the climate smart Agriculture technology can been develop and practice to the farmers through the Extension Agents in the case of Nigeria that is the Federal Capital Territory Agricultural Development Programs, which have an existing structure such practices that involve the soil management practices, development of a dairy manual, provision of the information on the drought-tolerant on maize, smart agriculture on catfish farming, adoption of new technology on how to reduce rice waste, provision of different agricultural machineries that support smart farming. Rain forecasts, provision of various incentives that will support smart farming and encourage the low- carbon Agriculture.

The different Agricultural research institutes, Ministry of Agriculture, Universities, individual's, non-Governmental organization can also help in developing and engaging the farmers with simple climate smart technology, promotional information, a long standing extension structure should also be develop and feedback reporting, documentation, from the farmers experiences and looking at the various constrain that may hinder the farmers to take up the technology and also a pilot programs should be established to teach the farmers and educate them and all technology being introduce should be friendly, simple, cost effective for the farmers to being able to accept it.

In addition the needs for the promotional of smart Agriculture and practicing, will make the farmers to have a good yields, different crop varieties will be develop, improved of Animal breeds and species helps in engaging in crop rotations, mixed cropping, strip cropping, shifting cultivation, fallowing, cover cropping, application manure, mulching, reduced or zero tillage, Agroforestry , irrigation, water harvesting , terraces, mold's diversion of ditches and drainages, contours.

This papers also suggest that the sustainability of the introduction of the smart agriculture which is very important and values the farmers opinions taken, their own practices, introduction of the effective policy on smart agriculture, the longevity of such technology, availability and easy management of the simple passage of the technology and replication of the processes across the West African country.

Objectives

To identify the existing, best practices of smart agriculture in the Northern part of Nigeria's and find out whether their practices are effective and the smart Agriculture extension services and the promotional publications whether they are available.

To ascertain the West African country perspective about the climate smart Agriculture and too find out whether the Nigeria populace knows much about the climate smart agriculture and whether they may be ready to accept the technology with the smart information and the synergies involving between the extension agent and the farmers and which promotional methods to being used.

Suggest ways in which the smart agriculture can help to improve the food security and marginalized groups which can also reduce food waste globally.

Material and Methods

The study was conducted in the North of Nigeria and the sampling techniques are cluster, using the Federal Capital Territory of the six areas council in Abuja. Some of the recent Nigeria newspapers of the daily trust of the Golden Harvests were documented, and with some of the write up and picture were taken.

Method of data collection Primary data and the Focus groups were used to validate the discussion and ask whether they have received enough information about the climate smart Agriculture, data collection from the farmers using the structured questionnaires and which was analyzed using descriptive statistics. Interview were also conducted from the few practicing farmers who are knowledgeable about the climate smart Agriculture and some students, agriculturist lecturer and non-practicing farmers to get their various views whether they will accept the technology and practice smart Agriculture.

Results and Discussion

The different quotes and statement were used to evaluate the needs for effective dissemination of climate smart Agriculture and promotional information of smart Agriculture, which is going to solve numerous Agricultural issues which was latter used to justify the urgent needs too past last longing technology that will boost production in Nigeria such information were outline.

Quote:

Mrs Imoyosola Ajao, an Abuja resident, speaking on the high cost of corn and cassava flours.'' ''Now that the blended corn flour is getting out of the reach of the common man, what is the alternative?. Semolina, Wheat flour and yam flour are not within our reach. What then should we eat?,

Chairman of the yam Farmers Association of Nigeria and the chairman, Technical Committee on Nigeria yam export programme. Yam farmers in the country have continued to express concern over many issues, which according to them, severally affect the nations yam economy.

Professor Simon lrtwange and a yam farmer, professor of processing and storage at the university of Agriculture Makurdi stressed that the inadequacy of varieties of yam seedlings to meet the farmers needs across the growing belts of the country.

Emmanuel Michael, a yam farmer whose farms is located in Nassrawa State said the cost of getting yam seedlings was quite high for the smallholder's farmers.

In Nigeria, the Institute for Agricultural Research (IAR) is in the forefront for breeding and releasing drought-tolerant maize. These varieties of maize are tested on-station and on-farm and found to be promising from both research and on farmers' fields. The Report indicates that DTMA technologies are disseminated to farmers in 13 African countries through national agricultural research systems and private seed companies. Although, these CSA technologies are being promoted in Nigeria, their impacts are not noticeable largely due to the comatose condition of the Agricultural Development Projects (ADP) nationwide. Aggressive promotion of CSA and injecting the ADP system with life reviving intervention will certainly popularize the CSA technologies among our farmers in this country.

Kenyan Agricultural Research Institute has already validated the efficacy of the organic fertilizer on crops production.

In Africa, the Drought-tolerant maize for Africa (DTMA) project were released with over 160 drought-tolerant maize varieties between 2007 and 2018 to reduce vulnerability and improve food security.

There are non – promotional materials on smart Agriculture in Nigeria, from the information gathered from the field there are needs to have publication that will help the farmers and the development of a simple innovation smart technology in Nigeria, which will create employment and it is a means of income generation to small-scale farmers, enhancement of soil fertility and a viable alternative to inorganic fertilizers.

In adequate research in the area of climate smarts agriculture was a constraint in adopting of the different smart agriculture and more research should be encourage and there exist a smart policy in Nigeria from 2010 -2016. Each West African country should support climate smart policies and programs Federal Government and state Government, individual, Non-Governmental Organization, donor partners should support climate smart policies and programs. The practices of smart innovation of smart agriculture farming and technologies has a high potential in Nigerian environment and other West African Country , because it is is a means of income generation to small-scale farmers, enhancement of soil fertility and a viable alternative to inorganic fertilizers. .

The various research institute's and the Extension Agent most work together to find a lasting solution to this various issues discuss just as the International Institute for Tropical Agriculture in Nigeria said that there is ongoing research that includes improving protocols for rapid mass propagation, using seed yam, mini sett technology, aeroponics and temporary immersion bioreactors that will advance yam cultivation in the country. With the urgent needs for the promotion of the smart Agriculture and the extension services.

Conclusion

The urgent needs for proactive extension services and the promotional smart Agriculture in West African country was discussed and the various important was made, which will boost the agricultural sectors and farmers are ready to adopt it and too solve the different agricultural problems, but enough platform, policy brief, establishment of a pilots projects in different West African country in that the technologies must be cost effective for the farmers to taken delivering and joint publication material and manual should be distributed within the farmers and it is quite necessary that the West African countries should embrace such technology and from the findings, it shows some African country as started smart agriculture the effective extension services and promotional means for the acceptance of smart technology by the Government, individuals and private sectors were also stressed.




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Daily Newspaper Thursday, May 24, 2018 pg 23

Development of a solar energy powered fixed water recirculation system for aquaculture in arid conditions.

