

“*Faidherbia-Flux*”: A long-term Collaborative Observatory on food security, GHG fluxes, ecosystem services, mitigation and adaptation in a semi-arid agro-silvo-pastoral ecosystem (groundnut basin in Niakhar/Sob, Senegal)

Dry season, 2/3 of the year



Wet season, 1/3 of the year

“*Faidherbia-Flux*” Web site :
<https://lped.info/wikiObsSN/?Faidherbia-Flux>

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Aims

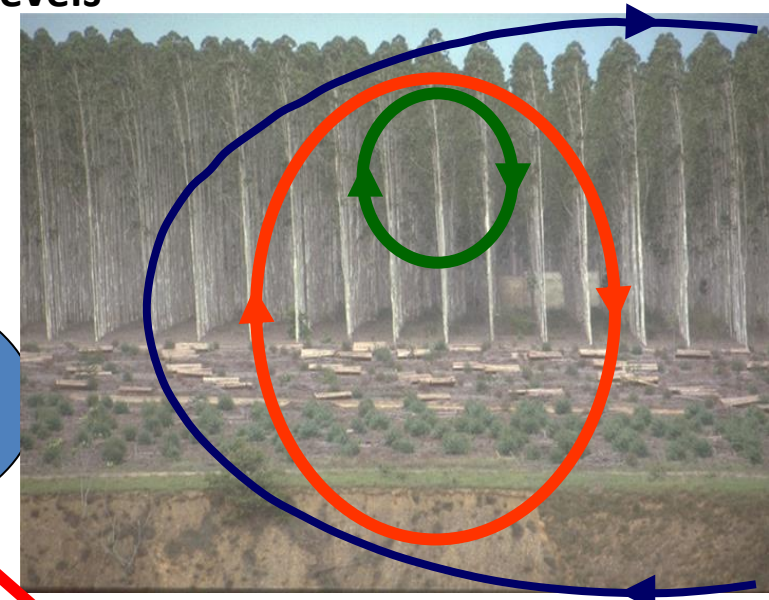
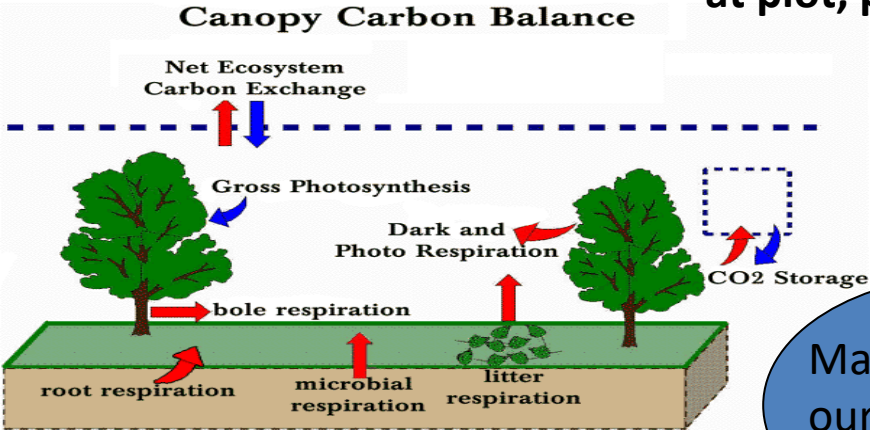
- To foster agro-silvo-pastoralism and sustainable intensification research, through a **Collaborative** & highly instrumented **Observatory**
- To run the Observatory on the **long term** (> 10 years), through projects
- To assess ecosystem services, NPP, GHG (CO₂, H₂O, N₂O, CH₄) fluxes and balances, 4‰, crop yield (millet, groundnut, cowpea...), the role of livestock, the effects of management options ...

Our Philosophy

- We offer to mutualize efforts in one complex but representative ecosystem;
- Any scientist, student, institution, NGO... can apply;
- Complementarity and facilitation will be fostered, overlaps will be minimized;
- Outcomes include high-level trans-disciplinary research, common projects, training, networking, international visibility...



