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Uniformly Valid First Approximation Shell Theory of Hybrid Anisotropic Materials

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Abstract
The theories in this article implies unique physical characteristics and formulated the governing equations. A uniformly valid shell theory which includes all the terms present in each of the asymptotic shell theories. The first approximation theories derived in this article represent the simplest possible shell theories for the corresponding length scales considered. Although twenty-one elastic coefficients are present in the original formulation of the problem, only six are appear in the first approximation theories.

Keywords: Shell Theory, Hybrid Anistropic Materials

CONSTITUTIVE EQUATIONS

The elasticity equations in terms of the dimensionless coordinate y are given by:

Stress-Displacement Relations

$$u_{r,y} = \lambda a[S_{11}\sigma_z + S_{12}\sigma_\theta + S_{13}\sigma_r + S_{14}\tau_{r\theta} + S_{15}\tau_{rz} + S_{16}\tau_{\theta z}]$$

$$u_{z,y} + \lambda a u_{r,z} = \lambda a\,[S_{51}\sigma_z + S_{52}\sigma_\theta + S_{53}\sigma_r + S_{54}\tau_{r\theta} + S_{55}\tau_{rz} + S_{56}\tau_{\theta z}]$$

$$\lambda u_{r,\theta} + (1+\lambda y)u_{\theta,y} - \lambda u_\theta = \lambda a(1+\lambda y)[S_{41}\sigma_z + S_{42}\sigma_\theta + S_{43}\sigma_r + S_{44}\tau_{r\theta} + S_{45}\tau_{rz} + S_{46}\tau_{\theta z}]$$

Equation (1)

Equilibrium Equations

$$[(1+\lambda y)\tau_{r\theta}]_{,y} + \lambda\sigma_{\theta,\theta} + \lambda a\tau_{\theta z,z} + \lambda\tau_{r\theta} = 0$$

$$[(1+\lambda y)\tau_{rz}]_{,y} + \lambda\tau_{\theta z,\theta} + \lambda a[(1+\lambda y)\sigma_z]_{,z} = 0$$

$$[(1+\lambda y)\sigma_r]_{,y} + \lambda\tau_{r\theta,\theta} + \lambda a\tau_{rz,z} - \lambda\sigma_\theta = 0$$

Equation (2)

The uniformly valid first approximation are determined by keeping only those terms found necessary in the various previous first approximation theories.

$$u_{r,y} = 0$$

$$u_{z,y} + \lambda a u_{r,z} = 0$$

$$\lambda u_{r,\theta} + (1+\lambda y)u_{\theta,y} - \lambda u_\theta = 0$$

$$u_{z,z} = S_{11}\sigma_z + S_{12}\sigma_\theta + S_{16}\tau_{\theta z}$$

$$(1/a)(u_{\theta,\theta} + u_r) = S_{21}\sigma_z + S_{22}\sigma_\theta + S_{26}\tau_{\theta z}$$

$$(1+\lambda y)u_{\theta,z} + (1/a)u_{z,\theta} = S_{61}\sigma_z + S_{62}\sigma_\theta + S_{66}\tau_{\theta z}$$

Equation (3)

Integration with respect to y can now be carried out in the same fashion as was done in the previous chapters. Integration of the first three equations yields the displacements.

$$u_r = U_r(z,\theta)$$

$$u_\theta = (1+\lambda y)U_\theta(z,\theta) - \lambda U_{r,\theta}y$$

$$u_z = U_z(z,\theta) - a\lambda U_{r,z}y$$

Equation (4)

Where **Ur** , **U$_\theta$** , **Uz** are the **y=0** surface displacement components. Note here that the radial displacement is independent of the thickness coordinate while the circumferential and longitudinal displacements are of linear dependence. Therefor the theory incorporates the hypothesis of the preservation of the normal. Substitution of results into the next three equations yields the in-plane stress-strain relations:

$$\begin{Bmatrix} \sigma_z \\ \sigma_\theta \\ \tau_{\theta z} \end{Bmatrix} = [\,C\,] \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_{12} \end{Bmatrix} + [C] \begin{Bmatrix} K_1 \\ K_2 \\ K_{12} \end{Bmatrix} \lambda a y$$

Equation (5)

where [C] is the symmetric matrix given by

$$[\,C\,] = \begin{bmatrix} S_{11} & S_{12} & S_{16} \\ S_{12} & S_{22} & S_{26} \\ S_{16} & S_{26} & S_{66} \end{bmatrix}^{-1}$$

Equation (6)

The **ε'ₛ** are defined by

$$\varepsilon_1 = U_{z,z}$$

$$\varepsilon_2 = (1/a)(U_r + U_{\theta,\theta})$$

$$\varepsilon_{12} = U_{\theta,z} + (1/a)U_{z,\theta}$$

Equation (7)

K's. are the changes of curvature by

$$K_1 = -U_{r,zz}$$

$$K_2 = -(1/a^2)(U_{r,\theta\theta} - U_{\theta,\theta})$$

$$K_{12} = -(2/a)(U_{r,\theta z} - U_{\theta,z})$$

Equation (8)

The equations (5) and (8) play the role of correction to the y=0 strains for points away from the inner surface of the shell. The strains of the inner surface are given by (7).

This theory which contains all the terms existing in the previous theories are the equilibrium equations

$$[(1+\lambda y)\tau_{r\theta}]_{,y} + \lambda\sigma_{\theta,\theta} + a\lambda\tau_{\theta z,z} + \lambda\tau_{r\theta} = 0$$

$$\tau_{rz,y} + \lambda\tau_{\theta z,\theta} + a\lambda\sigma_{z,z} = 0$$

$$[(1+\lambda y)\sigma_r]_{,y} + \lambda\tau_{r\theta,\theta} + a\lambda\tau_{rz,z} - \lambda\sigma_\theta = 0$$

Equation (9)

Substitution of equation (5) into the equilibrium equations and carrying out the integration with respect to y:

$$
\begin{aligned}
\tau_{rz} = T_{rz} &- \lambda[(A_{13}\varepsilon_{1,\theta} + A_{23}\varepsilon_{2,\theta} + A_{33}\varepsilon_{12,\theta}) \\
&+ a\lambda(B_{13}K_{1,\theta} + B_{23}K_{2,\theta} + B_{33}K_{12,\theta})] \\
&- a\lambda[(A_{11}\varepsilon_{1,z} + A_{12}\varepsilon_{2,z} + A_{13}\varepsilon_{12,z}) \\
&+ a\lambda(B_{11}K_{1,z} + B_{12}K_{2,z} + B_{13}K_{12,z})] \\
\tau_{r\theta} = T_{r\theta} &- \lambda[(A_{12}\varepsilon_{1,\theta} + A_{22}\varepsilon_{2,\theta} + A_{23}\varepsilon_{12,\theta}) \\
&+ a\lambda(B_{12}K_{1,\theta} + B_{22}K_{2,\theta} + B_{23}K_{12,\theta}) \\
&+ a\lambda^2(F_{22}K_{1,\theta} + F_{23}K_{12,\theta})] \\
&- a\lambda[(A_{13}\varepsilon_{1,z} + A_{23}\varepsilon_{2,z} + A_{33}\varepsilon_{12,z}) \\
&+ a\lambda[(B_{13}K_{1,z} + B_{23}K_{2,z} + B_{33}K_{12,z})] \\
\sigma_r = T_r &+ [(A_{12}\varepsilon_1 + A_{22}\varepsilon_2 + A_{23}\varepsilon_{12}) + a\lambda(B_{12}K_1 + B_{22}K_2 + B_{13}K_3)] \\
&- a\lambda[T_{rz,z}y - a\lambda^2(E_{13}K_{1,\theta z} + E_{23}K_{2,\theta z} + E_{33}K_{12,\theta z}) \\
&- a^2\lambda^2(E_{11}K_{1,zz} + E_{12}K_{2,zz} + E_{12,zz})] \\
&- \lambda[T_{r\theta,\theta}y - a\lambda^2(E_{12}K_{1,\theta\theta} + E_{22}K_{2,\theta\theta} + E_{23}K_{12,\theta\theta}) \\
&- a^2\lambda^2(E_{13}K_{1,\theta z} + E_{23}K_{2,\theta z} + E_{33}K_{12,\theta z})]
\end{aligned}
$$

Equation (10)

The conditions at the inner and outer surface of the shell yields

$$T_{rz} = T_{r\theta} = T_r = 0$$

Equation (11)

The in-plane stresses given by (5) into the original constitutive equations, we obtain the following expressions for the stress resultants:

$$
\begin{aligned}
&\underline{A}_{11}aU_{z,zz} + 2\underline{A}_{13}U_{z,\theta z} + \underline{A}_{33}(1/a)U_{z,\theta\theta} + \underline{A}_{13}aU_{\theta,zz} + (\underline{A}_{12} + \underline{A}_{33})U_{\theta,\theta z} + \underline{A}_{23}(1/a)U_{\theta,\theta\theta} \\
&+ \underline{A}_{12}U_{r,z} + \underline{A}_{23}(1/a)U_{r,\theta} - a\lambda[\underline{B}_{11}aU_{r,zzz} + 3\underline{B}_{13}U_{r,zz\theta} + (1/a)(\underline{B}_{12} + 2\underline{B}_{33})U_{r,z\theta\theta} \\
&+ \underline{B}_{23}(1/a^2)U_{r,\theta\theta\theta} + \underline{B}_{23}(1/a^2)U_{r,\theta} + (1/a)(\underline{B}_{12} + 2\underline{B}_{33})U_{r,z} \\
&- 2\underline{B}_{13}U_{\theta,zz}] = 0
\end{aligned}
$$

$$\underline{A}_{13} aU_{z,zz} + (\underline{A}_{12} + \underline{A}_{33})U_{z,\theta z} + \underline{A}_{23}(1/a)U_{z,\theta\theta} + \underline{A}_{22}(1/a)U_{\theta,\theta\theta} + \underline{A}_{33} aU_{\theta,zz} +$$

$$2\underline{A}_{23}U_{\theta,\theta z} + \underline{A}_{23}U_{r,z} + \underline{A}_{22}(1/a)U_{r,\theta} \quad -$$

$$a\lambda[\underline{B}_{13} aU_{r,zzz} + (\underline{B}_{12} + 2\underline{B}_{33})U_{r,\theta zz} + 3\underline{B}_{23}(1/a)U_{r,\theta\theta z} + \underline{B}_{22}(1/a^2)U_{r,\theta\theta\theta} +$$

$$2\underline{B}_{23}(1/a)U_{r,z} + \underline{B}_{22}(1/a^2)U_{r,\theta}] - a\lambda^2\Big[(2\underline{F}_{23}(1/a)U_{r,\theta\theta z} + \underline{F}_{22}(1/a^2)U_{r,\theta\theta\theta} -$$

$$- 2\underline{F}_{23}(1/a)U_{\theta,\theta z} - \underline{F}_{22}(1/a^2)U_{\theta,\theta\theta})\Big] = 0$$

$$\underline{A}_{12}U_{z,z} + \underline{A}_{22}(U_{r} + U_{\theta,\theta})/a + \underline{A}_{23}(U_{\theta,z} + U_{z,\theta}/a)$$

$$-a\lambda[\underline{B}_{12}U_{r,zz} + \underline{B}_{22}(U_{r,\theta\theta} + U_{r})/(a^2) + 2\underline{B}_{13}(U_{r,\theta z} - U_{\theta,z})/a]$$

$$+a\lambda[a\underline{D}_{11}U_{z,zzz} + 3\underline{D}_{13}U_{z,zz\theta} + (1/a)(\underline{D}_{12} + 2\underline{D}_{33})U_{z,\theta\theta z} + (1/a\ )\underline{D}_{23}U_{z,\theta\theta\theta} +$$

$$+a\underline{D}_{13}U_{\theta,zzz} + (\underline{D}_{12} + 2\underline{D}_{33})U_{\theta,zz\theta} + (3/a)\underline{D}_{23}U_{\theta,\theta\theta z} + (1/a^2)\underline{D}_{22}U_{\theta,\theta\theta\theta} +$$

$$+\underline{D}_{12}U_{r,zz} + 2\underline{D}_{23}(1/a)U_{r,\theta z} + (\underline{D}_{22}/a^2)U_{r,\theta\theta}]$$

$$-a^2\lambda^2[\underline{E}_{13}U_{r,\theta zzz} + (\underline{E}_{23}/a^2)U_{r,\theta\theta\theta z} + 2(\underline{E}_{33}/a)U_{r,\theta\theta zz}]$$

$$-a^3\lambda^2[\underline{E}_{11}U_{r,zzzz} + (\underline{E}_{12}/a^2)U_{r,\theta\theta zz} + \underline{E}_{13}(2/a)U_{r,\theta zzz}]$$

$$-a\lambda^2[\underline{E}_{12}U_{r,\theta\theta zz} + (\underline{E}_{22}/a^2)(U_{r,\theta\theta\theta\theta} + U_{r,\theta\theta}) + 2(\underline{E}_{23}/a)U_{r,\theta\theta\theta z}]$$

$$-a^2\lambda^2[\underline{E}_{13}U_{r,zzz\theta} + (\underline{E}_{23}/a^2)U_{r,\theta\theta\theta z} + 2(\underline{E}_{33}/a)U_{r,\theta\theta zz}] = p$$

Equation (12)

It is convenient for the readers to compute in terms of the stress resultants as follows.

$$\begin{Bmatrix} N_z \\ N_\theta \\ N_{z\theta} \\ N_{\theta z} \\ M_z \\ M_\theta \\ M_{z\theta} \\ M_{\theta z} \end{Bmatrix} = \left[\begin{array}{c|c} \overline{A} & \overline{B} \\ \hline \overline{B} & \overline{D} \end{array}\right] \begin{Bmatrix} \varepsilon_{1d} \\ \varepsilon_{2d} \\ \varepsilon_{12d} \\ K_1 \\ K_2 \\ K_{12} \end{Bmatrix}$$

Equation (13)

Where

$$\varepsilon_{1d} = \varepsilon_1 + dK_1$$

$$\varepsilon_{2d} = \varepsilon_2 + dK_2$$

$$\varepsilon_{12d} = \varepsilon_{12} + dK_{12}$$

And

$$[\,\bar{A}\,] = \begin{bmatrix} [\lambda a/(1+d/a)][\underline{A}_{11}, \underline{A}_{12}, \underline{A}_{13}] \\ (\lambda a)\ [\underline{A}_{21}, \underline{A}_{22}, \underline{A}_{23}] \\ [\lambda a/(1+d/a)][\underline{A}_{31}, \underline{A}_{32}, \underline{A}_{33}] \\ (\lambda a)\ [\underline{A}_{31}, \underline{A}_{32}, \underline{A}_{33}] \end{bmatrix}$$

$$[\,\bar{B}\,] = \begin{bmatrix} [\lambda a/(1+d/a)][(\lambda a\underline{B}_{11}-d\underline{A}_{11}), (\lambda a\underline{B}_{12}-d\underline{A}_{12}), (\lambda a\underline{B}_{13}-d\underline{A}_{13})] \\ (\lambda a)\ [\ (\lambda a\underline{B}_{21}-d\underline{A}_{21}), (\lambda a\underline{B}_{22}-d\underline{A}_{22}), (\lambda a\underline{B}_{23}-d\underline{A}_{23})] \\ [\lambda a/(1+d/a)][(\lambda a\underline{B}_{31}-d\underline{A}_{31}), (\lambda a\underline{B}_{32}-d\underline{A}_{32}), (\lambda a\underline{B}_{33}-d\underline{A}_{33})] \\ (\lambda a)\ [\ (\lambda a\underline{B}_{31}-d\underline{A}_{31}), (\lambda a\underline{B}_{32}-d\underline{A}_{32}), (\lambda a\underline{B}_{33}-d\underline{A}_{33})] \end{bmatrix}$$

$$[D] = \begin{bmatrix} [\lambda^2 a^2/(1+d/a)][(\lambda a\underline{F}_{11}-2d\underline{B}_{11}+\frac{d^2}{\lambda a}\underline{A}_{11}),\ (\lambda a\underline{F}_{12}-2d\underline{B}_{12}+\frac{d^2}{\lambda a}\underline{A}_{12}), \\ \qquad (\lambda a\underline{F}_{13}-2d\underline{B}_{13}+\frac{d^2}{\lambda a}\underline{A}_{13}) \\ (\lambda^2 a^2)\ [(\lambda a\underline{F}_{21}-2d\underline{B}_{21}+\frac{d^2}{\lambda a}\underline{A}_{21}),\ (\ldots),\ (\ldots) \\ [\lambda^2 a^2/(1+d/a)][(\lambda a\underline{F}_{31}-2d\underline{B}_{31}+\frac{d^2}{\lambda a}\underline{A}_{31}),\ (\ldots),\ (\ldots) \\ (\lambda^2 a^2)[\ (\lambda a\underline{F}_{31}-2d\underline{B}_{31}+\frac{d^2}{\lambda a}\underline{A}_{31}),\ (\ldots),\ (\ldots) \end{bmatrix}$$

Equation (14)

Equations (4), (5) and (10 – 14) indicate the equations of the uniformly valid first approximation theory.