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Abstract

Recirculating aquaculture systems have proven very successful in resolving problems relating to water shortages for fish production and environmental pollution. These systems however consume much energy in the running of pumps and heating of water since temperatures play a critical role in the growth of fish. The main objective of this study was to put in place a stable automatic temperature-controlled recirculating aquaculture system capable of using water and energy in an efficient manner. The objective was to develop a system that can use a fixed volume of water to grow fish to maturity. The system consisted of a 1000l capacity tank, a mechanical filter, a bio rock filter, a de-nitrification tank with water hyacinth, an aeration system, a 12 volt solar pump, a solar water heating system, and computerized Arduino microprocessor automatic controls. Everything was powered by a single 100 Watts solar module connected through a charge controller to a 200AH Battery. One hundred catfish fingerlings were raised in a period of 8 months. Water from the fish tank move by gravity to the mechanical filter before being pumped to the bio rock filter where it continued to the de-nitrification tank. From the de-nitrification tank the automatic control system either sent it back to the fish tank or directed it through the solar water heating system if tank temperatures were below 25 degrees C. In order to assess the performance of the system, physical and chemical water parameters were monitored including TDS, pH, EC, temperature, dissolved oxygen, nitrates, nitrites and ammonia. Results showed that the average daily weight gain of catfish fingerlings was 0.39±0.28 g and that the physical and chemical water quality parameters were at optimum levels for fish growth.It was concluded that such a system can enable farmers to grow fish to maturity in a region with limited water and energy resources.

key words: Recirculating aquaculture system, solar water heating, temperature control, automation

1. Introduction

Fish production in the world is driven by the forces of demand and supply and is the source of food, income, nutrition and livelihood for many people in the world. The united nation member states have set up a sustainable development agenda which is aimed at conducting and contributing aquaculture towards food security (UN,2015).

In Cameroon, as well as in many sub-Saharan countries, fish production does not meet up with the domestic demands, thereby pushing the government to spend considerable resources in the importation of fish (Business in Cameroon, 2014). The aquaculture sector contributes less than 1 % of national production (NIS.2012). Efforts have been made by the government to improve on productivity but production still remains low (MINEPIA, 2012). Many reasons accounted for the low productivity but poor techniques employed play a major role (Pitt and Conover, 1996). The lack of water resources and other environmental problems like underground water pollution and low temperatures seriously affect fish production. Domestic fish production is limited to regions where there is abundant free flowing water and favorable temperatures. The consequences are therefore low productivity, and heavy water and environmental pollution where fish farming if practiced.

Recirculating aquaculture systems (RAS) have been developed to overcome pollution concerns and stocking capacity. RAS offers several advantages over traditional flow-through systems that are mostly practiced in Cameroon. RAS uses 90 % to 99 % less water and land area compared with pond aquaculture systems (Ebeling and Timmons, 2012). The advancement of RAS technology and advantages over the flow through systems has led to its increasing use, especially among countries that place high values on minimizing environmental impacts and in urban areas where space is limiting (Barthelme *et al.*, 2017).

RAS is mostly used in Cameroon for fish hatcheries and not for production. This is because the system is very expensive to install and run. There is little access to electricity in most potential sites in Cameroon. Solar energy use can be a solution for energy requirement for these systems. Earlier attempts have tried to design and construct small scale RAS using solar energy in the Renewable Energy Laboratory of the University of Dschang in Cameroon (Wirsiy, 2017). The system function well but the growth rate of fish was relatively low. Low temperatures were amongst the factors hindering fish growth in the tank.

Fish generally show temperature optima for growth and survival (Brett, 1979; Gadomski and Caddell, 1991). The combined effects of size and temperature on growth have been described for several fish species (Brett, 1979; Fonds et al., 1992). Studies carried out on African catfish, Clarias *gariepinus* have shown that their growth rate increase with increased in temperatures. High growth rates have been recorded between 25 and 33°C and the best growth rate was obtained at 30°C (Britz & Hecht, 1987). The effect of solar-induced temperature on the growth performance of African sharp tooth catfish (*Clarias gariepinus*) has been studied and the investigation revealed that water temperature was significantly different among treatments ($p<0.05$) and the highest value was observed in treatment 3 (30.91±1.60 ℃), followed by treatment 1 (29.19±1.54 ℃) and treatment 2 (27.58±1.58 ℃), respectively (Wirawut, *et al*., 2015).

Results of the experiment further showed that the differences in temperatures affected the growth and survival rate of the fishes. After 90 days of culture, fishes in treatment 1 had significantly higher weight (298.75±4.32 g/fish), growth rate (3.32±0.05 g/day) and survival rate (95.0±2.0) than treatment 2 (198.40±5.25g/fish, 2.20±0.06 g/day and 89.0±2.0) and treatment 3 (198.40±5.25 g/fish, 2.20±0.06 g/day and 87.6±2.1) ($p<0.05$) (Wirawut, *et al*., 2015).

Many methods have also been used to raise water temperatures of fish tank amongst which we have active and passive solar collectors. System temperatures have been successfully controlled with green house installation, Fuller (2007). However, managing other parameters in the greenhouse proved very difficult.

The main objective of this work was to develop a low cost system that would use a fixed amount of water through recirculation system to grow fish to maturity while exploiting solar energy for pumping, heating and re-oxygenation of the water. Such a system would be very useful especially in arid land where water and energy are limiting.

2. Materials and method

This work was carried out in the Renewable Energy Laboratory of the University of Dschang in Cameroon. The experimental unit was made of a well-designed recirculating aquaculture system consisting of 1000 l transparent glass fish tank, a 20l capacity mechanical filter, 50l capacity plastic pump tank, a 240l capacity biological filter with scoria rock as the filter media and a 100 l denitrification tank containing water hyacinth plants.

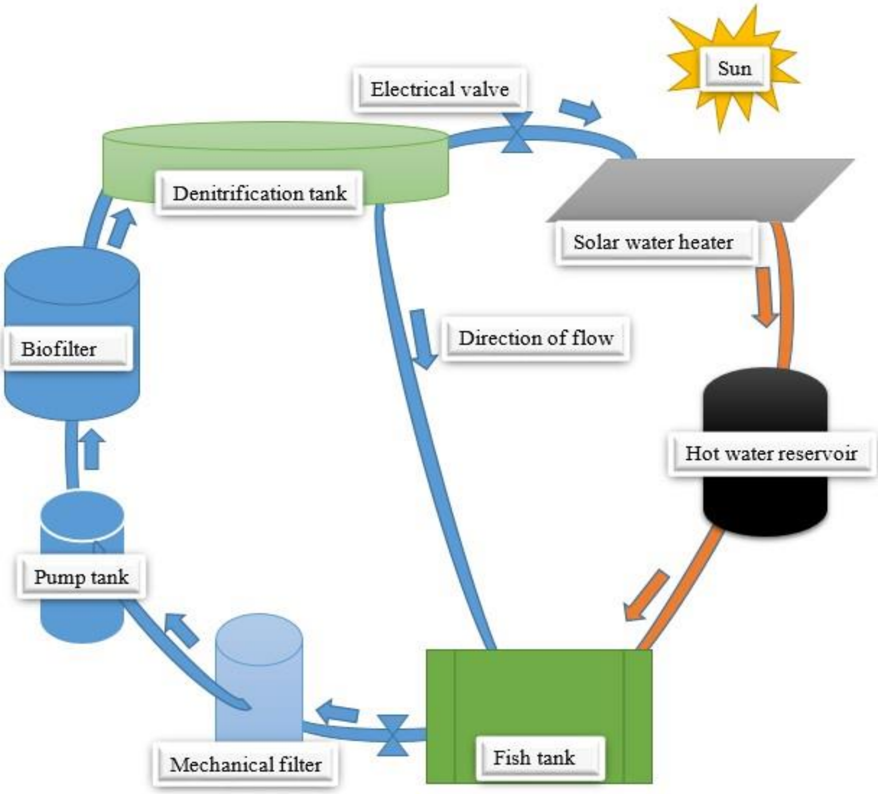
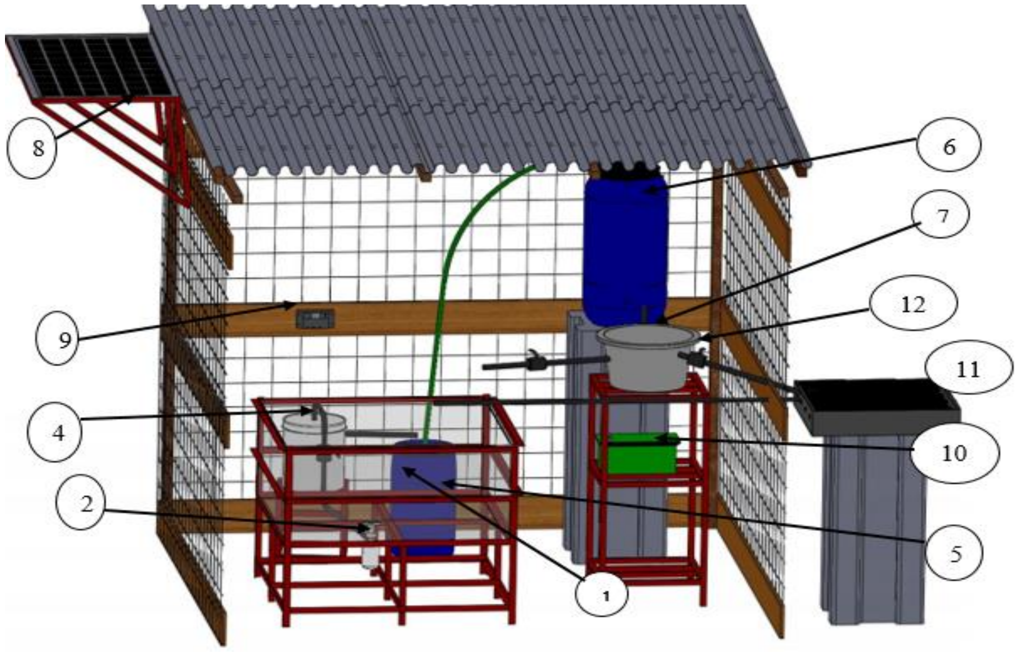