Our approaches: Monitoring + Modeling of fluxes, balances and ecosystem services at plot, plant and soil levels



Main research at our study sites

Carbon cycle

- Carbon sequestration
- Main fluxes (GPP, respiration, ANPP, NEP, C allocation)
- Dynamic of C stocks (soils, biomass)

Water cycle

Evapotranspiration, stomatal regulation, dynamic of soil water content, water-use efficiency, watershed hydrology, root hydraulic redistributions, water isotopes

Nutrient cycles

Nutrient inputs and outputs, nutrients fluxes between ecosystem compartments, evolution of soil fertility, etc.

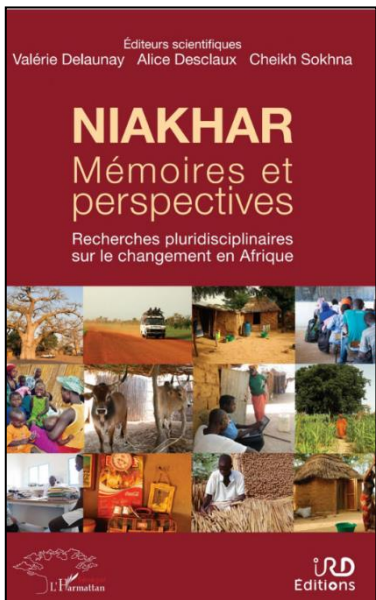
Faidherbia albida, a perfect candidate for ecological intensification?

- Widespread in semi-arid Africa
- Multi-purpose
- Domesticated and maintained by the people in parklands
- Reverse Phenology: minimum competition, forage for animals during the dry season
- N₂ Fixing
- Microclimate and fertility islets effects
- Phreatophytic (hydraulic redistributions?)
- Survived the 1970-2000 severe drought in the Sahel
- Positive effects on most crops
- Compliant with other options: livestock, mixed cropping, precision agriculture etc.



Where?

- In the Niakhar Health-Population-Environment Observatory (**OPSE-Niakhar** > 50 yrs of past research), <https://lped.info/wikiObsSN/>



“Faidherbia
-Flux”
is here

[Delaunay et al., 2018](#)

Lat. N: $14^{\circ}29'44.916''$
Long. W: $16^{\circ}27'12.851''$

Faidherbia-Flux

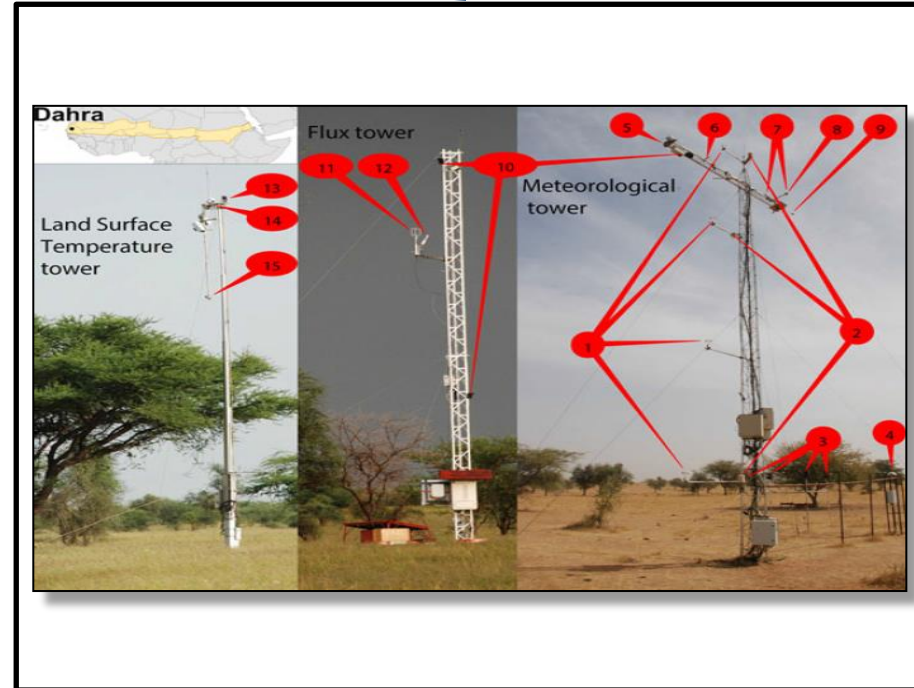
(agro-silvo-pastoral / Sudanian savanna ecoclimatic zone (Olson et al., 2001))