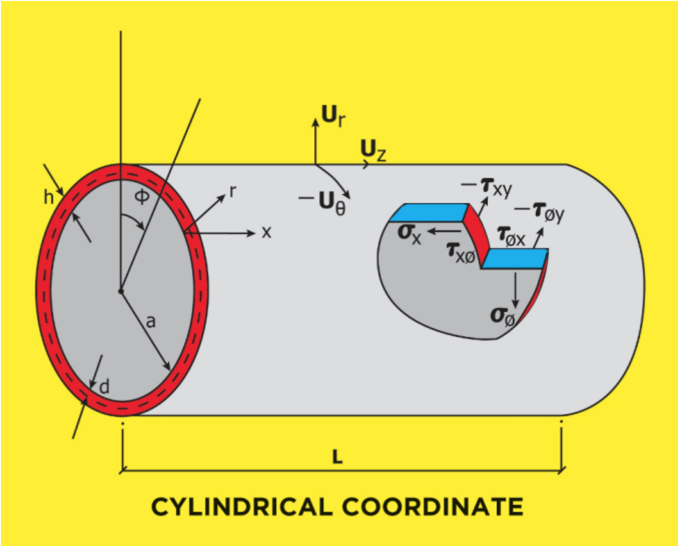

Figure 1: A Cylindrical Shell Showing Dimensions, Deformations, and Stresses

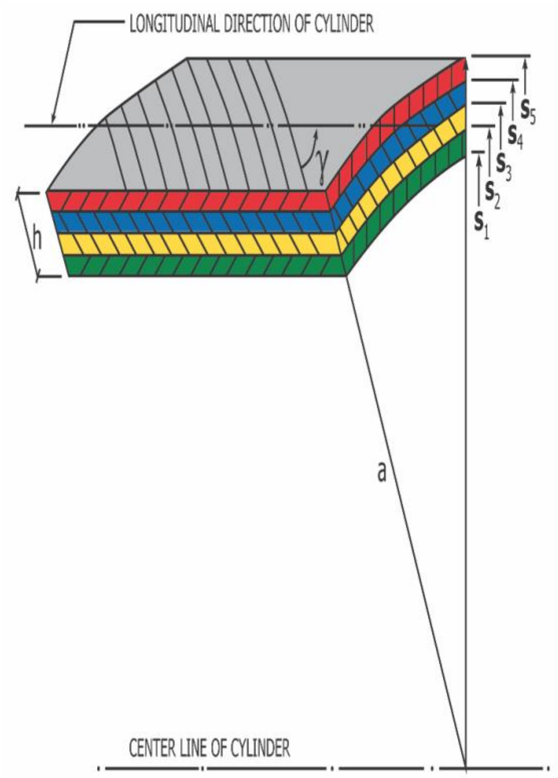

Figure 2: Laminated Cylinder and Angle of Orientation

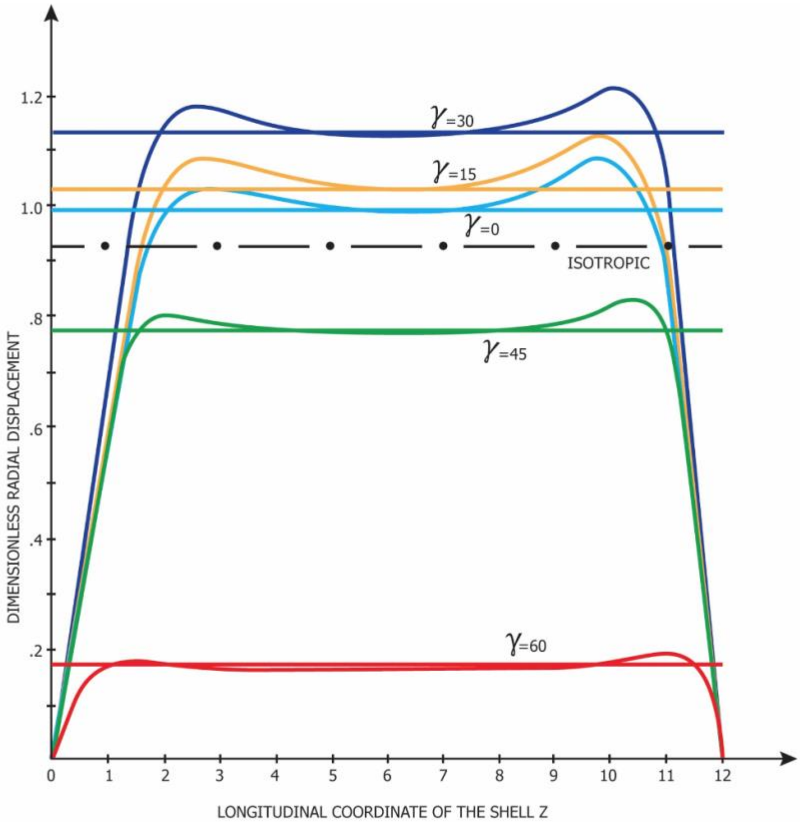

Figure 3: Radial Displacement of the Theory Associated with Longitudinal Length Scale $(ah)^{1/2}$ and Circumferential Lengths

CONCLUSION

The first approximation theories derived in this article represent the simplest possible shell theories for the corresponding length scales considered. Although twenty-one elastic coefficients are present in the original formulation of the problem, only six are appear in the first approximation theories. The fact that these expressions can be determined is extremely useful when discussing the possible failure of composite shells. It was seen that various shell theories are obtained by using different combinations of the length scales introduced in the non-dimensionalization of the coordinates and that each theory possess unique properties such as the orders of magnitudes of the stress and displacement components and edge effect penetration.

The two theories based on the axial length scale $(ah)^{1/2}$ show that a significant edge effect exists and that the penetration of the edge effect changes with the angle in similar fashion as for the radial displacement, being deepest at 30 degree. In this thesis the different theories were applied separately to the solution of a layered shell problem. The solution of a general non-homogeneous anisotropic shell problem can be obtained by a superposition of the theories derived here.

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Application of Uniformly Valid Shell Theory

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Abstract
For the purpose of demonstrating the applicability of the previously derived theories, the problem of a laminated circular cylindrical shell under internal pressure and edge loadings will be examined. The cylinder is assumed to consist of boron/epoxy composite layers. Each layer is taken to be homogeneous but anisotropic with an arbitrary orientation of the elastic axes. We need not consider the restriction of the symmetry of the layering due to the non-homogeneity considered in the original development of the theory expressed by the constitutive equations. Thus, each layer can possess a different thickness.

Keywords: Shell Theory, circular cylindrical shell, applicability

INTRODUCTION

We assume here that the contact between layers is such that the strains are continuous functions of the thickness coordinate. As the C's are piecewise continuous functions, the in-plane stresses are also. We would expect them to be discontinuous at the juncture of layers of dissimilar materials. The transverse stresses are continuous functions of the thickness coordinate. Although as mentioned above the theory developed can consider, random layering, numerical results are to be carried out for a four layer symmetric angle ply configuration (see Appendix C for asymmetric cross-ply layering). For this configuration the angle of elastic axes y is oriented at $+\gamma$, $-\gamma$, $-\gamma$, $+\gamma$, with the shell axis and the layers are of equal thickness. The coefficients Aij Bij Dij Eij and Fij for this configuration can be determined by making use of the results for layered shells developed in Appendix B. Let the cylinder be subjected to an internal pressure p, an axial force per unit circumferential length N and a torque T. The axial force is taken to be applied at r=a+H such that a moment N(H-d) is produced about the reference surface r=a+d. We introduce dimensionless external force and moments as follows:

$$\bar{N} = N/(\sigma\lambda a)$$

$$\bar{M} = [N(H-d)]/(\sigma\lambda^2 a)$$

$$\bar{T} = T/[2\pi\sigma\lambda^2 a^3(1+d/a)]$$

Equation (1)

The cylinder is taken to be clamped at both ends but free to rotate and extend axially at one end. The edge conditions can thus be written as

$$v_r = V_{r,x} = V_z = V_\theta = 0 \quad (x=0,\ y=d/h)$$

$$v_r = 0,\ \overline{N}_z = \overline{N},\ \overline{M}_z = \overline{M}, \quad (x=l,\ y=d/h)$$

$$(1+d/a)\overline{N}_{z\theta} + \lambda\overline{M}_{z\theta} = \overline{T}$$

Equation (2)

Here, l is the dimensionless length of the cylinder.

The above edge conditions are assumed to represent a close approximation to the test set-up used for obtaining the mechanical properties of the composites. In the theories developed in the previous chapters, the distance d at which the stress resultants were defined was left arbitrary. We now choose it to be such that there exists no coupling between N_z and K_1 and Mz and ε_{1d}

This can be achieved by setting the first component of sub- matrix [B] equal to zero,

$$B_{ij} = 0$$

This yield

$$d/h = \underline{B}_{11} / \underline{A}_{11}$$

Equation (3)

For a homogeneous, isotropic material we obtain, for example,

$$d/h = 1/2$$

As the loading applied at the end of the shell is axi-symmetric, all the stresses and strains are also taken to be axi-symmetric. We thus can set all the φ derivatives in the expressions for the stresses and strains and in the equations for the displacements equal to zero. The resulting simplifications and the general solution corresponding to each of the derived theories is now given. As the theory corresponding to axial length scale $a(a/h)^{1/2}$ and circumferential length scale a has been used in the analysis of long cylindrical shells with edges of the form φ = constant, it will not be considered.

a) <u>Theory associated with Length Scales a</u>

Strain-Displacement Relations

$$\varepsilon_1 = V_{z,x}$$

$$\varepsilon_2 = V_r$$

$$\varepsilon_{12} = V_{\theta,x}$$

$$\varepsilon_1 = V_{z,x}$$

$$\varepsilon_2 = V_r$$

$$\varepsilon_{12} = V_{\theta,x}$$

Governing Equations

$$\underline{A}_{11}V_{z,xx} + \underline{A}_{12}V_{r,x} + \underline{A}_{13}V_{\theta,xx} = 0$$

$$\underline{A}_{13}V_{z,xx} + \underline{A}_{23}V_{r,x} + \underline{A}_{33}V_{\theta,xx} = 0$$

$$\underline{A}_{12}V_{z,xx} + \underline{A}_{22}V_{r} + \underline{A}_{23}V_{\theta,x} = p^*$$

Equation (4)

By combining the first two equations, we obtain expressions relating Vz and Vr and V_θ and Vr , respectively,

$$V_{z,xx} = \mathbf{B}\, V_{r,x}$$

$$V_{\theta,xx} = \mathbf{C}\, V_{r,x}$$

Equation (5)

where the coefficients R and £ are defined as follows:

$$\mathbf{B} = [\underline{A}_{13}\underline{A}_{23} - \underline{A}_{12}\underline{A}_{33}]/[\underline{A}_{11}\underline{A}_{33} - \underline{A}_{13}^2]$$

$$\mathbf{C} = [\underline{A}_{11}\underline{A}_{23} - \underline{A}_{13}\underline{A}_{12}]/[\underline{A}_{13}^2 - \underline{A}_{11}\underline{A}_{33}]$$

$$V_{z,x} = \mathbf{B}\, V_r + C_1^*$$

$$V_{\theta,x} = \mathbf{C}\, V_r + C_2^*$$

Equation (6)

Integrating equations with respect to x yields where C_1* and C_2* are constants of integrations.