Fig. 1 System layout for the designed acquaponic system

The flow of water through the various components of the system is shown in figure 2.



1) Culture glass tank and stand (2) Solid trap; (3) PVC flexible horse; (4) Mechanical filtration; (5) Pump tank; (6) Biofilter tank; (7) Denitrification tank; (8) Solar panel; (9) Charge controller; (10) Battery bank; (11) Solar heater; (12) Electrical valve

Fig. 2 Placement of different components in the designed acquaponic system

The system lay out was as shown on Figures 1and 2. Energy for running a 12 V DC pump was provided by a 200 W solar panel accumulated in a 150 AH deep cycle battery.

2.1 Solar heater design and construction

A flat plate solar collector was chosen for this system. The method employed in designing solar water heaters for swimming pools as described by Cromer 1994, was adopted in designing this collector. It took into consideration the surface area of tank, volume and initial and final temperatures of the water. Copper tubes of 14 mm diameter were laid in a serpentine manner 10 cm apart inside a 150 cm by 150 cm wooden box and casted with aluminum. The internal surface was painted black and 5mm glass was used at the top of the collector. Water flew into the collector by gravity from the biological filter tank (Fig2). The flow of hot water from the collector to the reservoir was controlled by a temperature sensor and an electrical valve to the hot water reservoir.

2.2 System operation

One hundred catfish fingerlings were raised in a period of 8 months. Water from the fish tank move by gravity to the mechanical filter before being pumped to the bio rock filter. From the bio rock filter the water moved to the de-nitrification tank. From the de-nitrification tank the automatic control system either sent it back to the fish tank or directed it through the solar water heating if tank temperatures were below 25 degrees C. In order to assess the performance of the system, physical and chemical water parameters were measured with TDS, pH, EC, temperature meter, dissolve oxygen meter and ammonia, nitrite, nitrate and dissolve solids were analysed in the laboratory.

2.3 Automation

The system was automated with the help of Arduino UNO microprocessor. The Arduino card with the different input and output pins (Figure 3a) was used. A waterproof digital thermal probe sensors (DTPS) (figure 3b) was used to acquire instantaneous water temperatures. Two of the DTPS were intended to give the average water temperatures in the fish tank and one to give temperature values of the solar water heater (SWH). The temperature values were displayed on a liquid chrystal display screen (LCD). Temperatures values from the various sensors were stored on a smart disc (SD) using a real time clock (RTC) that records data on real time on an excel sheet (Figure 3c). Electrical solenoid valves (EV) were used to control the flow of hot water from the SWH. An electrical float switch (EFS) was used to control the level of the water in the pump tank. A backup water heating coil (WHC) was controlled by a 12-V relay which was commended by the microprocessor.

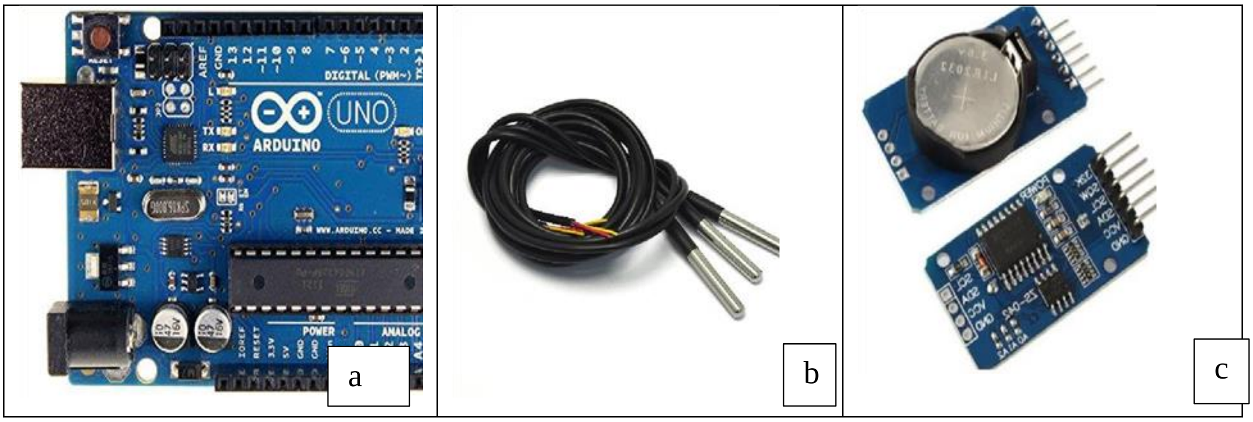


Figure 3: Arduino components for programing (a) Arduino board;(b) digital temperature probe; (c) real time clock

The Arduino programming language was used for coding. Each component was coded and tested separately using a test board. A flow chart for the running of the program was drawn using word paint. The system was setup including the backup electrical water heating element. The program was run for 8months. The program was set to maintain water temperatures in the fish tank between 27 and 30 °C which is the temperature range for optimum catfish growth.