Complementarity of 2 Flux tower observatories



Dahra

(silvo-pastoral):
/ Sahel ecoclimatic zone (Olson et al., 2001)



Opportunities for multi-site comparisons & regional studies

<https://doi.org/10.5194/gmd-2020-417>
Preprint. Discussion started: 5 February 2021
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Geoscientific
Model Development
Discussions

Open Access
EGU

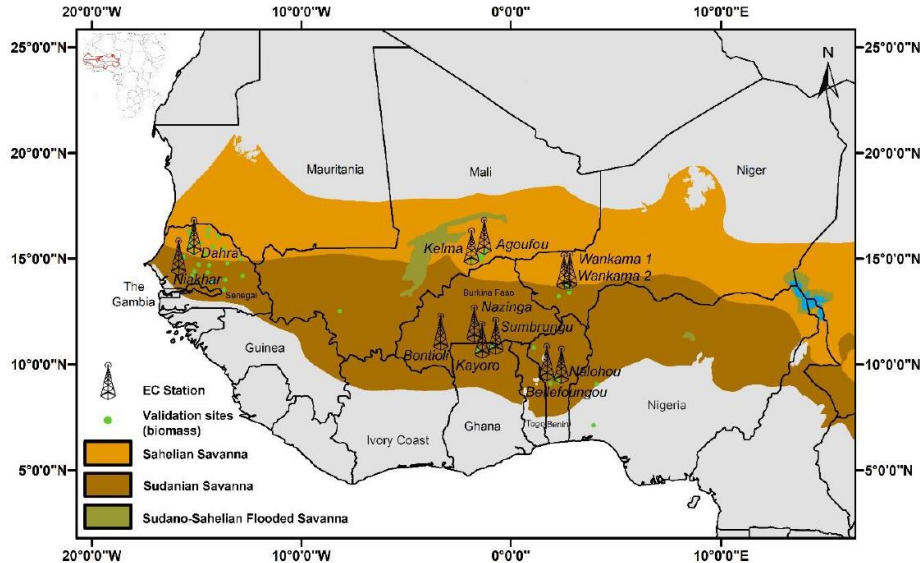


Figure 1: Map of West Africa showing the Sudanian and Sahelian ecological zones that were derived after Olson et al. (2001). Locations of measurements are indicated as towers (eddy covariance flux stations) or green dots (biomass production).

Modelling Gas Exchange and Biomass Production in West African Sahelian and Sudanian Ecological Zones

Jaber Rahimi¹, Expedit Evariste Ago^{2,3}, Augustine Ayantunde⁴, Sina Berger^{1,5}, Jan Bogaert³, Klaus Butterbach-Bahl^{1,6}, Bernard Cappelaere⁷, Jérôme Demarty⁷, Abdoul Aziz Diouf⁸, Ulrike Falk⁹, Edwin Haas¹, Pierre Hiemaux¹⁰, David Kraus¹, Olivier Rouspard^{11,12,13}, Clemens Scheer¹, Amit Kumar Srivastava¹⁴, Torbern Tagesson^{15,16}, Rüdiger Grote¹

<https://gmd.copernicus.org/preprints/gmd-2020-417/>

23 peer-reviewed articles since 2018 (project start)