On substituting the equations into the last equation of (4) we obtain,

$$N_1 V_r = p^* - \underline{A}_{21}C_1^* - \underline{A}_{23}C_2^*$$

Where

$$N_1 = \underline{A}_{12}\,\mathbf{B} + \underline{A}_{22} + \underline{A}_{23}\,\mathbf{C}$$

Equation (10) shows that the radial deformation depends on the pressure P* and the material properties of the individual layers. These effective properties in turn depend on the angle y between the elastic axis of the material of each layer and the shell axis.

a : Inside Radius of Cylindrical Shell
h : Total Thickness of the Shell Wall
d; Distance (thickness) from Inside Radius and to mechanical neutral surface
Si : Radius of Each Layer of Wall (I = 1, 2, 3 -- - to the number of layer)
L : Longitudinal Length Scale to be defined, Also Actual Length of the Cylindrical Shell
Π : Circumferential Length Scale of cylindrical shell to be defined
Ei : Young's Moduli in I Direction
Gij : Shear Moduli in i-j Face
Sij : Compliance Matrix of Materials of Each Layer
r : Radial Coordinate
Π : Circumferential Length Scale to be defined
Ɣ : Angle of Fiber Orientation
σ : Normal Stresses
ε : Normal Strains
z, θ, r : Generalized Coordinates in Longitudinal, Circumferential and Radial

Directions Respectively
τ : Shear Stresses
εij : Shear Strains in i-j Face
λ ; Shell Thickness / Inside Radius (h/a)
Cij : Elastic Moduli in General
X, φ, Y : Non Dimensional Coordinate System in Longitudinal, Circumferential and Radial Directions Respectively

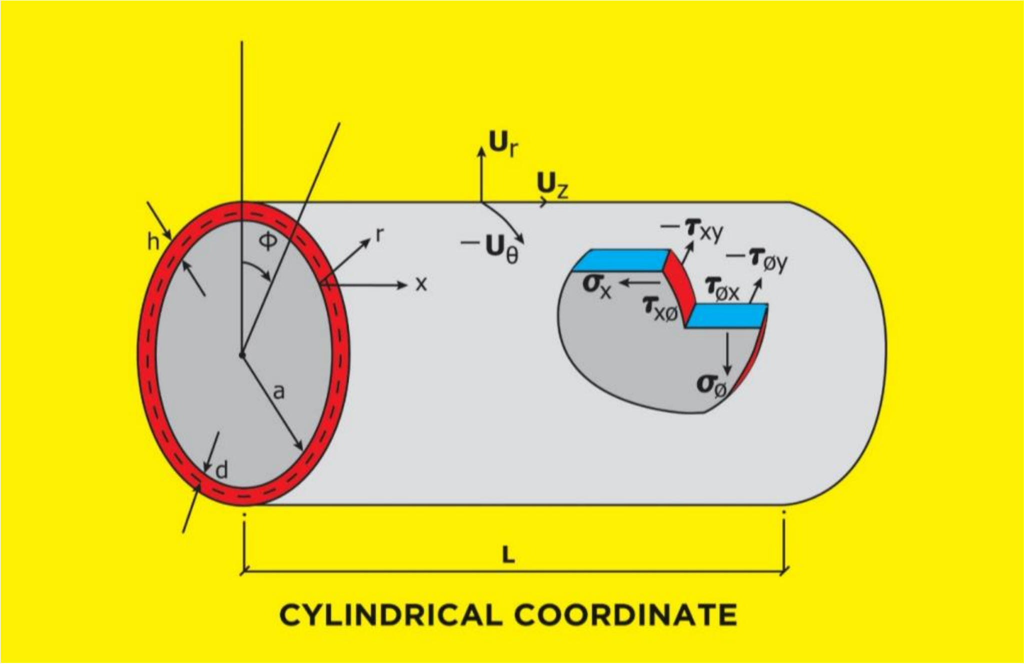

Figure 1: A cylindrical shell showing dimensions, deformations and stresses

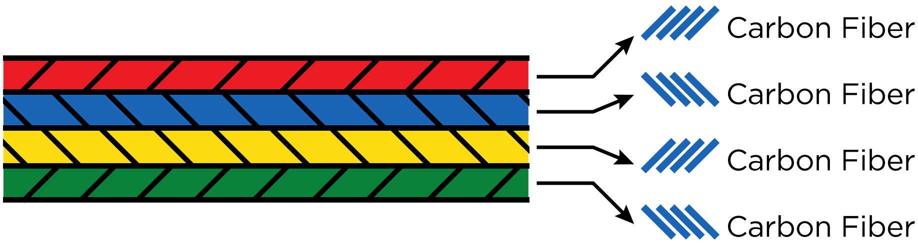

Figure 2: Anisotropic materials

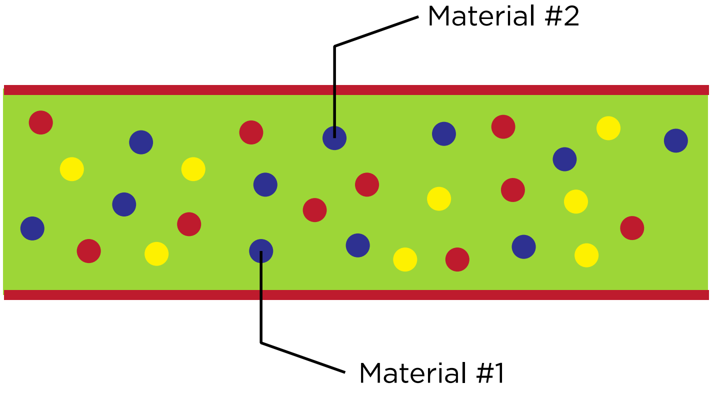

Figure 3: Non-homogenous materials

Note that since we have only four unknown constants, Ci*. (i = 1, 4), the solution of this theory can accommodate four boundary conditions. We therefore must abandon some of the boundary conditions specified in equations (9.3). The chosen two boundary conditions are:

$$v_z = v_\theta = 0 \qquad (x = 0)$$

$$\overline{N}_z = \overline{N}, \ (1+d/a)(\overline{N}_{z\theta}+\lambda\overline{M}_{z\theta})=\overline{T} \quad (x = \ell)$$

Equation (7)

where the external forces, >N" and T are as defined by equation (2) The equation (10) thus has a particular solution only

$$v_r^p = (p^*-\underline{A}_{21}C_1^* - \underline{A}_{23}C_2^*)/\ N_1$$

Equation (8)

From now on the superscript p_wm indicate the particular solution.

b) Theory Associated with Axial Length Scale (ah)$^{1/2}$ and Circumferential Length Scale a

<u>Strain-Displacement Relations</u>

$$\varepsilon_1 = V_z$$

$$\varepsilon_2 = V_r$$

$$\varepsilon_{12} = V_{\theta,x}$$

$$K_1 = -V_{r,xx}$$

$$K_2 = 0$$

$$K_{12} = 0$$

C*_ and C| arise from the integration

Equation (9)

<u>Governing Equations</u>

$$\underline{A}_{11}V_{z,xx} + \underline{A}_{12}V_{r,x} - \underline{B}_{11}V_{r,xxx} = 0$$

$$\underline{A}_{33}V_{\theta,xx} = 0$$

$$\underline{A}_{12}V_{z,x}-\underline{B}_{12}V_{r,xx}+\underline{A}_{22}V_r+\underline{D}_{11}V_{z,xxx}+\underline{D}_{12}V_{r,xx}-\underline{E}_{11}V_{r,xxxx} = p^*$$

Equation (10)

From the first two equations of above we obtain the following relations for V and V_Q:

$$V_{z,x} = \mathbf{D}\,V_{r,xx} + C_3^* - \mathbf{E}\,V_r$$

$$V_\theta = C_1^*\,x + C_2^*$$

Equation (11)

where $C^*_{i^s}$ (i = l,3) are the integration constants to be determined later and the coefficients **D** and **E** are defined as follows:

$$\mathbf{D} = \underline{B}_{11}/\underline{A}_{11}$$

$$\mathbf{E} = \underline{A}_{12}/\underline{A}_{11}$$

We can now express the third equation of (15) in terms of a single variable V by substituting (16) into it. This yield

$$N_1 V_{r,xxxx} - 2N_2 V_{r,xx} + N_3 V_r = p^* - \underline{A}_{21} C^*_3$$

Equation (12)

where the constants N_i (i = 1.2.3) are as follows:

$$N_1 = \underline{D}_{11}\mathbf{D} - \underline{E}_{11}$$

$$N_2 = (\underline{B}_{12} + \underline{D}_{11}\mathbf{E} - \underline{A}_{21}\mathbf{D} - \underline{D}_{12})/2$$

$$N_3 = \underline{A}_{22} - \underline{A}_{21}\mathbf{E}$$

The homogeneous solution of equation (9.18) can be expressed as,

$$V^H_r = \exp(-N_5 x)(A_1 \cos N_6 x + A_2 \sin N_6 x) + \exp(-N_5 \xi)(A_3 \cos N_6 \xi + A_4 \sin N_6 \xi)$$

Equation (13)

Here, the A_i's are constants to be determined by the edge conditions specified earlier, N^ and N, are given by

Governing Equations

$$\underline{A}_{11} V_{z,xx} + \underline{A}_{12} V_{r,x} - \underline{B}_{11} V_{r,xxx} = 0$$

$$\underline{A}_{33} V_{\theta,xx} = 0$$

$$\underline{A}_{12} V_{z,x} - \underline{B}_{12} V_{r,xx} + \underline{A}_{22} V_r + \underline{D}_{11} V_{z,xxx} + \underline{D}_{12} V_{r,xx} - \underline{E}_{11} V_{r,xxxx} = p^*$$

Equation (14)

From the first two equations above, we obtain the following relations for V and V_Q:

$$V_{z,x} = \mathbf{D}\, V_{r,xx} + C^*_3 - \mathbf{E}\, V_r$$

$$V_\theta = C^*_1 x + C^*_2$$

where $C^*_{i^s}$ (i = l,3) are the integration constants to be determined later and the coefficients **D** and **E** are defined as follows:

$\mathbf{D} = \underline{B}_{11}/\underline{A}_{11}$

$\mathbf{E} = \underline{A}_{12}/\underline{A}_{11}$

We can now express the third equation of (9.15) in terms of a single variable V by substituting (9.16) into it. This yield,

$$N_1 V_{r,xxxx} - 2N_2 V_{r,xx} + N_3 V_r = p^* - \underline{A}_{21} C_3^*$$

Equation (15)

where the constants N_i (i = 1.2.3) are as follows:

$N_1 = \underline{D}_{11}\,\mathbf{D} - \underline{E}_{11}$

$N_2 = (\underline{B}_{12} + \underline{D}_{11}\,\mathbf{E} - \underline{A}_{21}\,\mathbf{D} - \underline{D}_{12})\ /2$

$N_3 = \underline{A}_{22} - \underline{A}_{21}\,\mathbf{E}$

Equation (16)

The homogeneous solution of above equation can be expressed as,

$$V_r^H = \exp(-N_5 x)(A_1 \cos N_6 x + A_2 \sin N_6 x) + \exp(-N_5 \xi)(A_3 \cos N_6 \xi + A_4 \sin N_6 \xi)$$

Equation (17)

Here, the A_i' s are constants to be determined by the edge conditions specified. N^ and N, are given by

$N_5 = (N_3/N_1)^{1/4} \cos(\alpha/2)$

$N_6 = (N_3/N_1)^{1/4} \sin(\alpha/2)$

Equation (18)

where

$\alpha = \tan^{-1}[(N_1 N_3 - N_2^2)/N_2^2\ ]^{1/2}$

and £, is the dimensionless coordinate originating from the far edge of the shell defined as,

$\xi = L\ /\ (ah)^{1/2} - x$

The particular solution of

$V_r^p = (p^* - \underline{A}_{21} C_3^*\ )/N_3$

Thus the complete solution is given by

$V_r = V_r^p + V_r^H$

c) Theory Associated with Length Scales $(ah)^{1/2}$

Strain-Displacement Relations

$$\varepsilon_1 = V_{z,x}$$

$$\varepsilon_2 = V_r$$

$$\varepsilon_{12} = V_{\theta,x}$$

$$K_1 = -V_{r,xx}$$

$$K_2 = 0$$

$$K_{12} = 0$$

Equation (19)

Governing Equations

$$\underline{B}_{11}V_{r,xxx} - \underline{A}_{12}V_{r,x} - \underline{A}_{11}V_{z,xx} - \underline{A}_{13}V_{\theta,xx} = 0$$

$$\underline{B}_{13}V_{r,xxx} - \underline{A}_{23}V_{r,x} - \underline{A}_{13}V_{z,xx} - \underline{A}_{33}V_{\theta,xx} = 0$$

$$\underline{E}_{11}V_{r,xxxx} - (\underline{D}_{12} - \underline{B}_{12})V_{r,xx} - \underline{A}_{22}V_r - \underline{D}_{13}V_{\theta,xxx} - \underline{A}_{23}V_{\theta,x} - \underline{D}_{11}V_{z,xxx} - \underline{A}_{12}V_{z,x} = -p^*$$

The first two equations of the above will be as follows when solved for V_z and V_θ yield,

$$V_{z,x} = \mathbf{P}\,V_{r,xx} + C_3^* - \mathbf{Q}\,V_r$$

$$V_{\theta,x} = \mathbf{F}\,V_{r,xx} + C_1^* - \mathbf{G}\,V_r$$

Equation (20)

where the coefficients F, G, P. Q are defined as follows:

$$\mathbf{G} = (\underline{A}_{13}\underline{B}_{11} - \underline{A}_{11}\underline{B}_{13})/\mathbf{\Omega}$$

$$\mathbf{F} = (\underline{A}_{12}\underline{A}_{13} - \underline{A}_{11}\underline{A}_{33})/\mathbf{\Omega}$$

$$\mathbf{Q} = (\underline{A}_{13}\underline{B}_{13} - \underline{A}_{33}\underline{B}_{11})/\mathbf{\Omega}$$

$$\mathbf{P} = (\underline{A}_{13}\underline{A}_{23} - \underline{A}_{12}\underline{A}_{33})/\mathbf{\Omega}$$

and Q is given by

On substituting the above equations into the third equation of constitutive equations we obtain differential equation for V only,

$$N_1V_{r,xxxx} - 2N_2V_{r,xx} + N_3V_r = N_4(-p^* + \underline{A}_{23}C_1^* + \underline{A}_{12}C_2^*)$$

where C_1* and C_2* are constants of integration and

$$N_1 = (\underline{A}_{11}\underline{A}_{33} - \underline{A}_{13}^2)\underline{E}_{11} - (\underline{A}_{11}\underline{B}_{13} - \underline{A}_{13}\underline{B}_{11})\underline{D}_{13} - (\underline{A}_{33}\underline{B}_{11} - \underline{A}_{13}\underline{B}_{13})\underline{D}_{11}$$

$$N_2 = -\frac{1}{2}\,[(\underline{B}_{12} - \underline{D}_{12})(\underline{A}_{11}\underline{A}_{33} - \underline{A}_{13}^2) + (\underline{A}_{11}\underline{A}_{23} - \underline{A}_{12}\underline{A}_{13})\underline{D}_{13} + (\underline{A}_{12}\underline{A}_{33} - \underline{A}_{13}\underline{A}_{23})\underline{D}_{11}$$

$$- (\underline{A}_{11}\underline{B}_{13} - \underline{A}_{13}\underline{B}_{11})\underline{A}_{23} - (\underline{A}_{33}\underline{B}_{11} - \underline{A}_{13}\underline{B}_{13})\underline{A}_{12}]$$

$$N_3 = (\underline{A}_{11}\underline{A}_{33} - \underline{A}_{13}^2)(\underline{A}_{23} - \underline{A}_{22}) + (\underline{A}_{11}\underline{A}_{22} - \underline{A}_{12}\underline{A}_{13})\underline{A}_{23} + (\underline{A}_{12}\underline{A}_{33} - \underline{A}_{13}\underline{A}_{23})\underline{A}_{12}$$

$$N_4 = \underline{A}_{11}\underline{A}_{33} - \underline{A}_{13}^2$$

Equation (21)

The homogeneous solution of equation is representable in a similar fashion,

$$V_r^H = \exp(-N_5 x)(A_1 \cos N_6 x + A_2 \sin N_6 x)$$

$$+\exp(-N_5 \xi)(A_3 \cos N_6 \xi + A_4 \sin N_6 \xi)$$

where A_1's, and N_5 and N_6 are as defined previously, The particular solution is given by

$$V_r^P = (-p^* + \underline{A}_{23} C_1^* + \underline{A}_{12} C_2^*)(N_4/N_3)$$