2.4 Flow calculation

The procedure for flow calculations took into consideration, the maximum feeding rate (kg feed/day), maximum biomass and culture volume and the waste production per kg feed. For flow rate calculations and biofilter design, the concepts presented by Liao and Mayo (1972, and 1974) were used. They described the concentration of a metabolite at the outlet of a fish culture tank in a recirculation system as a proportion to the concentration of the same metabolite in a system without recirculation equation (1). The systems of Timmons et al. (2001); Summerfelt *et al*. (2001) using metabolites accumulation factor in estimating the quantity of metabolites at the outlet of the fish tank equation (2) were also used.

$$C = \frac{1}{1 - R + R * TE} \qquad (1)$$

Where:

C = allowable waste concentration in the fish tank effluent (g/m3)/single pass waste concentration (g/m3);

R =factor which is based on the fraction of the water flow that is reused;

TE = the treatment efficiency (decimal fraction);

$$\mathrm{Waste_{out}} = \left(\frac{1}{1-\mathrm{R}*\mathrm{TE}}\right) * \left(\left(\frac{\mathrm{Pwaste}}{\mathrm{Q}}\right) + (1-\mathrm{R}) * (\mathrm{Waste_{new}})\right) \qquad (2)$$

Where = $Waste_{out}$ -TAN concentration in the fish tank effluent;

(3)

Pwaste = waste (metabolite) concentration in the fish tank effluent (g/m3);

$\mathrm{Waste_{new}}$ = concentration of a metabolite in the make-up water (g/m3);

Q = water flow, for TAN the water flow recirculated across the bio filter (m3/day).

Knowing that many RAS are operated at a water recycling percentage of 96% or more (R 0.96), Timmons *et al*. (2002) used Eq. (4), (5) and (6) in arriving at the flow calculation.

$$C_{TAN,out} = \left(\frac{1}{TE}\right) * \left(\frac{P_{TAN}}{Q}\right) \qquad (4)$$

$$C_{Treatment,out} = C_{Treatment,in} + TE\left(C_{Treament,best} - C_{Treatment,in}\right) \qquad (5)$$

$$Q = \frac{P_{TAN}}{TE * C_{TAN,out}} = \frac{P_{TAN}}{C_{TAN,out} - C_{TAN,in}} \qquad (6)$$

Where

$C_{TAN, out}$ = TAN concentration in the fish tank effluent (g/m3)

$C_{TAN, in}$ = filter effluent concentration and fish tank influent concentration

$C_{treatment, best, TAN}$ = 0 (Timmons *et al.*, 2002)

P_{TAN} = production of TAN (g/day)

$C_{TAN, in}$ = TAN concentration of the fish tank influent (g/m3)

2.5 Dimensioning/sizing a biofilter

For dimensioning or sizing a trickling filter, TAN removal efficiency was determined for a fixed set of successful conditions such as fish species, feed load, filter height, filter media type, hydraulic surface load, suspended solids unit and TAN influent concentration. The required total nitrification surface area (A, m2); Eq. (6) was calculated from the trickling filter TAN load (P_{TAN} load, trickling filter, g/day) and the estimated nitrification rate (r_{TAN}, g TAN/m2/day). The bioreactor volume (V trickling filter, m^3; Eq. (7)) was taken as a function of the total filter surface area (A, m^2) and the specific surface area (a in m^2/m^3) biofilter media) of the filter media. The shape of the reactor (Eq. (210)– (2.11) was taken from the hydraulic surface load (HSL, m3/m2/ day) as recommended by (Losordo et al., 2000; Wheaton *et al.*, 1994).

$$A_{Trickling\ filter}(m^2) = \frac{P_{TAN\ load\ \ filter}\left(\frac{g}{day}\right)}{r_{TAN}\ \frac{g}{m^2}/day} \qquad (7)$$

$$\mathrm{V_{trickling\ filter}(m^3)} = \frac{\mathrm{A_{trick\ filter}(m^2)}}{\mathrm{a}\left(\frac{\mathrm{m^2}}{\mathrm{m^3 biological}}\mathrm{filter}\right)} \qquad (8)$$

$$\mathrm{S_{cross-sectional\ area}(m^2)} = \frac{\left(\mathrm{Q_{trickling\ filter}}\left(\frac{\mathrm{m^3}}{\mathrm{day}}\right)\right.}{\left(\mathrm{HSL}\left(\frac{\frac{\mathrm{m^3}}{\mathrm{m^2}}}{\mathrm{day}}\right)\right)} \qquad (9)$$

$$D_{diameters}(m) = 2\sqrt{\frac{S_{crossectional\ area}(m^2)}{3.1416}} \qquad (10)$$

$$H_{height}(m) = \frac{V_{trickling\ filter}(m^3)}{S_{crossectional\ area}(m^2)} \qquad (\ 11)$$

2.6 Empirical relations

The determine the ammonia accumulation factor (C) due to recirculation was done using equation 12

$$C = \frac{(C_{limit,TAN})}{C_{TAN}} \tag{12}$$

Where:

$C_{limit,\ TAN}$ = allowable ammonia concentration (g/m^3);

C_{TAN} = Single pass ammonia concentration (g/m^3);

The filter efficiency (E), was determined using equation 13 efficiency

$$E = \frac{1+CR-C}{CR} \tag{13}$$

Where:

E = filter efficiency (decimal fraction);

C = ammonia accumulation factor;

R = recycle percentage (as decimal).

To estimate the total ammonia load filter (g TAN/day) it was assumed that the total ammonia load was equal to total ammonia production.

2.7 Bio filter tank design

The type of filter chosen for this system was the trickling filter. The assumptions for the design of this filter were:

- Stocking density of 30 kg/m3 (Thomas *et al.*,1999),
- Feeding rate of 5 % daily weight at 32 % crude protein;
- Flow rate of 10.16 m3 through the system;
- Recirculation rate of 90 %
- allowable ammonia of 7 g/day
- Total ammonia load is assumed to be equal to total ammonia production
- Scoria rock is the filtering material

The empirical equations proposed by Liao and Mayo (1974) were again used in calculating the TAN loading rate. Equation 1 was used in calculating the ammonia accumulation factor. The value for the accumulation factor was used in determining the total ammonia load. Equation 13 was used in calculating the filter efficiency. Equation 2.16 was used to calculate the filter retention time at 22 °C. The filter volume and surface area were empirically determined using equation 2.17 and 2.18. Scoria rock of 50 % porosity and specific surface area of 127 m^3/m^2 was also used (Jaff, 2015). Equation 14 was used to calculate the TAN removal rate (Nar).

$$Nar = 0.96Al * tm \tag{14}$$

Where:

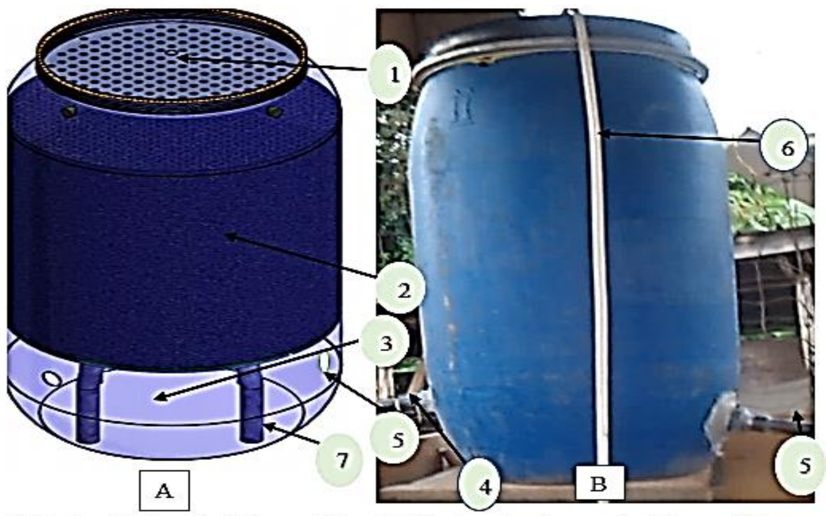
Nar = TAN removal rate (g/m2/day)

Al = total ammonia load (g TAN/day)

tm = filter retention time

Using the above filter empirical equations, the trickling filter surface area and volume were calculated using equation 9 and 10 respectively. The trickling filter cross-sectional area, diameter and height were also calculated using equations 9, 10 and 11.