1. Agbohessou, Y., Delon, C., Mougin, E., Grippa, M., Tagesson, T., Diedhiou, M., Ba, S., Ngom, D., Vezy, R., Ndiaye, O., Assouma, M. H., Diawara, M., & Rouspard, O. (2023). To what extent are greenhouse-gas emissions offset by trees in a Sahelian silvopastoral system? *Agricultural and Forest Meteorology*, 343, 109780. <https://doi.org/https://doi.org/10.1016/j.agrformet.2023.109780>
2. Agbohessou, Y., Delon, C., Grippa, M., Mougin, E., Ngom, D., Gaglo, E. K., Ndiaye, O., Salgado, P., and Rouspard, O.: Modelling CO₂ and N₂O emissions from soils in silvopastoral systems of the West-African Sahelian band, EGUSphere [preprint], <https://doi.org/10.5194/egusphere-2023-2452>, 2023
3. Clermont-Dauphin, C., Ndienor, M., Leroux, L., Ba, H.S., Bongers, F., Jourdan, C., Rouspard, O., Do, F., Cournac, C., Seghieri, J., 2023. *Faidherbia albida* trees form a natural buffer against millet water stress in agroforestry parklands in a Sub-sahelian environment. **Biotechnologie, Agronomie, Société et Environnement (BASE)** ; special issue “Agroforestry in West Africa”. Accepted September 2023, Colloque Agroforesterie en Afrique de l’Ouest 27 (3), 1–14. <https://doi.org/DOI: 10.25518/1780-4507.20477>
4. Diack, I., Diene, S.M., Leroux, L., Heuclin, B., Letourmy, P., Audebert, A., Rouspard, O., Diouf, A.A., Sarr, I., Diallo, M., 2023. Combining UAV and Sentinel-2 imagery for estimating millet FCover in an heterogeneous agricultural landscape of Senegal. **IEEE Transactions on Geoscience & Remote Sensing**. Accepted February 2024.
5. Diene, S.M., Diack, I., Audebert, A., Rouspard, O., Leroux, L., Diouf, A.A., Mbaye, M., Diallo, M., Sarr, I., 2023. Using Normalized Difference Texture Index allows to improve pearl millet yield estimation by UAV MS imagery in semi-arid agroforestry system of Senegal. **IEEE Access**. Submitted September 2023.
6. Diongue DML, Rouspard O, Do F, Stumpp C, Orange D, Sow S, Jourdan C, Faye S. 2022. Evaluation of parameterisation approaches for estimating soil hydraulic parameters with HYDRUS-1D in the Groundnut basin of Senegal. **Hydrological Sciences Journal**. [10.1080/02626667.2022.2142474](https://doi.org/10.1080/02626667.2022.2142474)
7. Diongue DML, Stumpp C, Rouspard O, Orange D, Do FC, Faye S. 2023. Estimating water fluxes in the critical zone using water stable isotope approaches in the Groundnut and Ferlo basins of Senegal. **Hydrological Processes**, 37: e14787. <https://doi.org/10.1002/hyp.14787>
8. Diongue DML, Brunetti G, Stumpp C, Do F, Rouspard O, Orange D, Faye W, Sow S, Jourdan C, Faye S. 2023. A probabilistic framework for assessing the hydrological impact of *Faidherbia albida* in an arid Area of Senegal. **Journal of Hydrology**. [622. 10.1016/j.jhydrol.2023.129717](https://doi.org/10.1016/j.jhydrol.2023.129717)
9. Duthoit, M., Rouspard, O., Créquy, N., Sauze, J., Van den Meersche, K., 2020. Conception d’un dispositif automatisé de chambres de mesures d’échanges gazeux du sol à fermeture horizontale. **Le Cahier des techniques de l’INRA** (2020, 102). https://www6.inrae.fr/cahier_des_techiniques/Les-Cahiers-parus/Les-N-reguliers/2020/Cahier-N-102/Art4-ct102-2020, 19 pp.
10. Faye, W., Fall, A.N., Orange, D., Do, F., Rouspard, O., Kane, A., 2020. Climatic variability in the Sine-Saloum basin and its impacts on water resources: case of the Sob and Diohine watersheds in the region of Niakhar. **Proc. IAHS** 383, 391-399. <https://piabs.copernicus.org/articles/383/391/2020/>