The complete solution is then

$$V_r = V_r^P + V_r^H$$

Equation (22)

d) Uniformly Valid Theory

Strain-Displacement Relations

$$\varepsilon_1 = U_{z,z}$$

$$\varepsilon_2 = U_r/a$$

$$\varepsilon_{12} = U_{\theta,z}$$

$$K_1 = -U_{r,zz}$$

$$K_2 = 0$$

$$K_{12} = 2U_{\theta,z}/a$$

Governing Equations

$$\underline{A}_{11} aU_{z,zz} + \underline{A}_{13} aU_{\theta,zz} + \underline{A}_{12} U_{r,z} - a\lambda[\underline{B}_{11} aU_{r,zzz} + (\underline{B}_{12} + 2\underline{B}_{33})(1/a)U_{r,z}$$

$$-2\underline{B}_{13} U_{\theta,zz}] = 0$$

$$\underline{A}_{13} aU_{z,zz} + \underline{A}_{33} aU_{\theta,zz} + \underline{A}_{23} U_{r,z} - a\lambda[\underline{B}_{13} aU_{r,zzz} + 2\underline{B}_{23}(1/a)U_{r,z}] = 0$$

$$\underline{A}_{12} U_{z,z} + \underline{A}_{22}(1/a)U_r + \underline{A}_{23} U_{\theta,z} - a\lambda[\underline{B}_{12} U_{r,zz} + \underline{B}_{22}(1/a^2)U_r - 2\underline{B}_{13}(1/a)U_{\theta,z}]$$

$$-a^3\lambda^2 \underline{E}_{11} U_{r,zzzz} + a\lambda(a\underline{D}_{11} U_{z,zzz} + a\underline{D}_{13} U_{\theta,zzz} + \underline{D}_{12} U_{r,zz}) = p$$

Equation (23)

The first two equations of above give us the following relations for U_z and U_θ:

$$U_{\theta,z} = \mathbf{R} a\lambda U_{r,zz} - \mathbf{S}\frac{1}{a}U_r + C_1^*$$

$$U_{z,z} = \mathbf{T} a\lambda U_{r,zz} - \mathbf{W}\frac{1}{a}U_r + C_2^*$$

where C_1* and C_2* are the constants of integrations and the coefficients R, S, T, W are defined as follows:

$$\mathbf{R} = (\underline{B}_{13}\underline{A}_{11} - \underline{B}_{11}\underline{A}_{13})/\boldsymbol{\psi}$$

$$\mathbf{S} = [\lambda\underline{A}_{13}(\underline{B}_{12} + 2\underline{B}_{33}) + \underline{A}_{11}\underline{A}_{23} - \underline{A}_{13}\underline{A}_{12} - 2\lambda\underline{B}_{23}\underline{A}_{11}]/\boldsymbol{\psi}$$

$$\mathbf{T} = (\underline{B}_{11}\underline{A}_{33} - \underline{A}_{13}\underline{B}_{13} - 2\lambda\underline{B}_{13}^2)/\boldsymbol{\psi}$$

$$\mathbf{W} = [\underline{A}_{33}\underline{A}_{12} - \lambda\underline{A}_{33}(\underline{B}_{12} + 2\underline{B}_{33}) - \underline{A}_{13}\underline{A}_{23} - 2\lambda\underline{B}_{13}\underline{A}_{23} + 2\lambda\underline{B}_{23}\underline{A}_{13} + 4\lambda^2\underline{B}_{13}\underline{B}_{23}]/\boldsymbol{\psi}$$

and

$$\boldsymbol{\psi} = \underline{A}_{11}\underline{A}_{33} - \underline{A}_{13}^2 - 2\lambda\underline{B}_{13}\underline{A}_{13}$$

On substituting (9.38) into the third equation of (9.36) we obtain a differential equation for U only,

$$N_1 U_{r,zzzz} - 2N_2 U_{r,zz} + N_3 U_r = p - N_4$$

Equation (24)

where

$$N_1 = a^3\lambda^2(\underline{D}_{13}\mathbf{R} + \underline{D}_{11}\mathbf{T} - \underline{E}_{11})$$

$$N_2 = a\lambda[\underline{B}_{12} - \underline{D}_{12} - \mathbf{T}\underline{A}_{12} - \mathbf{R}(\underline{A}_{23} + 2\lambda\underline{B}_{13}) + \underline{D}_{13}\mathbf{S} + a^2\lambda\underline{D}_{11}\mathbf{W}]/2$$

$$N_3 = [-\mathbf{W}\underline{A}_{12} - \mathbf{S}(\underline{A}_{23} + 2\lambda\underline{B}_{13}) + \underline{A}_{22} - \lambda\underline{B}_{22}]/a$$

$$N_4 = \underline{A}_{12}C_2^* + (\underline{A}_{23} + 2\lambda\underline{B}_{13})C_1^*$$

APPPLICATION

The homogeneous solution can be written as

$$U_r^H = \exp(-N_5 z)(A_1 \cos N_6 z + A_2 \sin N_6 z) + \exp(-N_5 \eta)(A_3 \cos N_6 \eta + A_4 \sin N_6 \eta)$$

where A_i (i = l, 2, 3, 4) are the constants of integration to be determined and N_5, N_6 are as defined previously. As we are now dealing with actual coordinates (except for the thickness coordinate), we define n as follows:

$$\eta = L - z$$

where L is the actual length of the cylinder. The constants of integration are to be determined from the following edge conditions:

$$U_r = U_{r,z} = U_z = U_\theta = 0 \qquad (z = 0,\ y = d/h)$$

$$U_r = 0,\ N_z = N,\ M_z = N(H-d),\ T = 2\pi a(1+d/a)[M_{z\theta} + a(1+d/a)N_{z\theta}]$$

$$(z = L,\ y = d/h)$$

The particular solution is

$$U_r^P = (p - N_4)/N_3$$

and the complete solution of equation is then given by

$$U_r = U_r^P + U_r^H$$

Equation (25)

Having obtained the above solutions for each of the theories, numerical calculations are now carried out for a shell of the following dimensions:

We thus have a thickness to radius ratio of

$$\lambda = 0.025$$

Each of the layers is taken to be .025 in. thick and thus the dimensionless distances from the bottom of the first layer are given by

$$s_1 = 0.,\ s_2 = 0.25,\ s_3 = 0.5,\ s_4 = 0.75,\ s_5 = 1.0$$

Equation (26)

As mentioned previously, each layer of the symmetric angle ply configuration (elastic symmetry axes y are oriented at ($+\gamma$, $-\gamma$, $-\gamma$, $+\gamma$) is taken to be orthotropic with engineering elastic coefficients representing those for a boron/epoxy material system,

$$E_1 = 35\times10^6 \text{ psi}, \qquad E_2 = 2.75\times10^6 \text{ psi}$$

$$G_{12} = 0.75\times10^6 \text{ psi}, \qquad \nu = 0.25$$

Equation (27)

Here direction 1 signifies the direction parallel to the fibers while 2 is the transverse direction. Angles chosen were = 0 , 15, 30, 45 and 60. Use of the results of Appendices A and B and the transformation equations (6) then yields the mechanical properties for the different symmetric angle ply configurations.

We next apply the following edge loads:

$$N = p$$

and take

$$\sigma = p/\lambda$$

$$H = (3/4)h$$

Shown in Figs. 3 - 5 is the variation of the dimensionless radial displacement with the actual distance along the axis for the different theories. The reference surface for the chosen configuration is given by

$$d/h = 1/2$$

As mentioned above, the theory associated with length scales a is a membrane type theory and it's radial displacement is a function of the dimension less pressure and the two integration constants determined from the edge conditions (12). As Fig.3 demonstrates the radial displacement of this theory is constant over the entire length of the shell. The variation of the magnitude of radial displacement due to the change of cross-ply angle is almost identical compared to the other theories except for the fact that the theory cannot describe the deformation pattern due to the boundary conditions while the other theories showing the radial deformations of the so-called edge effect zone. The theory associated with longitudinal length scale $(ah)^{1/2}$ and circumferential length scale a is similar to the axi-symmetric version of the theory of length scales $(ah)^{1/2}$ in the following aspects:

a) Expressions for strains and curvatures are identical as they were shown in (14) and (26). This is due to the fact that the theory of length scales $(ah)^{1/2}$ are much simplified by the axi-symmetric property while the other theory is closer in fashion to the axi-symmetric behavior by it's nature because of the larger circumferential length scale we used for the theory, i.e. a.
b) Although the expressions for the particular solutions are different as indicated in (24) and (33), the combined form of governing equations and the homogeneous solutions, as shown in (20) and (32), are identical in form. This is due to the same length scales being used in longitudinal direction, $(ah)^{1/2}$, for both theories and again, the axial symmetry. In obtaining the homogeneous solutions for both theories, it was assumed that the cylinder has such material properties and geometric dimensions so as to justify the decay type solutions (20) and (32). In order to have these decay type solutions we first must have that the value of term as shown in (22) must be real.

$$N_1N_3 - N_2^2 > 0$$

Secondly, the dimensionless shell length (must be sufficiently larger compared to the axial length scale used in the basic formulation of the theories, $(ah)^{1/2}$, so that interaction effects from the opposite edges may be neglected. The condition for satisfying this can be obtained by comparing the two decay terms in equation (20), exp ($-N_5$ x) and exp ($-N_5 5\, \zeta$).

This leads to

$$\ell > \Gamma$$

where

$$\Gamma = \pi(ah)^{1/2}(N_1/N_3)^{1/4}$$

The restriction of the cylinder length **l** to be larger than **r** is important in the analysis of cylindrical shells due to the difference, of nature of the solution. For the cylinder shorter than r, the edge conditions have an effect on each other and the solution is no longer of the decay type. Edge conditions in this case govern the deformation pattern as well as the magnitude. A short cylinder under external pressure and closed at both ends deform axi-symmetrically and can be considered a typical example of a problem where the solution has a decay length shorter than r. It must be noted here that unlike for isotropic homogeneous shells, the decay length **r** depends not only the shell geometry, h and a, but also on the material properties of each laminate.

CONCLUSION

As stated previously, Figs. 4 and 5 show that the radial displacement of the shell at distances from the edge greater than r, from now on called the edge effect boundary layer, is nearly identical for both theories and close in magnitude to that of the solution which is obtained for length scales a. This is because, in the regions away from, the particular part of the solutions of governing equations dominate while the homogeneous solutions are more important within the boundary layer regions. Because the results shown in the figures are nearly identical for the problem considered, no numerical calculations of the uniformly valid solution given above is carried out.

It is also seen that wide variations in the magnitude of radial displacement take place with change in the cross-ply angle. The maximum displacement occurs at

γ =30 degree while the minimum displacement is at
γ = 60 degree. In each case, the displacements increase with increase in γ up to
γ = 30 degree and thereafter decrease. The attached Figures show that the edge effect is sharper for small angle G than for larger ones. Similarly, deeper penetration of the edge effect is shown for small angles γ while weak and smooth edge effects are the case for large cross-ply angles.

Shown in Figs. 6 and 7 are the dimensionless displacement of an isotropic material of elastic coefficient $30x10^6$ psi and in Figs shown are of single layer boron/epoxy composite we used for four layers case. Circumferential component of stress resultant is also shown in Figures

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Spatial and Functional Relations of Indigenous Farms Around La Cocha Lagoon in Southern Colombia

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Abstract
Regarding global environmental crisis, the effort of various institutions to reduce hunger have not yet been enough. The dominant model of extensive agro-industry reveals a serious problem of instability, due to the use of agrochemicals and the non-rotation of crops. In this context, the academic community is increasingly interested in alternative agricultural models such as indigenous agriculture. Indigenous communities from the Andes have inherited highly complex agroecological systems whose practices for stability could be replicated in other agricultural models around the world. This qualitative research focuses on the functional and / or spatial relations of the traditional indigenous farms of the Quillacinga ethnic group in southern Colombia and seeks to verify that their practices coincide with what is exposed in authority texts. These relations and their role in the stability of soil fertility are explained through diagrams. The information collected can be expanded and contrasted with other studies on other Andean ethnic groups. These studies would seek to make a contribution to reduce the instability of the extensive agro-industrial model and potentially contribute to reduce hunger in the world.

Keywords: Indigenous Agriculture, Agroecology, Agroecosystems, Quillacingas, Spatial Relation

1. Introduction

1.1 Background and Relevance

Concerning the global environmental crisis, there are several obstacles to environmental development. One of them is the dominant culture of consumerism and excessive industrialization, promoted by dysfunctional economic policies. (Holmgren, 2015). Despite the growing industrialization processes in food production, it should be noted that in 2011-2013 twelve percent of the world population was not able to meet their minimum dietary requirements, for which it is estimated that one in eight people in the world suffers from chronic hunger, the vast majority live in developing countries (Food and Agriculture Organization of the United Nations, 2013).

To solve this problem, the concept of Food Security is important, its four main principles are: availability, access, use and stability (FAO, 2015). However, the aforementioned principle of 'stability' is threatened in the extensive agro-industrial model, due to long-term infertility in the soil caused by the use of agrochemicals and non-rotation of crops. (FAO, 2015).

1.2 Theoretical framework

The long-term instability shown by the extensive agro-industrial model has awakened a growing interest in academia to investigate more stable agricultural models such as permaculture or traditional indigenous agriculture, furthermore the efforts of influential countries such as China are currently focused on strengthening their food security, threatened by environmental crises such as climate change (Piao et al., 2010). Within the theoretical framework to carry out this research, first-hand texts from influential authors were considered, as well as publications from international organizations such as the UN and FAO, as can be found in the bibliographic references. However, the main reference text for this work is '*Teoría y Práctica para una Agricultura Sustentable*' by the authors Altieri and Nicholls for the United Nations Environment Program. In this text, the authors point out that, in the Andean area and other areas of Latin America, traditional agricultural systems have been developed over centuries of cultural and biological evolution; Furthermore, indigenous peoples have developed or inherited agroecosystems that adapt well to local conditions such as the climate, these systems are highly diversified and are characterized by the following five points:

A - Conservation of the genetic diversity of species and of productive continuity.
B - Optimal use of space and local resources.
C - Recycling of nutrients, waste, water and energy.
D - Soil and water conservation.
E- Control of the succession and protection of crops. (United Nations, 2000, p. 34).

1.3 Research objectives

1.3.1 Primary objective
The primary objective is to verify that the agricultural practices of the *Quillacingas* ethnic group in the El Encano reservation coincide with the five characteristics of the indigenous agroecological systems of Latin America, previously mentioned. (United Nations, 2000, p. 34). This research focuses on verifying these characteristics exclusively in the aforementioned study area. However, other researchers can take the approach of this work as a guide to verify or analyse these characteristics in any other indigenous community from the Andes. Thus, the obtained results may allow the collection, organization and comparison of valuable information about the diverse agricultural knowledge of the Andean indigenous communities.

1.3.2 Secondary objective
The present work aims to document with a functional / spatial approach the systematic processes of traditional indigenous agriculture in the study area. The foregoing considering that there is a lack of written documentation in English about the great variety of indigenous ethnic groups that inhabit the Andes mountain range, especially about those who live in the specific territory in which this research is carried out. (Deruyttere, 2001).

1.4 Definitions and relevant information.

The investigation was carried out in the territory of the *Quillacingas* ethnic group, specifically in the indigenous reservation of El Encano, which is located around the La Cocha lagoon in the village of El Encano, Municipality of Pasto, department of Nariño, southern Colombia. The *Quillacingas* have occupied these territories since pre-Hispanic times, they were advanced farmers in different thermal levels, their most important traditional crops are: corn, potatoes and beans (Quijano & García, 2018). Here are some important definitions for understanding the context of the participants.