The height and the diameter of the filter were the parameters taken into consideration in choosing a container for bio filter construction.



(1) Perforated sheet that allows uniform distribution of water over the filter media layer; (2) Filter media (soria rock) layer; (3) Collection area for filtered water; (4) Pipe and perforations for filter aeration; (5) Filtered water outlet into the denitrification tank; (6) Inlet pipe for poluted water; (7) Support stand inside the filter to support the rock

Fig 4 Components of the mechanical filter and the bio rock filter tank.

2.8 Mechanical clarification and denitrification tank design

The design for the mechanical clarification tank is shown in figure 5. It was designed to have an upward movement of water. The determination of the diameter and thickness of the mesh used was done by experimentation that is pouring water containing solid particles on the mesh and evaluating the quantity of solid particles present in the recollected clear water.

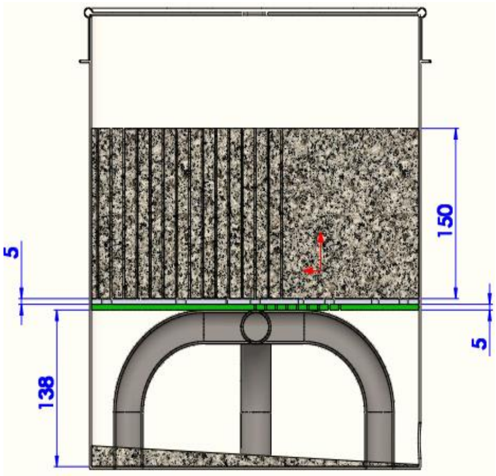


Figure 5: Mechanical filter tank design showing the different layers with adopted dimensions

Water hyacinth plant (*Eichhornia crassipes*) was used as a means of reducing water nitrate concentration. This plant was chosen because of its high nitrate uptake and floating ability in water (Jaff, 2015). The possibility of the plant to carry out photosynthesis was taken into account in choosing a vessel to host it.

2.9 Solar energy system design

❖ Determination of power consumption demand

A pump was chosen based on the hydraulic needs of the system. The energy requirement and the time of functioning of the pump was used in calculating the power consumption demand of the system. All other electrical components that could consume energy were taken into account. A load sizing worksheet was used in determining the power demand of the system (table1).

Table.1: load sizing worksheet for solar energy consumption the aquaponic system

DC appliances	Power (W)	Hours per day (H)	quantity	Energy /day (WH/day)	Energy/week (WH/week)
pump	85	7	1	595	4165
Arduino board	1	24	1	24	168
Total					4333

The total energy needed per week (E/week) for the DC load was calculated using equation 15

$$\frac{E}{week} = \frac{WH}{week} * f \tag{15}$$

Where f is a factor to compensate for losses during battery charging and its value is 1.2. The amp-hour require per week is was calculated using equation 16 and the average amp-hour per day was obtained by dividing equation 16 by 7.

$$\frac{Amphour}{week} = \frac{\frac{WH}{week}}{V} \tag{16}$$

Where:

V = voltage of the battery bank (volts)

❖ Battery bank sizing

The assumptions taken here in sizing the battery were that:

- it should have an autonomy (A) of two days;
- a discharge depth (d) of 50 % and;
- the ambient temperature multiplier (t) of 1.04 at 21 °C.

The required amp-hour of the battery was calculated using equation 17

$$Amphour(bat) = \frac{\frac{amphour}{day} * A * t}{d} \tag{17}$$

Where amp-hour(bat) = total required system amp-hour

The number of the batteries required in parallel were obtained using equation 18 and in series by the quotient of the system nominal voltage (12 V) to the battery voltage. The total number of batteries were obtained by product of the batteries in series and parallel. A solar battery of 200 AH was selected for the calculations

$$\text{Number of batteries in parellel} = \frac{\text{required amphour}}{\text{power rating of battery}} \tag{18}$$

❖ Solar array sizing

The solar irradiation value used for the design is that of the month of August for Dschang and is 3.9 kWH/m2/day (PVGIS, 2012) or approximately 4 h of daily Peak Sun Hours (PSH). The output current (Ic) i.e. the total amperage requirement of the array was calculated using equation 3.9

$$Ic\ (A) = \frac{AH/day}{PSH(Hours)} \tag{19}$$

The selected module for the design was a 200 W with a 3 % power tolerance, a short-circuit current (I_{out}) of 5.77 A and working current of 5.41 A giving the adjusted current (current output for each module) of 5.44 A. The number of module in an array in series is given by equation 3.10 and the number in parallel is given by equation 19. The total number of modules was obtained by the product of the module in series and parallel.

$$Number\ of\ module\ in\ series = \frac{system\ voltage}{norminal\ operating\ voltage} \quad (20)$$

$$Number\ of\ module\ in\ parellel = \frac{PV\ array\ output\ current\ (Ic)}{current\ output\ for\ each\ module} \quad (21)$$

❖ Sizing charge controller

The charge controller was sized to withstand at least 125 % of the short circuit current and withstanding the open circuit voltage of the array. The current value of the charge controller needed was calculated using equation 22

$$\boldsymbol{size\ of\ the\ controler\ (A) = 1.25 * I_{out\ (A)} * number\ of\ modules} \quad (\mathbf{22})$$

2.10 Hydraulic design

The system was designed such that water circulates by pumping and by gravity**.** The vessel communication principle was applied between the fish tank and the mechanical filtration tank. PVC pipes were used for water circulation in the system but for a flexible pipe that was used between the pump tank and the biofilter tank. In order to select the pump, the TDH was calculated using equation 23. Energy saving, system flow rate and pump availability are other aspects taken into account in selecting the pump.

$$TDH = H + \Delta H \quad (23)$$

Where:

H = vertical height from the soil (m)

$\boldsymbol{\Delta}$H = frictional losses (m). The value of $\boldsymbol{\Delta}$H is calculated using equation 24

$$\Delta H = 10.65 \left(\frac{Q^{1.85}}{(K''^{1.85} * D^{4.87})} \right) L \quad (24)$$

Where:

Q = flow rate (m3/s);

D = internal diameter of the pipe (m);

L= total length of the pipe (m);

K'= Hazen-William coefficient (150 for PVC and plastic pipes)

2.11 Fish growth monitor and test

Fish was weighted using an electronic balance. The length of the fish also measured using measuring tape. One hundred fingerlings of 206.4±12 g average weight were cultured in the system. Fish was fed with extruded pelleted floating feed using the recommended daily ration table for North African catfish, *Clarias gariepinus*. Water quality parameters including pH, dissolve oxygen ammonia, nitrite and nitride were also closely monitored using appropriate probe meters and tests. Fish was put in a temperature controlled environment for the same period of three weeks after which it was weighed. The water quality parameters were still closely monitored. The weight gain between the two environments was compared using SPSS software with paired sample T-test.