11. Gbodjo, J.E., Ienco, D., Leroux, L., 2021. Benchmarking statistical modelling approaches with multi-source remote sensing data for millet yield monitoring: A case study of the Groundnut basin in central Senegal. **Int. J. Remote Sens.** 42, 9277–9300. [doi:10.1080/10431161.2021.1993465](https://doi.org/10.1080/10431161.2021.1993465)
12. Gning F, Jourdan C, Marone D, Ngom D, Ræbild A. 2023. Root distribution of *Adansonia digitata*, *Faidherbia albida* and *Borassus akeassii* along a climate gradient in Senegal. **Agroforestry Systems**. 1-11; 1572-9680
13. Guzinski, R., Nieto, H., Ramo Sánchez, R., Sánchez, J. M., Jomaa, I., Zitouna-Chebbi, R., Rouspard, O., & López-Urrea, R. (2023). Improving field-scale crop actual evapotranspiration monitoring with Sentinel-3, Sentinel-2, and Landsat data fusion. *International Journal of Applied Earth Observation and Geoinformation*, 125, 103587. <https://doi.org/https://doi.org/10.1016/j.jag.2023.103587>
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15. Lembrechts et al., 2022. Global maps of soil temperature. **Global Change Biology**. Online. <https://doi.org/10.1111/gcb.16060>
16. Leroux, L., Falconnier, G.N., Diouf, A.A., Ndao, B., Gbodjo, J.E., Tall, L., Balde, A.A., Clermont-Dauphin, C., Bégué, A., Affholder, F., Rouspard, O., 2020. Using remote sensing to assess the effect of trees on millet yield in complex parklands of Central Senegal. **Agricultural Systems** 184, 102918. <https://doi.org/10.1016/j.agsv.2020.102918>
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18. Rahimi, J., Ago, E.E., Ayantunde, A., Berger, S., Bogaert, J., Butterbach-Bahl, K., Cappelaere, B., Demarty, J., Diouf, A.A., Falk, U., Haas, E., Hiernaux, P., Kraus, D., Rouspard, O., Scheer, C., Srivastava, A.K., Tagesson, T., Grote, R., 2021. Modelling Gas Exchange and Biomass Production in West African Sahelian and Sudanian Ecological Zones. **Geosci. Model Dev.** <https://gmd.copernicus.org/preprints/gmd-2020-417/>, 2021, 1-39.
19. Rouspard, O., Audebert, A., Ndour, A.P., Clermont-Dauphin, C., Agbohessou, Y., Sanou, J., Koala, J., Faye, E., Sambakhe, D., Jourdan, C., le Maire, G., Tall, L., Sanogo, D., Seghieri, J., Cournac, L., Leroux, L., 2020. How far does the tree affect the crop in agroforestry? New spatial analysis methods in a *Faidherbia* parkland. **Agriculture, Ecosystems & Environment** 296, 106928. <https://www.sciencedirect.com/science/article/pii/S0167880920301134>
20. Sarr, M. S., Diouf, K., Rouspard, O., Rocheteau, A., Orange F., D., Jourdan J., C., Diedhiou, I., Seghieri, J., & Do, F. (2023). Estimation of seasonal water use of *Faidherbia albida* (Del.) A. Chev. in a Sahelian agroforestry parkland. **Biotechnologie, Agronomie, Société et Environnement (BASE)**, 27(3), 196–204. <https://popups.uliege.be/1780-4507/index.php?id=20512>
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22. Siegwart L, Bertrand I, Rouspard O, Jourdan C. 2023. Contribution of tree and crop roots to soil carbon stocks in a Sub-Sahelian agroforestry parkland. **Agriculture, Ecosystems & Environment** . Accepted April 2023
23. Sow S, Senghor Y, Sadio K, Tounkara A, Vezy R, Rouspard O, Affholder F, Ndienor M, Clermont-Dauphin C, Gaglo E, Ba S, Tounkara A, balde AA, Agbohessou Y, Seghieri J, Sall SN, Couedel A, Leroux L, Jourdan C, Sanogo D, Falconnier G. 2024. Calibrating the STICS soil-crop model to explore the impact of agroforestry parklands on millet growth. **Field Crop Research**. Accepted November 2023.