- Worldview: It is the system of opinions and beliefs that make up the concept of reality for a certain person, society or culture. According to the worldview of the Quillacingas (like many other Andean ethnic groups) the elements of nature, including: plants, animals and humans, are incomplete by themselves, but they are part of a

system that complements them mutually. That is, neither is superior or inferior to the other, but rather they are interdependent.
-Chacra: It is the indigenous ancestral farm, where the soil, water, plants, animals, human beings and deities develop and relate affectionately. It promotes scenarios for the protection of natural resources, sustainable production, food security and food sovereignty. In addition, it is developed in a smallholding and protects the ancestral seeds.
-Mindala: It is the exchange of experiences and the exchange of knowledge that contributes to the collective construction of the historical memory of indigenous peoples (FAO, 2013).

2. Method

The qualitative method was used since the research focuses on a certain indigenous community and its environment. In addition, the triangulation tool was used in the following three scenarios: (1) to compare the information between various texts referenced in the bibliography, (2) to compare the information collected between the three participants and finally (3) to compare the information from the texts (theoretical) with the information collected of the participants (practical). On the other hand, the stages of the research were three: the stage of collecting information in texts, the stage of collecting information from the participants and finally the stage of analysing the collected information.

2.1 Stage of collecting information in texts

It consisted of a search, collection and reading of texts on: academic research, permaculture, food security, agroecology and indigenous agriculture (Lowder, Skoet, & Singh, 2014) (Kropff, Bouma, & Jones, 2001) (Earls, 1998). Then a tabulated and numbered selection and organization of the collected information was made, prioritizing pertinent and first-hand information (Schmidhuber, & Tubiello, 2007) (Altieri, 1999) (Colque, Urioste, & Eyzaguirre, 2015).

2.2 Stage of collecting information from the participants

Initially, the researcher made contact with one of the leaders of the El Encano indigenous reservation belonging to the *Quillacingas* ethnic group, the objectives and scope of the investigation were clearly explained to him, it should be clarified that the author of this article belongs to the Sister ethnic group of the *Quillacingas*, called *Los Pastos* ethnic group. Considering that the criteria for selecting the participants consisted of selecting examples of *Chacras* that are representative of traditional indigenous agriculture's customs, participants were identified, they are three families belonging to the reservation. The researcher made a series of visits and interviews aimed at learning about the spatial functioning of these *Chacras* and obtained maps, written records, photographs, and audio and video recordings. Finally, the information was organized, listed and numbered in tables that contain the elements of the *Chacras* and their functional and / or spatial relations.

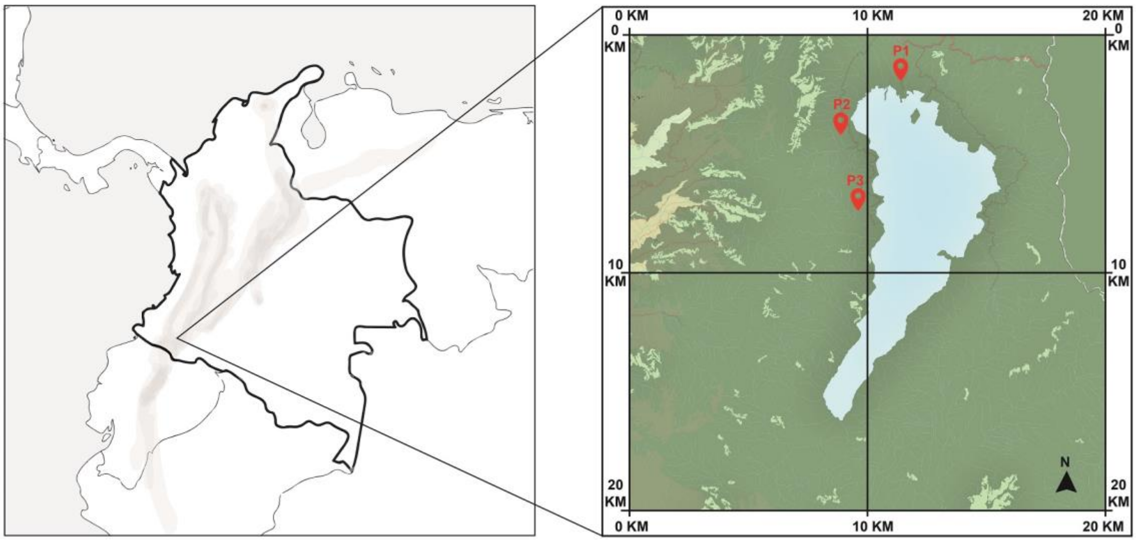
2.3 Stage of analysing the collected information

It began by making a comparison of the information collected in the three representative cases, identifying coincidences and differences. Considering that enormous coincidences and insignificant differences were found, it was decided to discard the differences and focus on the coincidences by making unique tables and diagrams that include the information from the three case studies as if they were only one. The information was synthesized and organized taking only the functional and / or spatial relations relevant to the study. Tables, diagrams and illustrations were made to explain these relations, including: location, elements, general diagram, contribution, feeding, environment and food and organic resources. Finally, a comparison was made between the postulates of the information collected in the texts and the results of the information collected from the participants to achieve the objectives of the research.

3. Results

3.1 Location

The *Chacras* of the three participants (P1, P2 and P3) are surrounding the La Cocha lagoon, which is located in the southwest of Colombia in a highly mountainous area known as the knot of *Los Pastos*, the lagoon is part of the water system that feeds the Amazon river. Taking into account the large number of streams that flow into the lagoon, it should be noted that all the case studies have important relationships with water. The lagoon has spiritual and landscape importance for this indigenous community.



Scheme 1: Location of Participants around La Cocha Lagoon.

Photography 1: La Cocha Lagoon View.

3.2 Elements of the Chacra

Unlike extensive monoculture agribusiness, *Chacra* agriculture is an agroecological polyculture that functions as a system in which many elements are interrelated. Table 1 does not show all its elements, but the most representative ones; These elements are organized in the following categories: plants, animals, buildings, water, community and others. In addition, they are grouped into several subgroups according to their nature in the *Chacra*, these subgroups are defined as follows:

-GROUP A: Plants that, for convenience, are generally planted in the same area, not necessarily all the plants in the group must be present. For example, arracacha can replace potato.
-GROUP B: Plants that attract animals and insects that contribute to pollination and control of unwanted pests. For example, the flowers of the laurel plant attract hummingbirds which contribute to pollination.
-GROUP C: Native plants that were cultivated in pre-Hispanic times and that had been displaced since the colonial period, they are currently in recovery.
-TUBER: Plants whose important stems grow underground.
-AQUATIC: Plants or trees that thrive in high humidity environments.
-INDICATORS: Elements that through their physical manifestations indicate some related natural phenomenon. For example, rocket (*Eruca vesicaria*) indicates that the soil has a high level of acidity.
-CLIMBING PLANTS: vines, usually grow up on trees.
-WILD: Plants and animals that do not depend on human care.
-DOMESTIC: Animals that depend on human care.

Table 1: List of elements of the Chacra. The information in the table was provided by the participants.

NAME IN ENGLISH	SCIENTIFIC NAME	FAMILY	SUB-GROUP	NOTES / USE
PLANTS				
Basil	*Ocimum basilicum*	Lamiaceae	GROUP B	Medicinal. Soothing.
Thymus	*Thymus spp*	Lamiaceae	GROUP B	Aromatic.
Garden mint	*Mentha spicata*	Lamiaceae	GROUP B	Medicinal. Aromatic. Seasoning. Salads.
Lemon balm	*Melissa officinalis*	Lamiaceae	GROUP B	Medicinal. Soothing.
Mint	*Mentha*	Lamiaceae	GROUP B	Aromatic.
Glory-bower	*Clerodendrum thomsoniae*	Lamiaceae	WILD, INDICATORS	Salads. High protein content. Indicates acidity in soil which can be countered by using quicklime.
Oregano	*Origanum vulgare*	Lamiaceae	GROUP B	Seasoning.
Amaranth	*Amaranthus*	Amaranthaceae	GROUP C	
Quinoa	*Chenopodium quinoa*	Amaranthaceae	GROUP A, GROUP C	High protein content.
Chard	*Beta vulgaris*	Amaranthaceae		Salads
Turnip	*Brassica rapa*	Brassicaceae	GROUP B	
Watercress	*Nasturtium officinale*	Brassicaceae	AQUATIC	High iodine content.
Rocket	*Eruca vesicaria*	Brassicaceae	WILD, INDICATORS	Salads. Indicates acidity in soil. Grows naturally after the potatoes are harvested.
Cabbage	*Brassica oleracea*	Brassicaceae		Salads
Broccoli	*Brassica oleracea*	Brassicaceae		Salads
Cauliflower	*Brassica oleracea*	Brassicaceae		Salads
Potato	*Solanum tuberosum*	Solanaceae	GROUP A, TUBER	It is usually sown in humid soil one week after the lunar quarter. After it has germinated it is fumigated

				weekly.
Eggplant	*Solanum melongen*	Solanaceae		Salads.
Tamarillo	*Solanum betaceum*	Solanaceae	INDICATORS	Indicates good quality soil
Chili pepper	*Capsicum*	Solanaceae		Seasoning.
Cape gooseberry	*Physalis peruviana*	Solanaceae		Medicinal, diuretic, improves skin. Natural sweetener
Naranjilla	*Solanum quitoense*	Solanaceae		Currently adapting to climate change.
Bean	*Phaseolus vulgaris*	Fabaceae	GROUP A	Nourishes the soil.
Lupin	*Lupinus spp*	Fabaceae	GROUP B, GROUP C	High protein content. After harvesting, it gives the soil enough nitrogen to plant some Group A crops such as potatoes, maize or quinoa.
Broad bean	*Vicia faba*	Fabaceae	GROUP A	Salads.
Pea	*Pisum sativum*	Fabaceae	GROUP A, CLIMBING PLANT	Salads.
Parsley	*Petroselinum crispum*	Apiaceae		Medicinal, antihemorrhagic. Seasoning.
Celery	*Apium graveolens*	Apiaceae		Aromatic.
Arracacha	*Arracacia xanthorrhiza*	Apiaceae	GROUP A	
Oxalis	*Oxalis spp*	Oxalidaceae	GROUP C	Medicinal, anti-fever. Salads
Oca	*Oxalis tuberosa*	Oxalidaceae	GROUP C, TUBER	Natural sweetener. Nourishes the soil. The grain is dried in the sun and boiled in milk for consumption.
Yacon	*Smallanthus sonchifolius*	Asteraceae	GROUP A, TUBER	Natural sweetener.
Dandelion	*Taraxacum officinale*	Asteraceae	WILD, INDICATORS	Medicinal, purifies the liver, skin and blood.
Lettuce	*Lactuca sativa*	Asteraceae		Salads.
Common fig	*Ficus carica*	Moraceae		
Blackberry	*Moraceae*	Moraceae		It is sown in dry and sandy soil.
Sweet granadilla	*Passiflora ligularis*	Passifloraceae	CLIMBING PLANT	Currently adapting to climate change. Medicinal, digestive benefits.
Banana passionfruit	*Passiflora supersect*	Passifloraceae	CLIMBING PLANT	
Welsh onion	*Allium fistulosum*	Amaryllidaceae		Must be exposed to the sun. Seasoning
Calabaza	*Cucurbitaceae*	Cucurbitaceae	CLIMBING PLANT	
Maize	*Zea mays*	Poaceae	GROUP A, GROUP C	Usually sown in September or October.
Bay laurel	*Laurus nobilis*	Lauraceae	GROUP B	
Curly dock	*Rumex crispus*	Polygonaceae	WILD, INDICATORS	
Malva	*Malva sylvestris*	Malvaceae		Medicinal, anti-fever.
Valerian	*Valeriana officinalis*	Caprifoliaceae		Medicinal. Soothing.
Ullucus	*Ullucus tuberosus*	Basellaceae	GROUP A, TUBER	Medicinal, healing and antiacid.
Mountain papaya	*Vasconcellea pubescens*	Caricaceae		Attracts wild mammals.

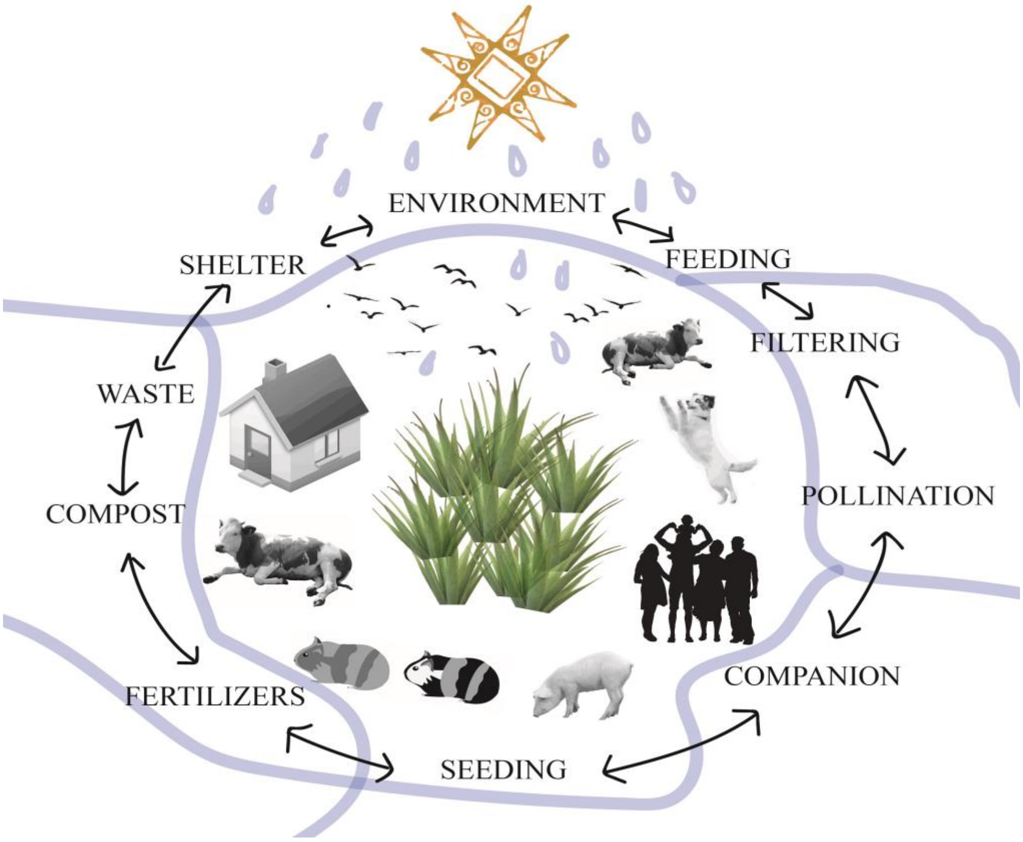
Mashua	*Tropaeolum tuberosum*	Tropaeolaceae	GROUP C, TUBER	Medicinal, antioxidant.
Azolla	*Azolla*	Salviniaceae	AQUATIC	Filters dirty water that flows into the ditches after washing the pig's shelter.
Garlic	*Allium sativum*	Amaryllidaceae		Seasoning.
Onion	*Allium cepa*	Amaryllidaceae		Seasoning.
ANIMALS			INDICATORS	Animal behaviour indicates natural or climatic phenomena such as earthquakes.
Guinea pig	*Cavia porcellus*	Caviidae	DOMESTIC	Spiritual, different colours have different meanings for indigenous peoples. They cannot eliminate gases so they must eat dry grass. Their faeces composts for 1 month.
Chicken	*Gallus gallus domesticus*	Phasianidae	DOMESTIC	Their shelters are made out of trees and vines like the calabaza. They walk freely on the ground contributing to fertilization and seeding.
Pig	*Sus scrofa domestica*	Suidae	DOMESTIC	Their faeces composts for 4 months. After death they bones are burned into ashes to mineralize the plants.
Cattle	*Bos taurus*	Bovidae	DOMESTIC	Their dairy products that are not consumed are exchanged with neighbours.
Goose	*Anserinae*	Anatidae	DOMESTIC	Take Care of the house. Their faeces composts for 1 month.
Dogs	*Canis lupus*	Canidae	DOMESTIC	Take Care of the house.
Insects			WILD	They contribute to pollination and pests' control.
Native birds			WILD	Their faeces contain seeds that contribute to seeding.
Violetear or hummingbird	*Trochilinae*	Trochilidae	WILD	Spiritual, different colours have different meanings for indigenous peoples.
Wild Mammals			WILD	Their faeces contain seeds that contribute to seeding.
CONSTRUCTIONS				
Shelter for chicken				It is composed of trees, vines and dry straw.
House for the family				Contains the traditional stove.
Shelter for guinea pigs				It is made of wood.
Pigsty				The waste from the cleaning of the pigsty that flows into the ditches is finally decontaminated by the azolla plant.
Greenhouse				Some plants such as broccoli, cauliflower, celery, chard or lettuce, etc. Are planted in the greenhouse and transplanted to another place when they have reached 15 cm in height.
WATER				