3. Results and discussion

3.1 Results

The flow diagram showing the automation program is as shown in figure 6 showing the partway of the program.

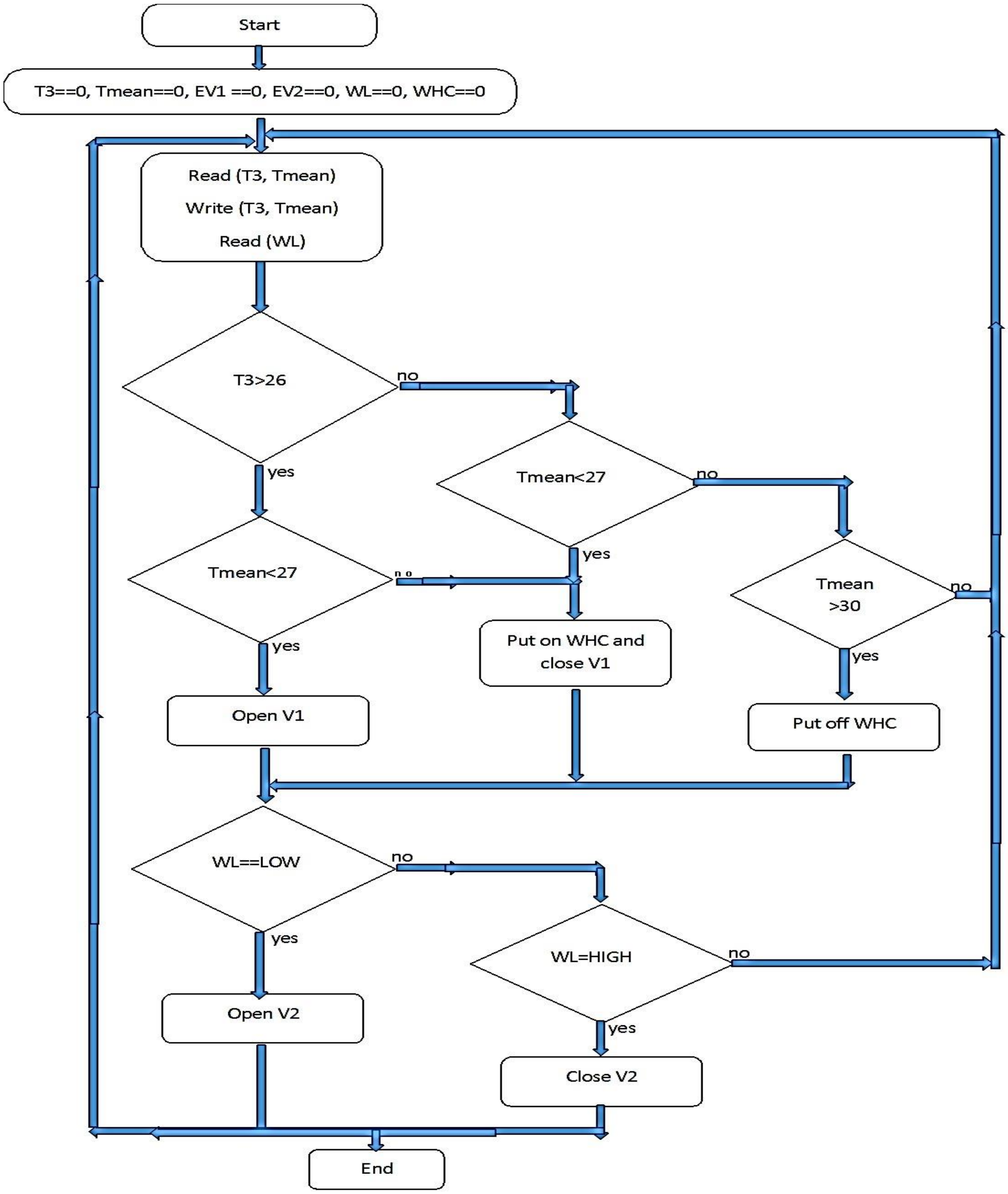


Figure 6: Flow chart design for automation in temperature and water level regulation (Tmean is the average temperatures in the fish tank given by two temperature sensors T1 and T2, T3 temperature of water in the SWH and V1 and V2 are the electrical valves)

The performance of the solar water collector without the backup is as shown in figure 7 during testing. Meanwhile figure 8 shows the variation in temperatures of water in the fish tank for 21 days (recorded at 30 minutes' interval) being automatically controlled by the microprocessor and its components.

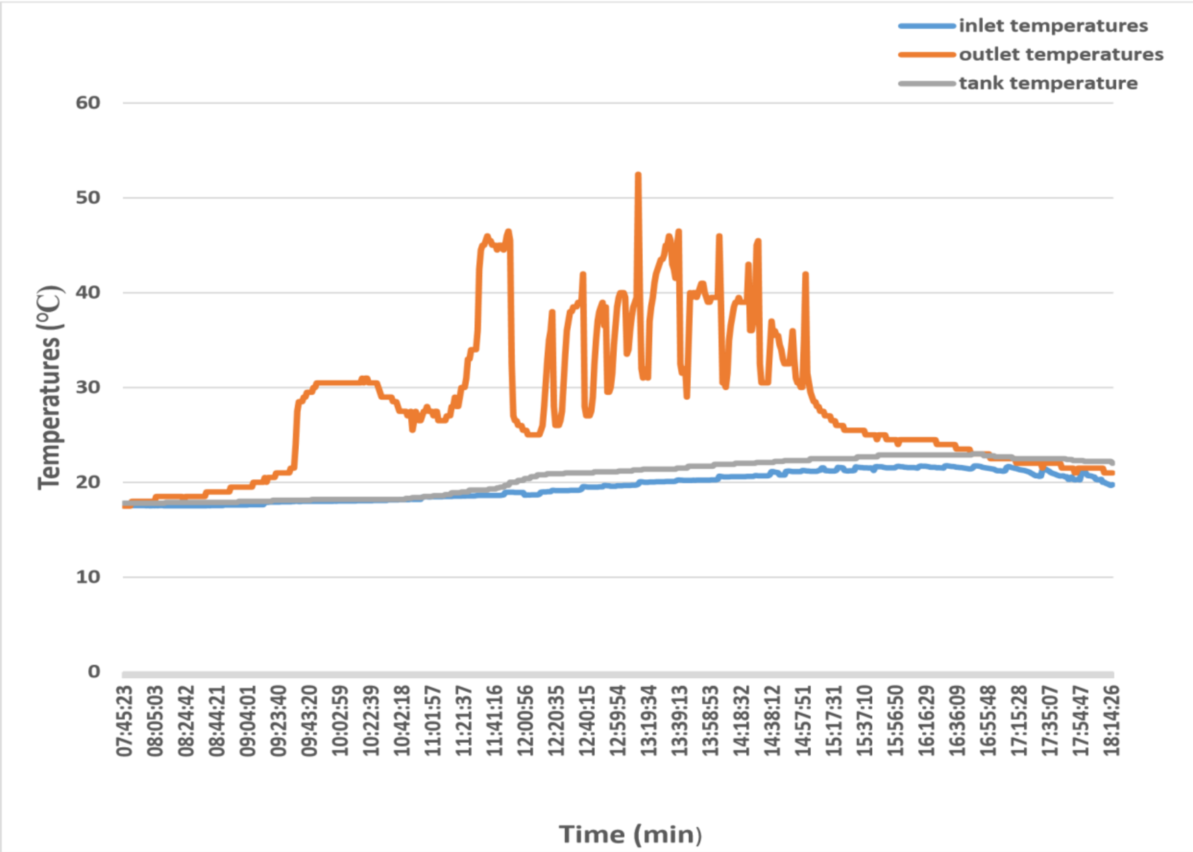


Figure 7: variation of temperature of water from the SWH collector (considering inlet and outlet temperatures) and the overall effect on the total volume of water in the tank at a fixed flow rate of 1.58 l/min an average sunny day