Communications

- Agbohessou YFU, Roupsard O, Clermont-Dauphin C, et al. 2019. Using drones to upscale yield and land-equivalent-ratio from plot to stand in an agro-silvo-pastoral system: the “Faidherbia-Flux” collaborative observatory (groundnut basin, Senegal). Conférence Intensification Durable (CID) 2019: Leviers d’intensification pour une transition agroécologique des systèmes de production en Afrique Subsaharienne. 08-09 Octobre 2019. Hotel Ngor Diarama, Dakar, Sénégal. Oral Presentation. <https://sites.google.com/site/cidintensificationdurable/home/cid-2019>.
- Ba S, Roupsard O, Diongue D, Agbohessou Y, Serça D, Sambou B, Guerin F, Tagesson T, Lardy L. 2021. Monitoring GHG balance in an agro-silvo-pastoral ecosystem dominated by Faidherbia albida: comparing the soil and ecosystem scales (groundnut basin in Niakhar/Sob, Senegal). Conférence Intensification Durable (CID) 2021. Dakar, 23-26 nov. 2021: Senegal.
- Dangleant, C. et al., 2019. L’agroforesterie à la rescousse des cultures au Sahel. Video. In: World Congress of Agroforestry (Editor). CIRAD, France, <https://www.cirad.fr/actualites/toutes-les-actualites/articles/2019/science/video-agroforesterie-au-sahel>.
- Diongue DML, Sow S, Faye W, Stumpp C, Roupsard O, Orange D, Jourdan C, Faye S, Do F. 2021. Estimation of soil hydraulic parameters from a transient water flow field experiment in an agroforestry system of Central Senegal. Conférence Intensification Durable (CID) 2021. Dakar, 23-26 nov. 2021: Senegal.
- Faye, W. et al., 2018. Climatic variability in the Sine-Saloum basin and its impacts on water resources: case of the Sob and Diohine watersheds in the region of Niakhar. ID 3917. China, 8th Global FRIEND-Water Conference. Hydrological Processes and Water Security in a Changing World. November 6-9, 2018.
- Faye, W., Fall, A.N., Orange, D., Do, F., Jourdan, C., Roupsard, O., Kane, A., 2020. Caractérisation des relations eau de surface eau souterraine dans un agrosystème à fortes contraintes climatiques du centre ouest du bassin arachidier : cas des bassins versants de Sob et de Diohine dans l’OPSE de Niakhar (Senegal). Cotonou, Benin, 20-24 November 2020, 4TH INTERNATIONAL CONFERENCE HYDROLOGY OF AFRICAN LARGE RIVER BASINS FRIEND/UNESCO/ INTERNATIONAL HYDROLOGICAL PROGRAMME.
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- Gubert, N., Dupraz, C., Peltier, R. and Roupsard, O., 2019. Faidherbia albida, arbre refuge de l’agriculture sahélienne. Dépêche AFP & Article Science et Avenir. <https://t.co/CKVIWpGESi>; https://www.sciencesetavenir.fr/nature-environnement/faidherbia-albida-arbre-refuge-de-l-agriculture-sahelienne_133856; https://www.sciencesetavenir.fr/nature-environnement/faidherbia-albida-arbre-refuge-de-l-agriculture-sahelienne_133856. France, pp. 2.
- Roupsard, O. et al., 2019. “Faidherbia-Flux”: adapting crops to climate changes in a semi-arid agro-silvo-pastoral open observatory (Senegal). Oral Presentation, 4rth World Congress on Agroforestry. , 20-22 of May 2019. Le Corum Conference Centre, Montpellier, France. Oral presentation. Session 2: Agroforestry and adaptation to climate change.
- Roupsard, O. et al., 2019. “Faidherbia-Flux”, an open observatory for GHG balance and C stocks in a semi-arid agro-silvo-pastoral system (Senegal). Poster, 4rth World Congress on Agroforestry. . France, 20-22 of May 2019. Le Corum Conference Centre, Montpellier, France. Poster. Session 1: Mitigating Climate change with agroforestry.
- Roupsard, O., Do, F., Rocheteau, A., Diouf, K., Sarr, M.S., Faye, W., Diongue, D.M.L., Orange, D., Faye, S., Timouk, F., Kergoat, L., Grippa, M., Jourdan, C., Bouvery, F., Tall, L., Gaglo, E., Sow, S., Agbohessou, Y., Diatta, S., Sanogo, D., le Maire, G., Vezy, V., Seghier, J., Chapuis-Lardy, L., Cournac, L., 2020. More C uptake during the dry season? The case of a semi-arid agro-silvo-pastoral ecosystem dominated by Faidherbia albida, a tree with reverse phenology (Senegal). Oral presentation Monday 4rth of May 11h45. Session BG3.30: Tropical landscapes and peatlands: Biogeochemistry, ecohydrology and land use impacts. <https://meetingorganizer.copernicus.org/EGU2020/EGU2020-11203.html>. Austria, EGU, Vienna, 3-8 May 2020, Session BG3.30 / Land use and climate effects on carbon, greenhouse gas and water dynamics in Africa / EGU2020-11203 /
- Sarr MS, Diouf K, Diedhiou I, Roupsard O, Jourdan C, Do F. 2021. Water uptake by Faidherbia albida A. Chev. in an agroforestry parkland in Senegal. Conférence Intensification Durable (CID) 2021. Dakar, 23-26 nov. 2021: Senegal.