Artificial ditches				Transportation of products. Carries seeds naturally.
La Cocha Lagoon				Spiritual, purification. It is a substantial part of the water cycle.
Waste water				Leachate treatment
Rainwater			INDICATORS	Spiritual, natural signs.
TREES				
Black Cherry	*Prunus serotina*	Rosaceae		
Wax palm	*Ceroxylon quindiuense*	Arecaceae		
Alder	*Alnus glutinosa*	Betulaceae	AQUATIC	Its wood is used for small things such as handicrafts or firewood.
Elderberry	*Sambucus*	Adoxaceae		Its wood is used for small things such as handicrafts or firewood.
Eucalyptus	*Eucalyptu*	Myrtaceae		Eliminates the excess of water in the ground. Wood.
Yerba mate	*Ilex paraguariensis*	Aquifoliaceae		
Colombian pine	*Retrophyllum rospigliosii*	Podocarpaceae		Wood
Motilon	*Hyeronima macrocarpa*	Phyllanthaceae	GROUP C	Its fruit is used to make wine. Medicinal, antioxidant.
OTHERS				
Seeds				Spiritual. Wild animals are related to planting through the seeds present in their droppings.
Handicrafts				Spiritual. Wood from some trees is used as a material. Usually represent the scenery.
Grass			WILD	Forage
Hedgerow				surrounds every ‘property’, it can be made using blackberry plants and others.
Organic fertilizers				May include feces, sediment, dry straw, or quicklime
Natural Pesticide				May include quicklime, ashes, chili pepper or soap among others.
Kitchen organic waste				Feeding animals such as chicken, pig, goose, dogs.
Vermicompost				May include pigsty's waste, quicklime or dry straw.
Plastic waste				Vermicompost is covered with plastics to help decomposition
Plastic bottle waste				Some plants germinate in a recycled plastic pot to later be transplanted.
Sediment in ditches				Brings seeds
Traditional stove				It can be made of stone or brick. It is used for cooking. the family gathers around it. the *Mindala* takes place around it.
Ashes				Minerals for plants.

Paths				Circulation, access, transport and commerce.
Quicklime				Multipurpose
Solar radiation				Drying products. Spiritual.
Dry Straw				Multipurpose
COMMUNITY				
Barter				Exchange of dairy products, seeds, handcrafts, animals, fruits, etc.
Mindala				It is the exchange of knowledge and experiences within the community.
Family				
Neighbours				Practice barter.

3.3 General Organization

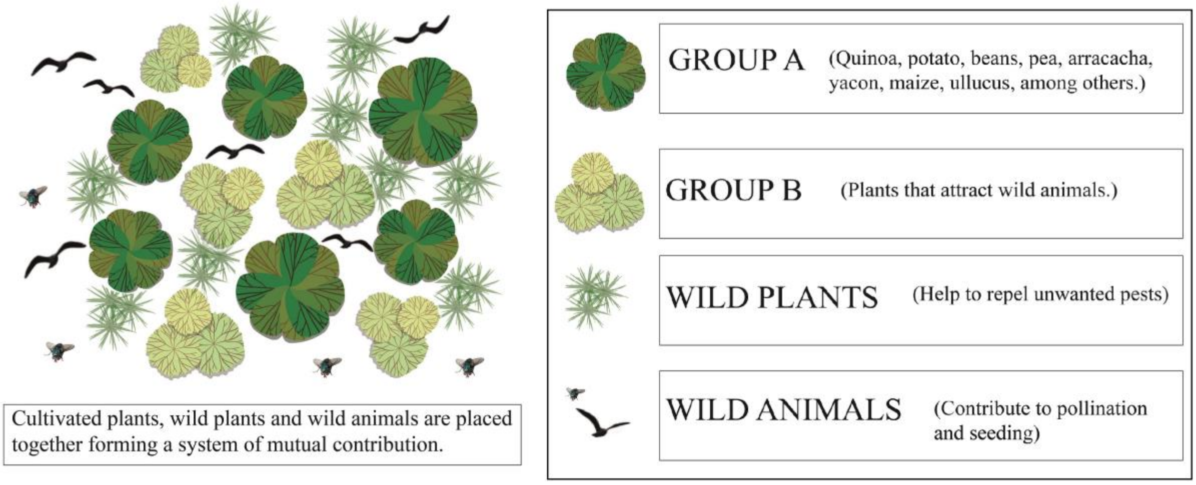
According to the worldview of the *Quillacingas*, the elements of the *Chacra*, including humans, are not organized according to a vertical hierarchy, in which there are superiors and inferiors. For them, each of the elements of the *Chacra* has a specific function and has a certain type of relation with others. (Feeding, Shelter, etc.). It is worth mentioning that the sun and water are elements of spiritual importance (Quijano & García, 2018).



Scheme 2: General organization of a Chacra.

3.4 Pollination and contribution

For there to be a contribution and pollination process in crops, the location of the plants in the sowing is a key aspect. Cultivated plants, plants that attract desirable animals, native plants that repel undesirable animals, and native animals that contribute to pollination are mixed in one zone. Consequently, the sowing of the polyculture becomes an agroecological system in which each element has a certain location, function and contributes to others.



Scheme 3: *Pollination and contribution.*

3.5 Environment

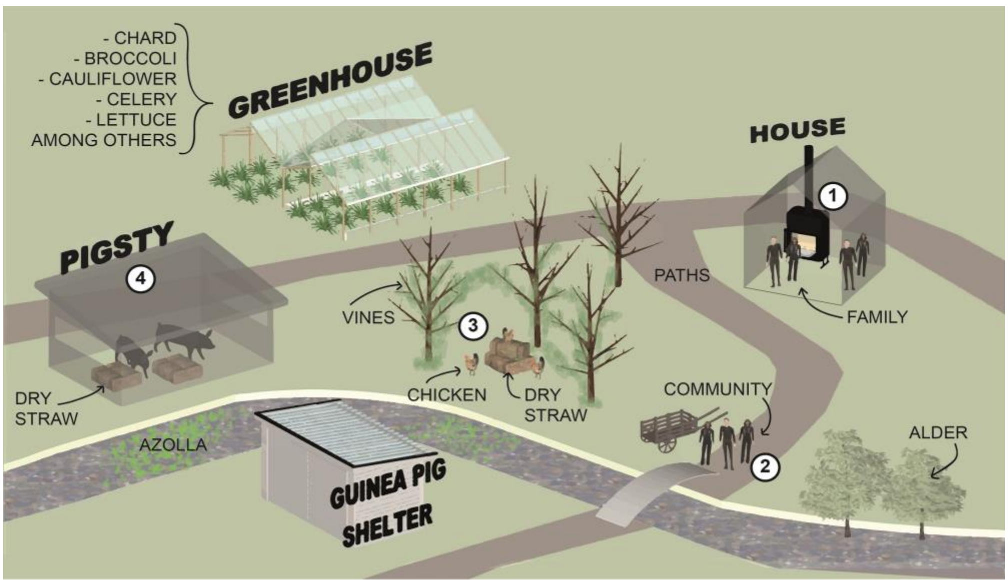
The constructions within the *Chacra* are located organically, according to their functionality and are connected through trails. Scheme 4 lists four functional and / or spatial relations that exemplify how the environment is arranged in the *Chacra*:

o;1: The family gathers around the traditional stove known as 'Tulpa', around it they eat and talk, it is also the place where they receive friends and neighbours.

o;2: The trails are spaces to mobilize and transport products, these also serve for community meetings and bartering with neighbours.

o;3: The chickens that are loose throughout the *Chacra* and whose excrements nourish the soil, take refuge in the dry straw that is placed under the trees wrapped in climbing plants.

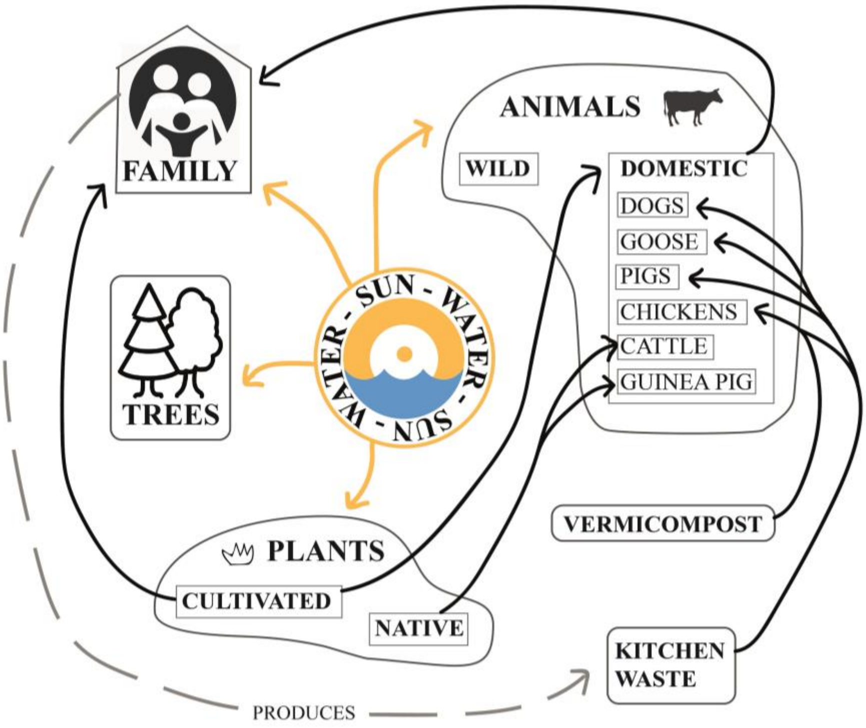
o;4: The pigsty is made up of dry straw in a wooden shed. When it is washed, the waste that flows into the nearby ditches is filtered by the azolla aquatic plant.



Scheme 4. Environment.

3.6 Feeding

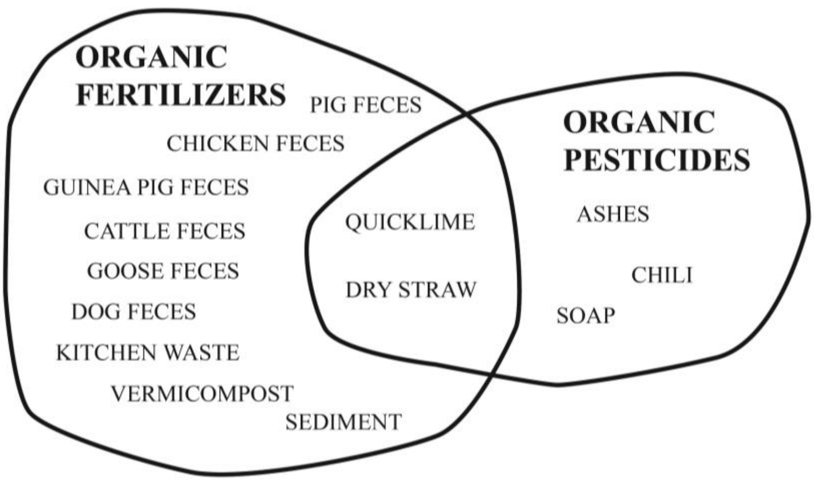
The elements of the *Chacra* feed each other, internally, which means, the food is produced within the same *Chacra*. The sun and water play a central role in this relationship as they feed the family, trees, animals and plants. The other elements feed each other, for example, native plants feed the cows and guinea pigs which in turn feed the family.



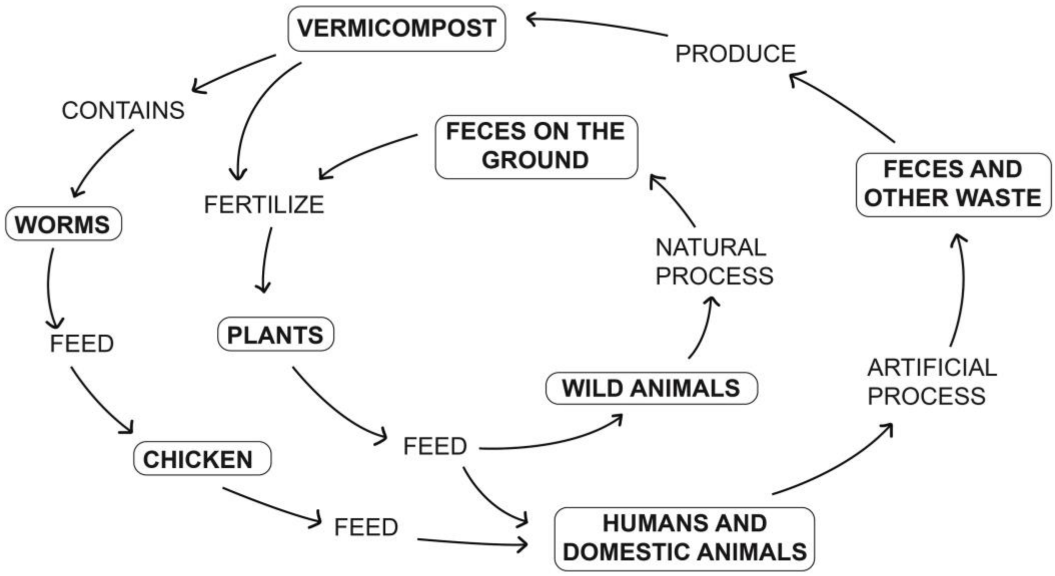
Scheme 5: Feeding.