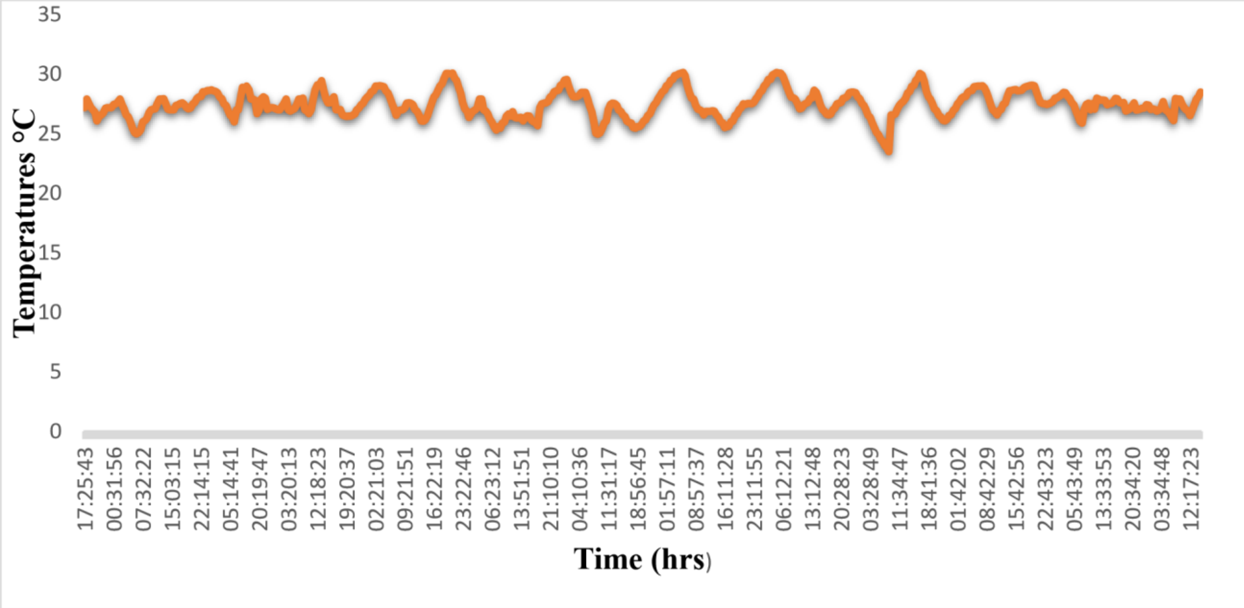


Figure 8 Temperature variation in fish tank being automatically controlled with solar heater and backup heater recorded continuously for 21 days in a data logger

The fish growth performance parameters for both heated and non-heated system is as shown in table 1. While the test statistics for heated and non-heated (paid sample t-test) is as shown in table 2.

Table 3: fish growth performance parameters

Parameters	Control periods		
	Initial	Non heated	Heated
TL (cm)	28.43±4.09	31.45±4.09	33.84±3.09
W (g)	206. 4±12.10	238.40±77.14	330.83±101.53
WG (g)		32.311±17.70	91.62±26.32
DWG (g)		1.54±0.84	4.36±1.23
SWG (g)		1.52±3.10	4.40±1.61
SR (%)		100	100
K		0.77±0.001	0.86±0.003

Table 4: Statistical Comparison between heated and non-heated in the system

	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
	lower	upper			
Heated - Non heated	53.5343362	65.0914703	20.962	30	.000

3.2 Discussion

Water from the bio filter is collected in the denitrification tank. There are two exits from the denitrification tank; one that supplies the fish tank directly and the other the supplies the solar water heater. There is an electrical valve before the SWH that controls the flow of water commanded by the Arduino microcontroller. Hot water from the heater is collected first in the reservoir which in turn supplies the fish tank. The backup electrical heating coil is uses to raise the temperatures further when need arises. The cycle of water continues.

The programming had to perform the following tasks:

- Read and display temperatures in the fish tank (Tmean) and the temperatures of SWH (T3);
- Provide the control of temperatures of water in the fish tank by maintaining it within a particularly range ($27 \leq Tmean \leq 30$);
- Provide the control of the flow of water in and out of the fish tank and finally;
- Store the temperature data in an SD card as means of data acquisition and verification of problems

The performance solar water heater in raising water temperatures is as shown in figure 8. From the maximum and minimum values obtained within the fish tank, it can be noticed that temperatures are increased by 5.2 °C which doubles the increase without heating. This further shows how performant the SWH is in increasing the water temperatures in the fish tank during the day not withstanding that the tank is open and oxygenation is by gravity which increased heat losses. Also from the graph, we can observe that temperatures from the SWH drop to a very low value at evening due do the departure of solar radiations which implies that the heater will be acting as coolant at this time. This is one the reason why an EV was programmed to cut off the flow of water entering the heater at temperatures less than 26 °C.

Automation in the system worked as programed as can be seen on the graph (figure 9) where temperatures averagely vary between 27 and 30 °C for the 21 days. The data here was recorded at 30 minutes' intervals in the SD card. The drop in temperatures to 25 ℃ observed in some days (4 6 hours) was due to over discharging of the battery there by not providing enough energy for the backup heater to take relay.

The growth parameters of weight gain and survival rate was performant as seen in table 3. Table 4 also shows the statistical analyses with SPSS between the heated and non-heated system. It shows from the table that there exist a significance difference between the heated temperature control and non-heated (non-temperature control) periods. This further implies that temperatures were the major hindrance to growth of fish in the system in the previous attempted experiments in the same laboratory as daily weight gain of 0.33 gram was obtained (Wirsiy, 2017). The average weight gain obtained from the heated is greater than that abstained by Anyanwu *et al.* (2012) for their experiment on catfish fingerlings as their values ranged from 2.71 to 2.96 for four experimental tanks with temperatures greater than 25 °C. it is also different from the daily weight gain of 3.32±0.05 g obtained by (Wirawut, *et al*., 2015) in their experiment on catfish in a greenhouse with temperatures at 30. This can be explained because other parameters than temperature need to control if not will reduce growth rate.

The system is thus efficient. With this growth rate obtained, we can say that it will take a very short period of time to grow fish in this system. The system is therefore very stable and easy to manipulate unlike solar heated systems in a green which are very complicated in controlling other parameters (aeration, humidity) inside the house.