Shared databases

[Faidherbia-Flux Collaboratif\Database](https://baobab.sedoo.fr/)

<https://baobab.sedoo.fr/>

Academic reports

PhD

- Faye W. 2021. Ecohydrologie du bassin arachidier (cas de Niakhar): dynamique de l'infiltration et modélisation des aquifères superficiels dans un espace sylvopastoral semi-aride. PhD, UCAD : Faculté des Lettres et Sciences Humaines, Géographie. Dakar, Sénégal. Thèse défendue le 10 décembre 2021

MSc, Engineer

- Agbohessou, Y.F.U., 2020. Effets du *Faidherbia albida* (Del.) A. Chev. sur la productivité aérienne et souterraine de la culture associée (arachide) : Utilisation des drones pour l'estimation du rendement et du Land-Equivalent-Ratio (LER), depuis les placettes à tout le système agro-sylvo-pastoral à la parcelle entière. Senegal, 31rd of October 2020. Master en Agroforesterie, Ecologie et Adaptation (AFECA), UCAD-Faculté des Sciences et Techniques, Département de Biologie Végétale, Dakar, Senegal. Félicitations du jury, p. 60 pp + Annexes.
- Diatta, S., 2021. Estimation du stock et du stockage annuel de carbone dans la biomasse aérienne de *Faidherbia albida* (Del.) A chev du parc agroforestier de Sob (Observatoire de Niakhar, Sénégal) : approches par inventaires et dendrochronologie. Senegal, Master en Foresterie et Environnement pour une gestion durable des ressources naturelles. Université de Thiès-ENSA, Thiès, Senegal., soutenu le 06 janvier 2021. 45pp + Annexes. Mention Bien.
- Diouf, K., 2020. Evaluation de la transpiration par mesure du flux de sève chez l'espèce agroforestière *Faidherbia albida* (Del.) A. Chev. dans un site semi-aride du bassin arachidier au Sénégal. Senegal, Diplôme d'ingénieur agronome de l'Université de Thiès-ENSA, option Productions Végétales. ENSA, Thiès, Senegal. 13 juillet 2020, p. 55.

Projects, Networks...