3.7 Organic fertilizers and Organic pesticides.

Organic pesticides and fertilizers are made mostly with local ingredients, in scheme 6 their components are specified, the only common ingredients are dry straw and quicklime. On the other hand, it is worth mentioning that the relationship of organic fertilizers is cyclical and therefore is sustainable over time (scheme 7).



Scheme 6: Components of Organic Fertilizers and Pesticides.



Scheme 7: Cycle of organic fertilizers.

4. Discussion

4.1 Meaning of the results.

Considering that the primary objective of the research consisted in verifying in the practices of the participants the five characteristics of the indigenous agroecological systems of Latin America exposed by the authors Altieri and Nichols in the main reference text of this research. It was found that, among the three participants, all meet the five characteristics.
A - Conservation of the genetic diversity of species and of productive continuity. They comply because they use native seeds, their *Chacras* are polycultures that promote the diversity of seeds and species, and produce food continuously throughout the year.
B - Optimal use of space and local resources. They comply with the optimization of space through organic spatial organization and comply with the optimization of local resources through barter and the sustainable use of resources such as wood or wild animals and plants.
C - Recycling of nutrients, waste, water and energy. They comply because waste is reused to make natural fertilizers through composting, organic pesticides and the optimal use of water.
D - Soil and water conservation. They comply because the *Chacras* are part of an agroecological system that cares for the soil and water through the non-use of agrochemicals and rest periods for the land.
E- Control of the succession and protection of crops. They comply because they practice crop rotation and because different kinds of plants are planted in the same area so that there is a contribution between them to nourish themselves and repel pests (United Nations, 2000, p. 34).

4.2 Review of the method.

The use of the qualitative method, the triangulation tool and the organization of the research in stages was useful to achieve the objective of the research. However, the academic community lacks a generic method that can be used to investigate Andean agriculture regardless of ethnicity and location. This article is unique considering the little information written in English about the agriculture of the *Quillacinga* ethnic group with a functional / spatial approach.

4.3 Impact of the research.

It is expected that this work can be used as a contribution to the creation of methodological models that allow studying traditional indigenous agriculture with a functional / spatial approach; and that can be used with other ethnic groups from the Andes mountain range. Therefore, the valuable knowledge that these communities keep through oral tradition can be useful to solve the problem of stability as a principle of food security, which is important to reduce famine in the world. (FAO, 2017).

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Statistical Software Programs Used for Business Research

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Abstract
In this paper we discuss software programs used for teaching business courses and used in business research. The software programs used are MATLAB, R Studio, Microsoft Excel, SPSS, SAS and Python. This paper goes into details about the functions of each software program and how each program is proficient and programmed for different areas of research. Using tables and figures, we discuss the ease of use per program, the difficulty based on a scale for beginner uses, the storage capacity of each programming language, the availability to business students and researchers and how applicable each program is with a basic knowledge of how to use it. The cost of each statically programing package is also covered. The detailed functions of the various programs are covered in Figures throughout and tables through the paper as well. It is a well-known fact that MATLAB, R, Python, Excel, SPSS and SAS are the most important five languages to be learned for data analysis.

Keywords: Big Data, Teaching R, Teaching Python, Teaching SPSS, Teaching Microsoft Excel, Teaching SAS, Teaching MATLAB, Demonstrations of Examples for Teaching Statistical Software Packages

Introduction

MATLAB, R, Excel, SAS, SPSS and Python are analytical software programs that configure statistical analyses by producing outputs ibn the form of graphs. MATLAB is a matrix-based program that expresses math computations for engineers and science-based field research. R is open-source. It is a versatile statistical software program that can be used in a range of changing field preferences. It is highly standardized. SAS is a paid software system that provides high performance analytics operations. Through using this software program organizations can identify and investigate the life cycle of any inquiry. Excel is a free program provided by Microsoft, available to everyone that has Windows. SPSS is a statistical analysis software program provided by IBM. Python is a programming language created by Guido van Rossum which was designed to emphasis code readability. When it comes to data science one of the most common points of debate is R vs SAS vs Python vs Excel vs SPSS vs MATLAB. It is a well-known fact that MATLAB, R, Python, Excel, SPSS and SAS are the most important five languages to be learned for data analysis.

Amongst all six statistical software programs, each has different storage capabilities. For example, R Studio requires 250 Gb SAS requires 10-15 Gb to download. While Python requires 2 Gb and Excel only requires 1 Gb of RAM as the minimum system requirement for the 32-bit version of Windows 10. SPSS rule of thumb is to have four times as much space. 2 Gb hard drive space and 4Gb of RAM will be used. Booth and Ozgur discuss how predictive modeling is utilized in evaluation of technical acquisition performance using survival analysis. (Booth, Ozgur 2019)

Table 1: Comparison of Software Programming Languages.

	SPSS	**SAS**	**R Studio**	**Python**	**MATLAB**	**Excel**
Ease of use 1-6 (1 being the easiest)	4	6	5	3		1
Difficulty	Moderately Difficult	Most Difficult	Not difficult if user knows of package plan assistance.	Moderately Difficult	Not Difficult if codes are known	Not Difficult
Storage	**2 GB of Hard Drive space**, **4 GB of RAM**	Requires 10-15 Gb to download	250 Gb. R will not need as much scratch space as SAS.	2 Gb	Minimum: 3.5 **GB. Typically, 5-8 Gb used.**	1GB of RAM is the minimum system requirement for the 32-bit version of Windows 10
Availability to students and researchers 1-5 (1 being the least prevalent)	2 (moderate)	1	2 (moderate) depending on if package programs are used.	2 (moderate) users must know software language to operate.	2 (moderate) users must know software language to operate.	3
Cost	\$99.00 / month subscription	\$8,000 / year	Free Download Available	\$0-\$8.00/month /user	\$95.00 /home user	Free with the purchase of Microsoft
Application	2nd Most Applicable.	Most Applicable.	Very Applicable with knowledge of package programs.	Applicability is to be determined by user.	Applicability is to be determined by user.	Only Applicable for small to medium sized problems.

In this table we compare SPSS, SAS, R Studio, Python, MATLAB, and Excel in terms of the program's ease of use, difficulty, storage capacity, availability to students and researchers, overall cost, and each programs applicability in the real world.

MATLAB

MATLAB is an integrated software program that numerically computes a high level statically language. As well as visualization in the form of graphics and simulations which can be used for data analysis exploration. Application of this software program can help the user develop models and algorithms in a system interface.

R Studio

R Studio is a programming language used in different fields. R is an open source and easy to access, supported by the R Foundation, which Is a statistical computing foundation. R is widely used by data miners for developing data analysis with the aid of pre-packaged programs. These pre-packaged have a command line interface and several graphical front-ends which are available.

Microsoft Excel

Microsoft Excel is more than a spreadsheet for that it is capable of doing mathematical analysis for the user. Given it can encode data, create complex graphs, and manipulate numbers through formula functions. Provides easy reference to input. All while being able to manipulate numbers in a mathematical environment.

SPSS/ Statistical Package for the Social Sciences

SPSS analyses data to solve research problems through an interface that is easy to use. It has the capabilities of advanced statistical procedures. These procedures can use extensions such as R, Python which ensure accurate data analysis and progressive decision making. This programing language follows a spread sheet format similar to Excel. Users are able to solve large scale problems.

SAS/ Statistical Analysis System

SAS is a programming language that uses a common spread sheet layout which results in different statistical analyses in the form of tables, graphs, RTF, PDF, HTML documents. SAS is an expensive software language however schools and business can afford it. SAS is involved in many different sectors of business. Helping users make cost effective decisions.

Python

Python is a programming language designed to emphasize code readability. Python has variants for C and Java programming languages. The C variant is known as Python and is designed to give Python the advantages of C. One of these characteristics is in terms of performance. The variant can act both as an interpreter and at the same time as a compiler. Python has a wide range of applications.

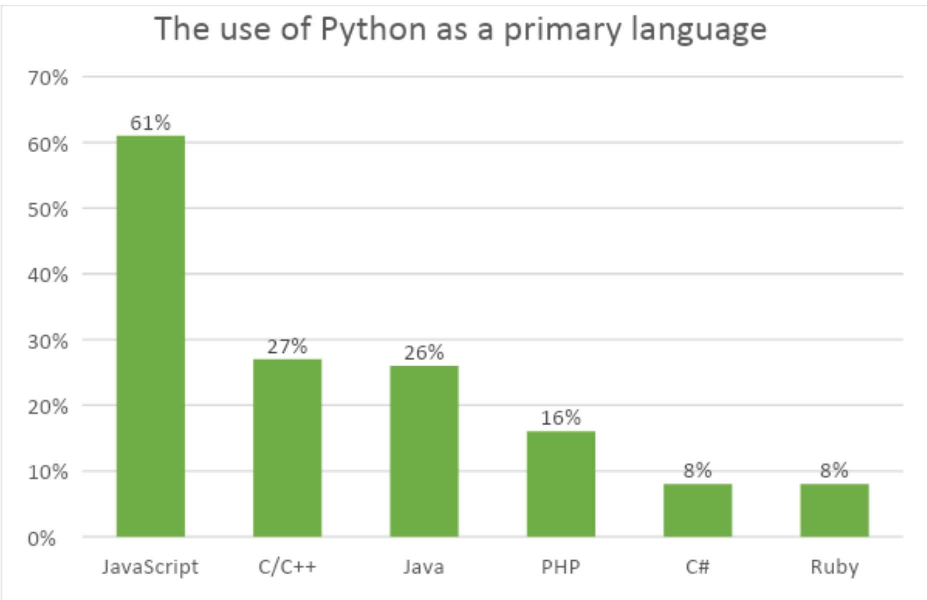


Figure 1: The use of Python as a primary language
(Python Developers Survey 2016: Findings)

In this Figure we describe how many users (JavaScript, C/CC+, Java, PHP, C#, Ruby) prefer Python as their primary language.

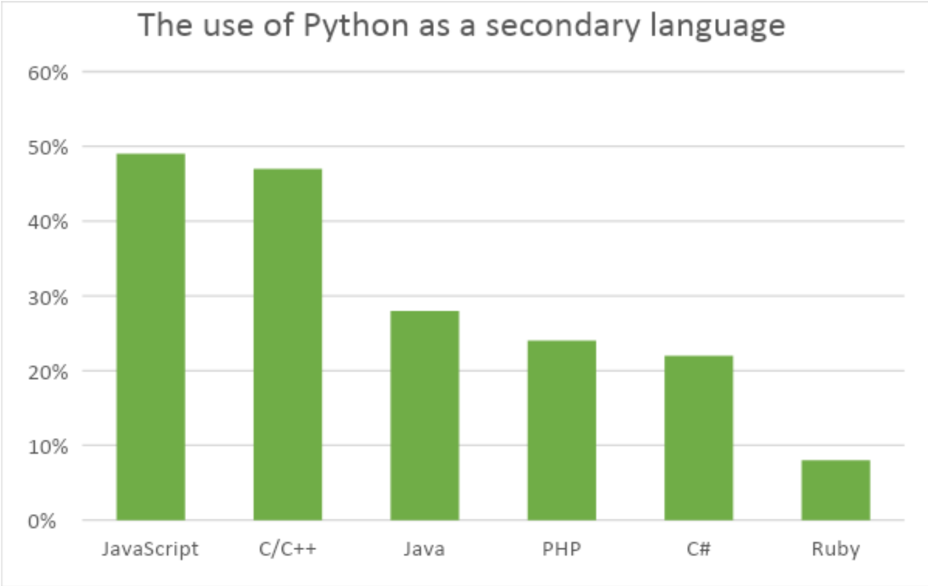


Figure 2: The use of Python as a secondary language.
(Python Developers Survey 2016: Findings)

In figure 2, about 49% of user's (JavaScript, C/CC+, Java, PHP, C#, Ruby) prefer to use python as their secondary development language.

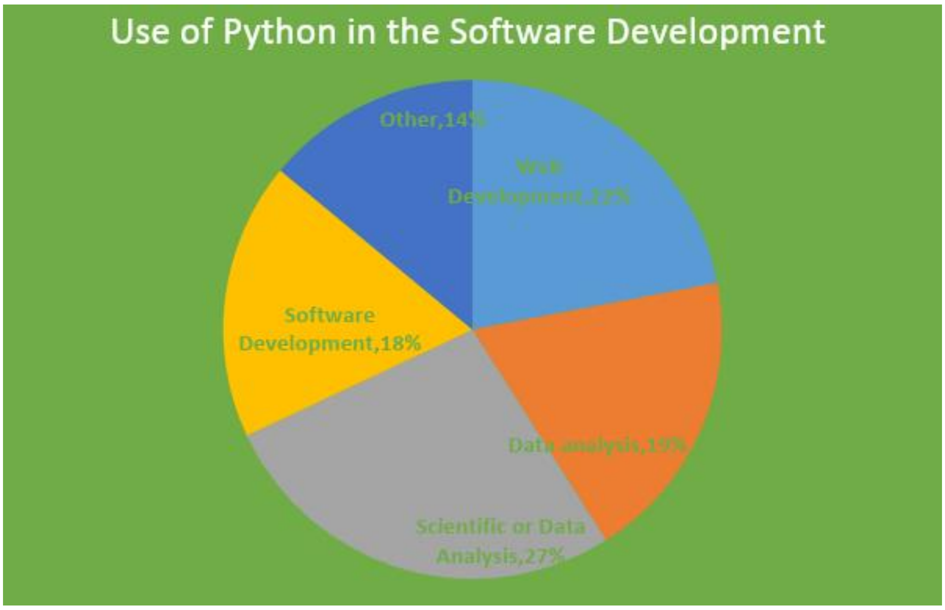


Figure 3: Use of Python in the Software Development.
(Python Developers Survey 2016: Findings)

There are about 46% of developers which use Python programing language as their Data analysis tool instead of traditional programmers or Web developers.

In an early paper Ozgur, et.al. In journal of Data Science compared the effectiveness of MatLab, Python and R in a teaching environment. For example, Python is the programming language that is based on C which contains a standard library which is structured to focus on different modules for threading, networking and databases.

Table 2: Python vs. R in Google Citations.

	Google result-R	Google result-python	Ratio of R / python
XX+programing	2,430,000	72,700,000	0.33
XX+data collection	4,200,000	1,520,000	2.76
XX+statistics	108,000,000	29,000,000	3.72
XX+model	154,000,000	8,270,000	18.62
XX+ code	130,000,000	2,710,000	47.97
	79,726,000	10,375,000	15

In this Table, using Google citations we can see the prevalence of a Python citation versus an R Studio web search.

Table 3: Comparisons of R vs. Python Books and Papers.

	Books-R	Books-python	Ratio of R / python	Papers-R	Papers-Python	Ratio of R / python
programming for statistics	207	13	15.92	**2,680,000**	47,600	56.3
Data	6970	310	22.48	9,290,000	205,000	45.32
statistics	4235	42	100	5,470,000	104,000	52.59
model	8631	126	68.5	7,830,000	163,000	48.03
code	6084	105	57.94	4,650,000	158,000	29.43
	5225.4	119.2	52.968	5984000	135520	46.334

In this Table, we compare the books for R versus books for Python. First we compare the scholarly papers for R versus Python. We show the ratio of R books/ papers versus Python books/ papers.