3.3 Monitoring and evaluation of water quality parameters

- Temperature, pH, dissolve oxygen, TDS, and electrical conductivity

The mean values for the physical and some chemical properties of water in the tank during the experimental period are presented in table 4.6

Table 5 Mean physical and chemical water parameters during experimentation

parameters	**Temp (°C)**	**DO (mg/l)**	**pH**	**SS (mg/l)**	**TDS (ppm)**	**EC (mS/cm)**
range	20.15-22.95	4.51-6.10	6.6-7.3		28-60	2-5
mean	21.75±0.033	5.37±0.55	6.78±0.18	23.3±2.82	40.4±9.04	3.55±0.88

During the first week of the experiments, the temperature of biofilter effluent varied between 21.7°c and 22.4 °c. The pH also varied between 6.5 and 7.5. light which inhibits the growth of microorganisms was reduced by covering the roof of building. These conditions are suitable for the development of microorganisms in the biofilter milieu since the water from the fish tank contains dissolve nutrients for the microorganism.

Water temperature in the fish tank varied as shown in table 5. The average temperature of 21.75 obtained during the experimental period lower than that obtained by Olusegun and Faturoti (2007) in one of their experimental tanks containing catfish fingerlings as temperature ranged from 23 °C to 25 °C. The average value obtained is however low for an optimum growth of catfish as it requires temperatures between 25 and 27 °c (Eding *et al*, 2005). It was observed that, fish in the tank was relatively inactive at temperatures less than 21 °C. Feed thrown in the tank at these low temperatures was not eaten as much uneaten feed was found in the solid trap and the washout pipe of the mechanical filter.

The pH varied between 6.6 and 7.3 which is within the limit for an optimum growth as recommended values for the growth of African catfish lies between 6 and 9 (Losordo *et al.* (1999). The pH values obtained favoured the ionised ammonia in solution which is not toxic for the fish. These values were due to the self-cleaning nature of the fish tank as most of the uneaten feed and fish waste flew out through the base drain.

Observation of fish behaviour and also on the rate and quantity of bubbles in the fish tank was used as a good indicator for dissolve oxygen in the tank as fish seldom moved to surface of water for gasping, implying that, there was enough dissolve oxygen within the system to cover up for their needs. This is conformed with the measured values of the dissolved oxygen in the fish tank which ranged from 4.5 to 6.1 mg/l within the fish tank. The values obtained are high and lie within the recommended values for catfish production as the minimum recommended value is 4 mg/l (FAO, 2006). These values were far greater than those obtained by Jaff (2015) as dissolve oxygen in her 1 m3 tank ranged from 0.5 to 1.8 mg/l. The reason for these high values is the waterfall like nature of the systems that all allows water to fall to bottom of the tanks thereby liberating more oxygen into water and sending out other gases such as carbon dioxide and nitrogen.

TDS varied between 28 and 60 ppm in the fish tank and electrical conductivity from 2 to 5 mS/cm. These values show the level of mineralisation of the water in the tank.

The average amount of suspended particles was 23.3 mg/l in the fish tank. The value of SS in the tank was within recommended range for fish production as recommended values should be less than 25 mg/l (Eding *et al*, 2005). The low values are due to the high performance of the mechanical clarification tank as 100 mg/l of SS was obtained in the inflow water after stirring the fish tank water and 20 mg/l obtained in the outflow water.

- Nitrogenous compounds in water

The variation of the nitrogenous compounds in the fish tank within the first four weeks of the experiments is as shown in figure 9.

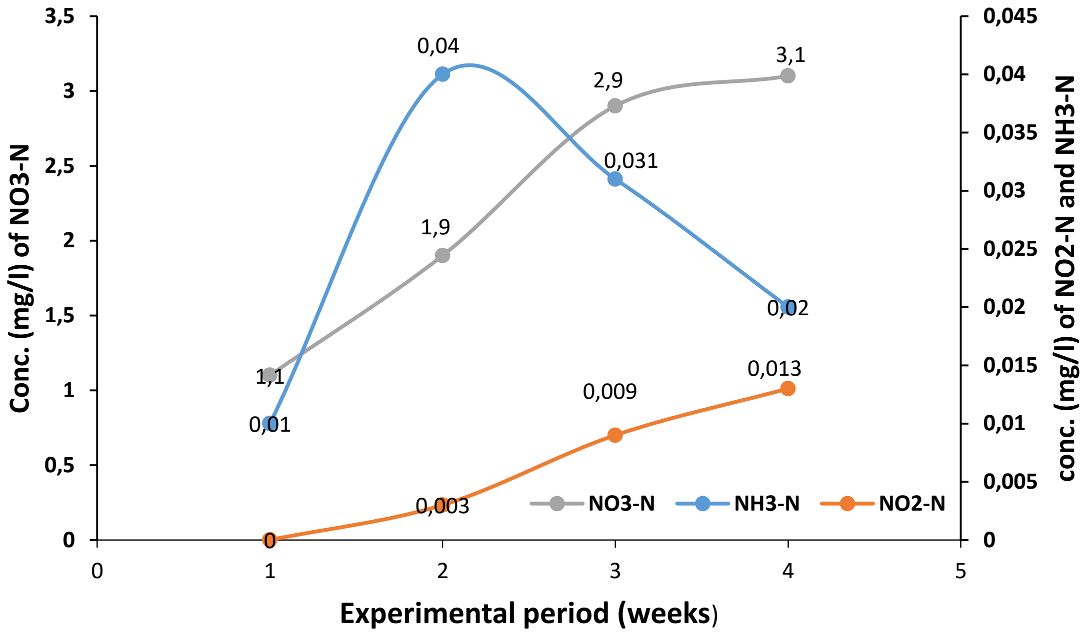


Figure 9. Evolution of nitrogenous compounds in the fish tank during the experimental period

As shown in fig 9, the nitrogenous compound measured within the first four weeks were within the recommended rage. Unionized Ammonia concentration rose to 0.04 mg/l closer to the toxicity limit of 0.05 mg/l ((Eding *et al*, 2005) in the second week but gradually dropped within the third and the fourth week. The high value was due low growth of microorganisms in the biofilter tank. The low values obtained in the third and fourth week was due to the proliferation of these microorganisms in the biofilter tank. The lower values of ammonia in the third and fourth week were also due to the lower pH values which favoured the ionized form of ammonia in the water.

Nitrite levels concentrations were within the recommended values of 0.1 mg/l. the lower values obtained within the first two weeks with high ammonia concentration was due mainly by the absent of azotobacterial to convert the ammonia to nitrate. Unlike in the system of Jaff (2015) where nitrite toxicity was reached within the third week, there was no nitrate toxicity even in the fourth week.

Nitrate values were the highest in the system but far lower than the maximum recommended values of 100 mg/l. the values were similar to those obtained by Jaff (2015) in her one-meter cube tank. The healthy fish in the tank during harvesting can be seen in fig 10.

Fig 10 Display of cat fish during harvesting after 8 months with some weighing up to 1 kg

4. Conclusion

A solar energy powered acquaponic system was successfully deigned, constructed and tested with 100 fingerlings. The automated system was successfully designed and the circuit built using Arduino microprocessor and other sensors. Solar thermal and electrical energy were both exploited in this system to run the system and for heating of water. Solar water heater contributed a daily increase of more than 5.2 ℃ there by raising the temperature in the fish tank during the day The automation is very efficient as it regulates the temperatures within the instructed values and water level thereby making the environment favorable for fish growth. There exists a significant difference between the heated and non-heated periods of growth in fish leading to the conclusion that temperatures were the actual growth retarding factor in the system. The three stage filtration made of a mechanical filter, a bio rock filter and a denitrification tank successfully cleaned the water permitting recirculation and avoiding the disposal of waste water to the environment. The system enable the use of a fixed volume of water to grow fish to maturity.

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