- « **Big** » projects: RAMSES II (EU-LeapAgri, ANR, AFD), CASSECS (EU-DESIRA), SustainSahel (EU-H2020), DSCATT (Agropolis+Total Fond.), PEPR FaircarboN (ANR),
- **Other projects**: GLDC (CGIAR), ENCAS (EC2CO); SOCA (Fondation BNP-Paribas); OpenOPSE (FSPI); ELISA (CIRAD-CRESI),
- **Networks**: FLUXNET (*), AMMA-CATCH (**), SEACRIFOG, ECOSTRESS (NASA)...

(*) 'SN-Nkr' site at <http://www.europe-fluxdata.eu/pi-area/sites-info>

(**) Met DOI : http://dx.doi.org/10.17178/AMMA-CATCH.PA.Met_SNNs; Flux DOI Jeu flux:

http://dx.doi.org/10.17178/AMMA-CATCH.PA.H2OFlux_SNNs

PhD Students (13)

- **ISRA/UCAD/CNRF/SUPAGRO:** W. Faye (hydrology); E. Gaglo (ORCHIDEE landscape modelling); F. Gning (tree roots and water content); S. Sow (Tree+crop modelling with MAESPA + STICS); D.L. Diongue (HYDRUS water and isotopes modelling); O. Malou (SOC = f(pratiques culturales)); K. Sadio (SOM, manure and GES); Y. Agbohessou (STEP, STICS MAESPA GHG Modeling); Diedhiou Moussa (Tree allometry); S. Ba (soil GHG and C stocks); L. Siegwart (soil C dynamics); M. Diene (Drone, from subplot to plot); I. Diack (Satellite, from plot to landscape), S. Talla (Hydraulic redistributions)

MSc & Fellowships

- G. Demarchi; S. Diatta; K. Diouf; Y. Agbohessou; N. Crequy; M. Faye; P. O. Bousso; Dabo; R. Beye; A. Lesimple; M. Bourchanin; E.H.M. Ndour; K. Diop;

Partner institutions, per country

- **Sénégal:** ISRA (LNRPV, CNRF, CRZ), UCAD (EDEQUE), UGB, U. Thiès, ENSA Thiès: Prof. S. Faye; Prof. D. Ngom; Prof. S.N. Sall; Prof. A. Kane; Prof. A.N. Fall; Prof. I. Diedhiou,,D. Sanogo; M. Sokhna Sarr; M. Ndienor; O. Ndiaye; C.O. Samb; O. Ndiaye; L. Tall; Y. Ndour; Tcheheumeni Axel
- **Burkina Faso:** INERA: J. Koala, J. Sanou; B. Bastide
- **France:** CIRAD , IRD, INRA, CNRS, CNRM, IPGP : O. Roupsard; C. Jourdan; F. Do; A. Rocheteau; D. Orange; L. Cournac; M. Duthoit; F. Bouvéry; Valade Aude; I. Bertrand; A. Audebert; J. Seghieri, L. Leroux; L. Chapuis-Lardy; C. Clermont-Dauphin; F. Timouk; L. Kergoat; Delon Claire; Serça Dominique; C. Pierre; J.L. Rajot; G. le Maire; R. Vezy; S. Taugourdeau; P. Salgado; H. Assouma; E. Faye; K. Van den Meersche; D. Masse; P. Moulin; H. Aroui; A. Albrecht; V. Delaunay; R. Lalou; L. Fleury; Montes Nicolas; Grippa; K. Assigbetse; R. Manlay; C. Coillot; K. Telali; V. Lesur; N. Leroy; M. Vallee; S. Lewicky-Dhainaut; L. Vidal; I. Henry; J-L. Chotte; J.P. Laclau
- **Scandinavia:** U. Copenhagen + U. Lund: R. Fensholt; J Ardö; T. Tagesson; A. Raebuild

Thank you !!!



“Faidherbia-Flux” Web site :
<https://lped.info/wikiObsSN/?Faidherbia-Flux>