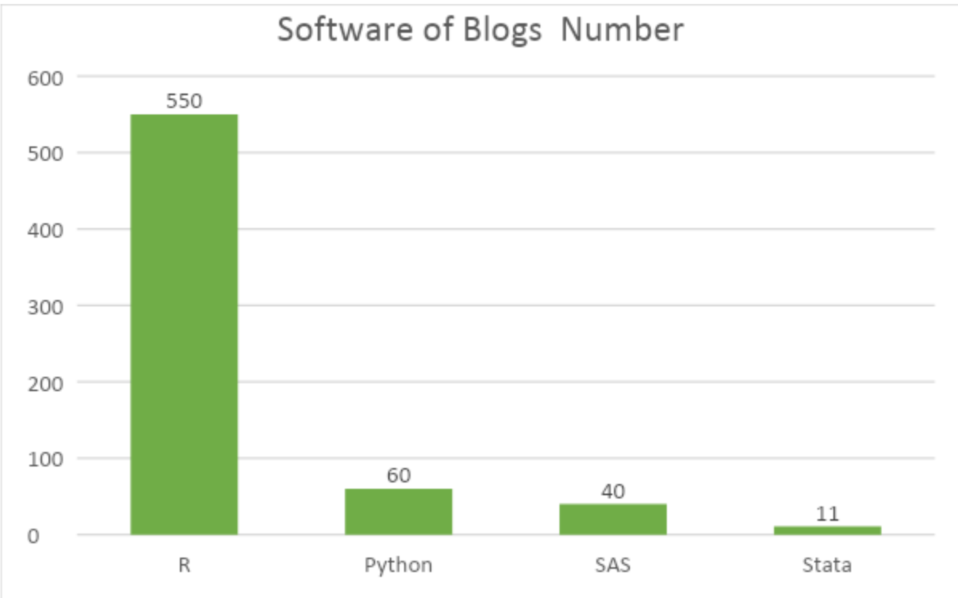


Figure 4: Software Blogs: Number of blogs devoted to each software package on April 7, 2014, and the source of the data.

R's blogs have an impressive number of 550. For Python, only 60 blogs that were devoted to the SciPy subroutine library were found. SAS 40 blogs was an impressive figure given that Stata only possessed 11 blogs.

While searching for a list of blogs related to software, individual blogs were found which related to software. Unfortunately, the list was not kept updated, and would be far too time consuming to deal with. If you know of other lists of relevant blogs, please inform us. They will be added to the list. Internet blogs are written by passionate people who speak about problem solving methods and software. Blogs contain information that has the potential to sway the popularity of a software packages.

```
import time
timer_start = time.time()

for i in xrange(1, 100000):
    print "Hi!"
#End for

print "Finished!"

timer_end = time.time() - timer_st

print timer_end
```

```
ptm <- proc.time()

for(i in 1:100000) {
  print("Hi")
}

print("Finished!")

print(proc.time() - ptm)
```

Figure 5: Computer Codes for R and Python.

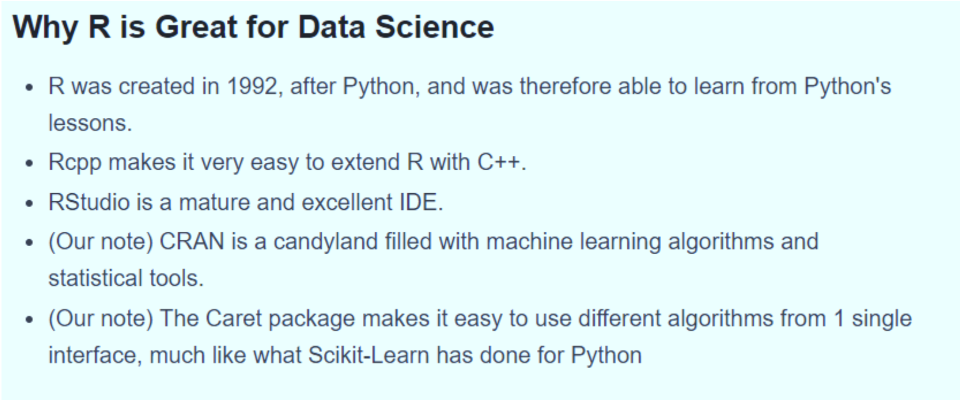
In this illustration of computer codes for R and Python we can see how both programming Python and R are utilized. The top depiction shows simple Python format. While bottom shows an R Studio format. Python: 0.769 seconds / R: 4.86 seconds.

Why Python is Great for Data Science

- Python was released in 1989. It has been around for a long time, and it has object-oriented programming baked in.
- IPython / Jupyter's notebook IDE is excellent.
- There's a large ecosystem. For example, Scikit-Learn's page receives 150,000 - 160,000 unique visitors per month.
- There's Anaconda from Continuum Analytics, making package management very easy.
- The Pandas library makes it simple to work with data frames and time series data.

Figure 6: Python for Data Science.

Figure 6 goes into detail about the history and competition of Python programming language.



Why R is Great for Data Science

- R was created in 1992, after Python, and was therefore able to learn from Python's lessons.
- Rcpp makes it very easy to extend R with C++.
- RStudio is a mature and excellent IDE.
- (Our note) CRAN is a candyland filled with machine learning algorithms and statistical tools.
- (Our note) The Caret package makes it easy to use different algorithms from 1 single interface, much like what Scikit-Learn has done for Python

Figure 7: R Studio for Data Science.

Figure 7 shows how R can be utilized in Data Science. Figure 7 also goes into detail about the history and competition of R Studio programming language.

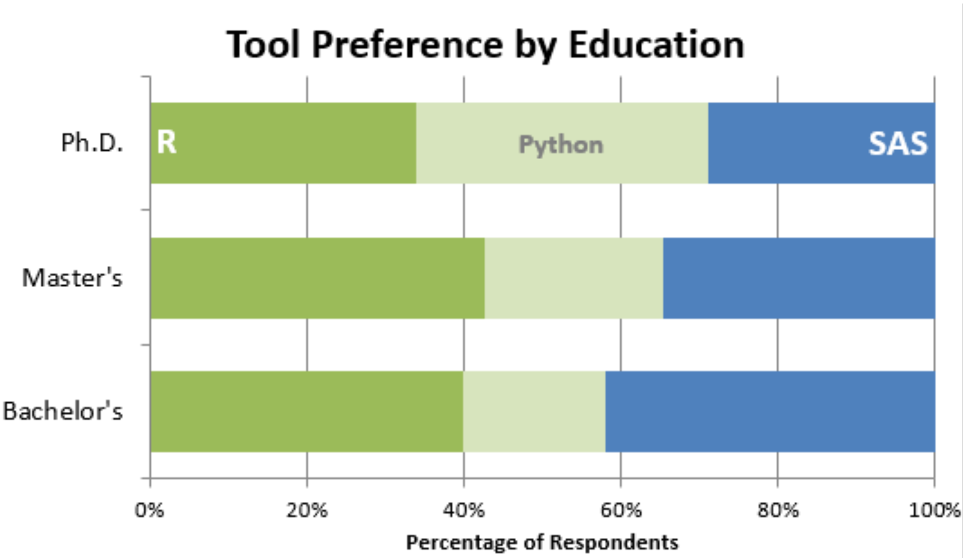


Figure 8: Preference by Education.

(http://www.burtchworks.com/2017/06/19/2017-sas-r-python-flash-survey-results/)

Figure 8 shows the preference of R, Python or SAS by education levels. At least 40% of each educational level prefers the R Studio software. About 23% of the overall education level of users prefer Python. Roughly 37% prefer SAS.

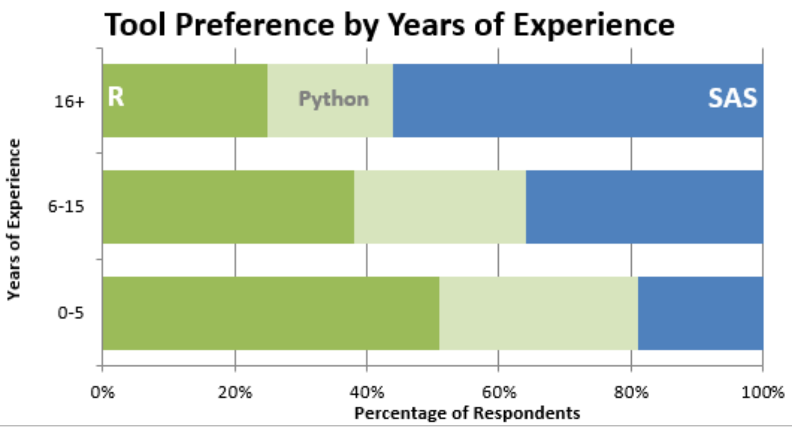


Figure 9: Depicts tool preference by the years of experience.

(http://www.burtchworks.com/2017/06/19/2017-sas-r-python-flash-survey-results/)

In Figure 9, about 25% of users who have 16 years or more of experience prefer R. While About 20% of users who have 16 years or more of experience prefer Python and about 55% of users with 16 or more years of experience prefer SAS. About 35% of users who have 6-15 years prefer R, roughly 27% of users with 6-15 years of experience prefer Python and about 38% of users with 6-15 years prefer SAS. Lastly, 50% of users with 0-5 years of experience prefer R, about 32% of users with 0-5 years' experience prefer R, and about 18% of users with 0-5 years' experience prefer SAS.

Figure 10: Comparison of salaries of different disciplines against data scientists (Data analyzers)

This Figure compares the salaries for different occupations. Upon observation of this graph, we can see that Data Scientists earn the highest salary when compared to the other occupations.

Table 4: Recommend for first learning statistical software language-

Language Recommendation Select	count	percent
Python	6941	63.11147481
R	2643	24.03164212
SQL	385	3.50063648
C/C++/C#	307	2.79141662
MATLAB	238	2.16402982
Java	138	1.2547736
Scala	94	0.85470085
SAS	88	0.80014548
Other	85	0.77286779
Julia	30	0.27277687
Stata	28	0.25459174
Haskell	17	0.15457356
F#	4	0.03637025
Total	10998	1

In this Table, we compare the recommended selection from the users about software programs.

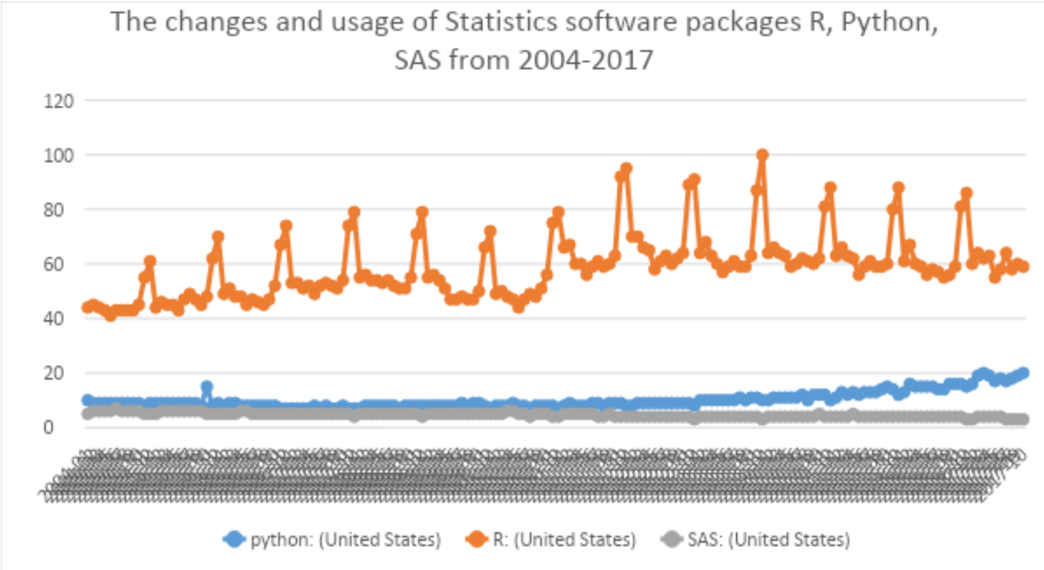


Figure 11: The use of software packages and how they have changed over the years.
(https://trends.google.com/trends/explore?date=all&geo=US&q=python,R,SAS)

This figure shows how the usage of Python, R, and SAS have changed in the United States over the years from 2004-2017 though a linear depiction.

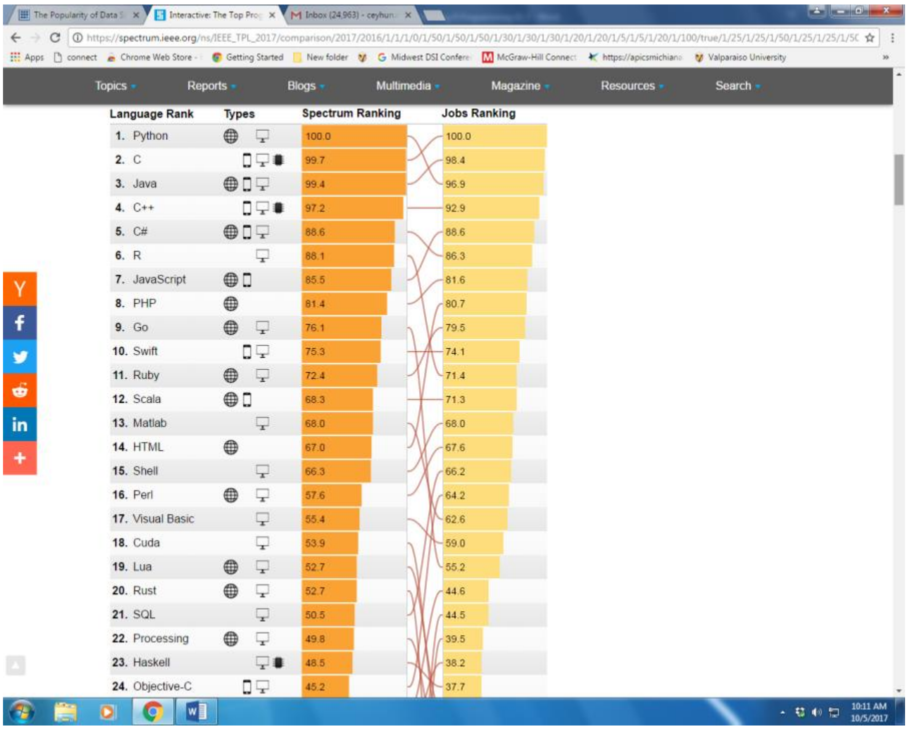


Figure 12: Spectrum and Jobs Ranking of software languages in 2017
(https://spectrum.ieee.org/ns/IEEE_TPL_2017/comparison/2017/2016/1/1/1/1/1/50/1/50/1/50/1/30/1/30/1/30/1/20/1/20/1/5/1/5/1/20/1/100/true/1/25/1/25/1/50/1/25/1/25/1/50/1/25/1/25/1/100/1/100/1/25/1/40/)

This figure addresses the use of R and Python programming Languages for Jobs. The IEEE (Institute Electrical and Electronics Engineers). Spectrum Ranking is a site that will combine 12 metrics from 10 different sites. Some measures that are presented are popularity of job sites/search engines. While at the same time the site can show how much new programming code has been added to GitHub over last year.
Databases such as Oracle should be investigated and included in this study.

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